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Abstract

This report identifies trends in land, water, and commercial input use, reports on the condition of natural resources used in the agricultural sector, and describes and assesses public policies that affect conservation and environmental quality in agriculture. Combining data and information, this report examines the complex connections among farming practices, conservation, and the environment, which are increasingly important components in U.S. agriculture and farm policy. The report also examines the economic factors that affect resource use and, when data permit, estimates the costs and benefits (to farmers, consumers, and the government) of meeting conservation and environmental goals. The report takes stock of how natural resources (land and water) and commercial inputs (energy, nutrients, pesticides, and machinery) are used in the agricultural sector; shows how they contribute to environmental quality; and links use and quality to technological change, production practices, and farm programs.

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Contents

1. Land

2. Water

3. Production Inputs

4. Production Management

5. Technology

6. Conservation and Environmental Programs

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Preface

This 1996-97 edition of *Agricultural Resources and Environmental Indicators (AREI)* updates information provided in the first edition published in December 1994, and expands coverage to include more detailed data and analysis on resource-conserving production practices. *AREI* takes stock of how natural resources (land and water) and commercial inputs (energy, nutrients, pesticides, and machinery) are used in the agricultural sector; shows how they contribute to environmental quality; and links use and quality to technological change, production management practices, and farm programs. Our objective is to provide a comprehensive source of data and analysis on the factors that affect resource use and quality in American agriculture, and information on the costs and benefits of improving the quality of the Nation's resources.

Because environmental indicators are used for multiple purposes, no single set can serve all needs. Uses of indicators range from identifying specific resource problems at local levels to providing national assessments of broad aggregates to judging the effectiveness of specific conservation and environmental programs. Most indicators are devoid of economic content: they are primarily physical measures. But indicators can also be constructed and used to help identify cost-effective solutions to solving resource-related problems and to help answer questions about whether we are using natural resources efficiently. For example, water quality indicators may point to a reduction in polluting chemicals in a lake or stream, but it is also important to know the costs associated with achieving such reductions and the value of the benefits provided by the cleaner water.

By focusing on the economic dimension of environmental indicators, *AREI* fills a unique niche in the indicators literature. Unlike other indicators reports, *AREI* is not a monitoring report in the sense of establishing an environmental baseline for interspatial or intertemporal comparisons of physical measures of environmental quality. Instead, *AREI* focuses on examining the complex economic links between agricultural activity and environmental performance and on assessing the costs and benefits associated with changes in resource quality.

Like the first edition, *AREI 1996-97* begins with the two major agricultural resources, land and water. We examine both the quantity and quality of land and water, the factors that affect their use, and the value (market and nonmarket) associated with each. The subsequent chapters examine commercial inputs used in agricultural production with a special emphasis on how input use affects the quality of land, water, and wildlife habitat. We then turn to a set of chapters that examines production management practices. Here we focus on describing the factors that affect the adoption of these practices and examine how these practices can use commercial inputs more efficiently and result in less damage to water and land resources. These chapters are followed with an overview of agricultural technology development, which focuses on how new technologies are developed, what public policies encourage development and adoption, and how technological change is an important factor in meeting conservation goals. The final set of chapters is devoted to conservation and environmental programs with a particular emphasis on water quality programs, the Conservation Reserve Program, Conservation Compliance, and wetlands programs. Our goal is not only to describe the programs but to examine the associated costs and benefits to farmers, taxpayers, and consumers.

To facilitate the use of *AREI 1996-97*, we have provided an appendix that describes the agricultural resource surveys and data used throughout the volume, and a subject index. Most chapters also contain a listing of related recent ERS reports. *AREI 1996-97* is also available on the ERS homepage at http://www.econ.ag.gov under *Briefing Rooms*.

Agency Acronyms Used in This Report

ACE	**U.S. Army Corps of Engineers**
CRS	**Congressional Research Service**
EPA	**U.S. Environmental Protection Agency**
GAO	**U.S. General Accounting Office**
OMB	**U.S. Office of Management and Budget**
USDA	**U.S. Department of Agriculture**
APHIS	Animal and Plant Health Inspection Service
ARS	Agricultural Research Service
CSREES	Cooperative State Research, Education, and Extension Service
ERS	Economic Research Service
FSA	Farm Service Agency. Consolidates former Agricultural Stabilization and Conservation Service (ASCS), and Farmers Home Administration (FmHA)
FS	Forest Service
NASS	National Agricultural Statistics Service
NRCS	Natural Resources Conservation Service. Formerly Soil Conservation Service (SCS)
OBPA	Office of Budget and Program Analysis
OGC	Office of General Counsel
USDC	**U.S. Department of Commerce**
ITA	International Trade Administration
USDI	**U.S. Department of the Interior**
BLM	Bureau of Land Management
BOR	Bureau of Reclamation
FWS	Fish and Wildlife Service
OPA	Office of Policy Analysis
USGS	U.S. Geological Survey

This handbook was prepared by the Economic Research Service (ERS), the economic and social science research agency of the U.S. Department of Agriculture. ERS's mission is to provide economic and other social science information and analysis for public and private decisions on agriculture, food, natural resources, and rural America.

1.1 Land Use

The three major uses of land in the contiguous 48 States are grassland pasture and range, forest-use land, and cropland, in that order. Total cropland (used for crops, used for pasture, and idled) has trended down slightly since the late 1960's. Greater variation has occurred in cropland used for crops, largely reflecting changes in cropland idled in Federal crop programs. Also, weather, such as the drought in 1988 and the heavy rains in 1993, can strongly influence the mix and acreage of cropland used for crops.

The total land area of the contiguous 48 States is approximately 1.9 billion acres, with an additional 365 million acres in Alaska and a little over 4 million acres in Hawaii (table 1.1.1). Because Alaska has very little crop area and Hawaii grows primarily crops that are not grown elsewhere in the United States, the discussion in this chapter focuses on the contiguous 48 States.

Land is the first factor of production. Land's potential uses and its location determine its economic value. Land use can affect the environment and the sustainability of production. Competition and conflicts occur among users of land because land used in one way often prevents or reduces other uses (see box, "Land Use Choice: Theory and Practice").

Major Land Uses in the Contiguous States

Grassland pasture and range, the largest use of land, accounted for 589 million acres (31 percent of major land uses in the 48 States) in 1992 (latest year data are available, table 1.1.2, fig. 1.1.1). (For definitions of land use terms, see "Glossary of Land Use Categories," p. 24.) However, grassland pasture and range has declined since the mid-1960's, when it was 636 million acres. One reason for this decline has been that farmers—with assistance from the Cooperative State Research, Education and Extension Service, the Natural Resources Conservation Service, and other agencies—have improved the forage quality and productivity of grazing lands. A second reason is

Table 1.1.1—Major uses of land, United States, 1992

Land use[1]	Acreage		Proportion of land	
	48 States	United States	48 States	United States
	Million acres		*Percent*	
Cropland	460	460	24.3	20.3
Grassland pasture and range	589	591	31.1	26.1
Forest-use land	559	648	29.5	28.6
Special uses	194	340	10.2	15.0
Miscellaneous other land	92	224	4.9	9.9
Total land area[2]	1,894	2,263	100.0	100.0

[1] See the Glossary, p. 24, for definitions of land-use categories.
[2] Distributions by major use may not add to totals due to rounding.
Source: USDA, ERS, based on Daugherty, 1995.

Land-Use Choice: Theory and Practice

In theory, land-use choice is straightforward: Land is devoted to the use that provides the greatest value to its owner, as measured by the present value of the stream of returns *expected* in future years. In reality, land-use choice often involves a complex interaction of factors, including the characteristics of the land, the landowner, and the economic and policy contexts in which the choice is made.

Complexity arises in part because land is a highly differentiated economic resource. The location of land—as measured by proximity to the city center, transportation links, or recreational and aesthetic amenities—is a key determinant of its value for residential or commercial development. Productivity, erodibility, and topography largely determine future returns to crop production, pasture, and forestry. Moreover, land may simultaneously pose characteristics that are favorable to and detract from its value for a particular use, creating tradeoffs in land-use decisions. For example, highly productive land may also be highly erodible. Using such land for crops will result in high yields, but may also mean high erosion control costs or, if erosion is unchecked, loss of future productivity. Finally, technological change may ameliorate land-related limitations to specific uses. One example is the development of rolling land for irrigated crop production following the introduction of center-pivot irrigation technology.

Exactly how these factors are assessed depends on the inclinations, circumstances, and economic expectations of individual landowners. For example, landowners who are optimistic about future returns to crop production will use more land for crops than those who are pessimistic. Other factors that affect land-use choices include management skills; discount of future income (where initial land conversion costs are high or for land uses where returns are delayed, e.g. forestry); risk aversion; and the age, occupation, or residence of the landowners.

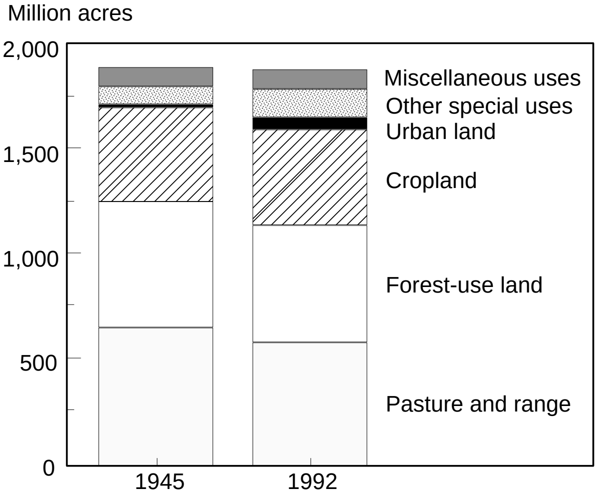
Landowner expectations and actions are affected by government policies and programs. Federal farm commodity programs have long been suspected of encouraging crop production on marginally productive or environmentally sensitive land. Under the Sodbuster and Swampbuster provisions of the 1985 Farm Bill, payments are now withheld from farmers who crop highly erodible land without an approved conservation plan or who drain wetlands. Zoning rules and land taxation may be important in urban fringe areas where rural land is being rapidly developed for residential or commercial purposes. For example, a jurisdiction seeking to retain open space may zone land for agricultural purposes or provide "use value" taxation to landowners who use land for agriculture.

that the number of domestic animals, particularly sheep and draft animals, has been declining in recent years.

Forest-use land, the second largest area among major uses, declined from about 32 percent of total land in 1945 to less than 30 percent in 1992. All land with a forest cover comprises an even larger area—nearly 606 million acres (32 percent) in 1992. However, much forested land is in special uses (parks, wilderness areas, and wildlife areas) that prohibits forestry uses such as timber production. These areas increased from 22 million acres in 1945 to 89 million acres in 1992. As a result, land defined as forest-use declined consistently from the 1960's to 1987, while special uses increased rapidly (table 1.1.2). There was a slight increase in forest-use land from 1987 to 1992, primarily in commercial timberland.

Cropland comprises the third largest use of land (24 percent in 1992) (table 1.1.1). Total cropland in the contiguous States varied about 8 percent between 1945 and 1992—ranging from 478 million acres in

Figure 1.1.1--Major uses of land in the contiguous 48 States



Source: USDA, ERS, based on Krupa and Daugherty, 1990; Daugherty, 1995.

Table 1.1.2—Major uses of land in the contiguous 48 States, 1945-92

Land use[1]	1945	1949	1954	1959	1964	1969	1974	1978	1982	1987	1992
	Million acres										
Cropland[2]	450.7	477.8	465.3	457.5	443.8	471.7	464.7	470.5	468.9	463.6	459.7
Cropland used for crops	363.2	382.9	380.5	358.4	334.8	332.8	361.2	368.4	382.6	330.7	337.4
Cropland idled	40.1	25.6	18.7	33.6	51.6	50.7	20.8	26.0	21.3	68.0	55.5
Cropland used for pasture	47.4	69.3	66.1	65.4	57.4	88.2	82.7	76.1	65.0	64.9	66.8
Grassland pasture and range	659.5	631.1	632.4	630.1	636.5	601.0	595.2	584.3	594.3	588.8	589.0
Forest-use land	601.7	605.6	615.4	610.9	611.8	602.8	598.5	583.1	567.2	558.2	558.7
Forestland grazed	345.0	319.5	301.3	243.6	223.8	197.5	178.9	171.3	157.5	154.6	145.0
Forestland not grazed	256.7	286.1	314.1	367.3	388.0	405.3	419.6	411.8	409.7	403.6	413.7
Special uses[2]	100.0	105.3	110.2	124.4	144.5	143.1	148.0	167.2	176.9	191.2	194.4
Urban land	15.0	18.3	18.6	27.1	29.2	30.8	34.6	44.2	49.6	55.9	58.0
Transportation	22.6	22.9	24.5	25.1	25.8	25.7	26.0	26.3	26.4	25.2	24.8
Recreation and wildlife areas	22.6	27.6	27.5	31.9	49.7	53.4	56.9	66.0	71.1	84.1	86.9
National defense areas	24.8	21.5	27.4	28.9	29.3	22.9	22.4	22.3	21.8	18.9	18.6
Misc. farmland uses	15.1	15.1	12.2	11.3	10.5	10.3	8.0	8.4	8.0	7.1	6.2
Miscellaneous other land	93.4	84.0	80.5	78.9	63.0	78.4	90.6	91.9	88.5	93.9	92.4
Total land, 48 States[2,3]	1,905.4	1,903.8	1,903.8	1,901.8	1,899.6	1,897.0	1,897.0	1,897.0	1,895.7	1,895.7	1,894.1

[1] See the Glossary, p. 24, for definitions of land-use categories.
[2] Distribution may not add to totals due to rounding.
[3] Totals differ over time due to remeasurement of the U.S. land area
Source: USDA, ERS, based on Krupa and Daugherty, 1990; Daugherty, 1995.

1949 to 444 million acres in 1964 (table 1.1.2). The 1992 cropland base of 460 million acres was the lowest since 1964.

The cropland base includes cropland used for crops, cropland idled, and cropland used only for pasture. These components vary more than total cropland. The amount of cropland used for crops has ranged from 383 million acres in 1949 to 331 million acres in 1987 (table 1.1.2). There has been no trend, but instead seemingly two major cycles, with cropland moving from idle into crop use and back again.

Between 1945 and the 1949 peak, cropland used for crops expanded rapidly to meet increased foreign demand for U.S. grain. After the postwar agricultural recovery in these foreign nations, cropland used for crops gradually declined until the early 1970's, when a second round of strong foreign demand occurred for U.S. grains. In 1982, a severe recession in the United States and in other major markets weakened the demand for U.S. agricultural products and grain surpluses piled up. Annual Federal crop programs and the long-term Conservation Reserve Program (starting in 1986) idled additional cropland, again reducing the acreage used for crops.

Cropland is idled every year for reasons other than government programs, including weather or soil conditions at planting time, low crop prices, or holding for eventual conversion to nonagricultural uses.

Between 1945 and 1992, cropland used for pasture ranged from 47 million acres in 1945 (10 percent of total cropland) to 88 million acres (19 percent) in 1969 (table 1.1.2). Cropland pasture averaged about 14 percent of total cropland.

Special uses include urban; rural transportation; rural parks and wildlife; defense and industrial uses; and farmstead, farm roads and lanes, and other miscellaneous onfarm uses (table 1.1.2). These uses increased from 100 million acres (5 percent of the

Table 1.1.3—Major uses of land in the contiguous 48 States, by region, 1992

Land use[1]	North-east	Lake States	Corn Belt	Northern Plains	Appala-chian	South-east	Delta States	Southern Plains	Mountain	Pacific	United States
						Million acres					
Cropland[2]	14.3	42.5	99.6	106.6	29.1	18.1	23.7	55.1	46.7	23.9	459.7
Cropland used for crops	11.1	34.7	80.7	84.5	16.6	10.4	16.5	31.6	33.0	18.2	337.3
Cropland idled	1.2	5.2	8.8	11.5	3.4	3.4	3.0	8.0	7.9	3.1	55.5
Cropland used for pasture	2.0	2.6	10.1	10.6	9.1	4.2	4.3	15.5	5.7	2.6	66.8
Grassland pasture and range	3.0	5.3	12.3	69.7	6.0	9.8	6.4	118.7	303.5	54.5	589.0
Forest-use land	68.5	48.3	31.3	3.7	71.6	73.4	48.3	21.7	112.7	79.3	558.7
Forestland grazed	1.4	3.1	6.6	1.6	5.2	7.3	15.9	11.6	66.7	25.6	145.0
Forestland not grazed	67.1	45.2	24.7	2.1	66.4	66.1	32.4	10.1	46.0	53.7	413.7
Special uses[2]	20.0	13.0	14.9	7.5	13.2	17.3	6.4	12.8	58.4	30.7	194.2
Urban land	10.5	4.0	7.6	1.1	5.6	8.0	2.7	6.4	4.5	7.4	57.8
Transportation	1.9	2.9	3.6	3.5	2.0	2.2	1.2	2.3	3.2	1.9	24.8
Recreation and wildlife areas	7.0	5.3	2.0	1.8	4.1	5.1	1.9	2.7	37.7	19.3	86.9
National defense areas	.4	.1	.3	.2	.9	1.6	.2	.7	12.6	1.6	18.6
Misc. farmland uses	.3	.7	1.3	.8	.6	.4	.4	.8	.5	.5	6.2
Miscellaneous other land	5.6	12.9	6.5	6.9	3.9	4.8	6.4	3.3	26.6	15.5	92.5
Total land, 48 States[2]	111.4	122.1	164.6	194.3	123.7	123.4	91.2	211.6	547.9	203.9	1,894.1

[1] See the Glossary, p. 24, for definitions of land-use categories.
[2] Distribution may not add to totals due to rounding.
Source: USDA, ERS, based on Daugherty, 1995.

land area of the contiguous United States) in 1945 to 194 million acres (10 percent) in 1992.

In response to expanding U.S. population, land in urban uses—for homes, schools, office buildings, shopping sites, and other commercial and industrial uses—increased 285 percent from 15 million acres in 1945 to an estimated 58 million acres in 1992. While the U.S. population nearly doubled, the amount of land urbanized almost quadrupled. However, urban uses still amount to only 3 percent of total land area (table 1.1.2). (See "Preservation of Agricultural Lands," later in this chapter, for a more detailed discussion of recent urbanization of land in the United States.)

Land in transportation uses (highways and roads, railroads, and airports in rural areas) increased by 4 million acres (17 percent) between 1945 and 1982. Transportation uses declined by 2 million acres from 1982 to 1992 (table 1.1.2) due to the abandonment of railroad facilities and rural roads, and the inclusion of some transportation uses into urban areas.

Land used for recreation and wildlife areas expanded 285 percent from 1945 to 1992 (86.9 million acres) mostly from conversion of Federal lands to meet greater public demand for such areas. Land in defense and industrial uses declined 25 percent from 1945 to 1992 (18.6 million acres), with some conversion to urban use. Miscellaneous farmland uses declined 9 million acres between 1945 and 1992 (6.2 million acres). Behind this decline were fewer farms; a trend toward larger, consolidated farms; and an increasing tendency for farm families to live off the farm.

Miscellaneous other land uses changed very little during 1945-1992. These uses include marshes and open swamps that have very little surface use and comprise only a small portion of the Nation's wetlands, which are distributed over other land uses.

Table 1.1.4—Net change in major uses of land in the contiguous 48 States, by region, 1945-92

Land use[1]	North-east	Lake States	Corn Belt	Northern Plains	Appala-chian	South-east	Delta	Southern Plains	Mountain	Pacific	United States
					Million acres						
Cropland[2]	-10.7	-3.7	+7.4	+11.1	-5.9	-8.9	+1.5	+3.3	+14.3	+.5	+9.0
Cropland used for crops	-9.8	-4.5	+2.7	+0.9	-6.3	-9.7	+0.2	-11.0	+8.8	+3.0	-25.8
Cropland idled	-.6	+3.0	+5.9	+2.8	-.3	-1.0	+.6	+5.2	+1.7	-1.8	+15.4
Cropland used for pasture	-.2	-2.3	-1.3	+7.4	+.8	+1.8	+.7	+9.1	+3.9	-.6	+19.3
Grassland pasture and range	-7.1	-4.8	-14.0	-12.6	-7.7	+1.1	-.9	+13.6	-35.7	-2.3	-70.5
Forest-use land[2]	+6.6	-6.1	+2.3	-.4	+7.9	+.4	-3.1	-24.6	-8.8	-17.3	-43.0
Forestland grazed	-7.6	-12.2	-11.0	-1.7	-34.4	-46.3	-27.2	-30.8	-17.9	-10.8	-200.0
Forestland not grazed	+14.3	+6.1	+13.3	+1.3	+42.4	+46.8	+24.0	+6.2	+9.1	-6.4	+156.9
Special uses[2]	+9.7	+6.0	+4.9	-.1	+6.3	+10.8	+2.7	+6.9	+30.4	+16.7	+94.2
Urban land	+6.5	+2.5	+5.0	+.7	+4.5	+6.8	+2.1	+5.5	+3.9	+5.5	+42.8
Transportation	.0	+.2	+.1	-.5	+.3	+.6	+.4	+.6	+.3	+.3	+2.1
Recreation and wildlife areas	+4.2	+4.7	+1.8	+1.1	+2.9	+4.4	+1.5	+1.8	+29.0	+13.0	+64.3
National defense areas	-.1	-.3	-.5	-.4	-.1	-.2	-.7	-.4	-1.9	-1.6	-6.2
Misc. farmland uses	-.8	-1.0	-1.5	-.9	-1.3	-.8	-.5	-.5	-1.0	-.5	-8.9
Miscellaneous other land	+.5	+7.9	-1.4	+.8	-1.9	-4.5	-2.0	-.6	-1.2	+1.4	-.9
Total change, 48 States[2]	-1.0	-.6	-.9	-1.1	-1.2	-1.1	-1.8	-1.5	-1.1	-1.0	-11.3

[1] See the Glossary, p. 24, for definitions of land-use categories.

[2] Distribution may not add to totals due to rounding. Totals of net change do not add to 0 due to periodic remeasurement of the U.S. land area (see table 1.1.2).

Source: USDA, ERS, based on Krupa and Daugherty, 1990; and Daugherty, 1995.

Regional Changes in Land Use

While land in every use occurs in all 10 regions of the contiguous States, some uses are more concentrated in some regions than others (table 1.1.3). Regions with the largest cropland acreages are the Northern Plains, Corn Belt, and Southern Plains. Grassland pasture and range is concentrated in the Mountain and Southern Plains regions. Acreages in forest-use and special uses are highest in the Mountain region.

Some regional shifts in total cropland and cropland used for crops have occurred since 1945. The largest increases occurred in the Corn Belt, Northern Plains, and Mountain regions with smaller increases in the Delta States, Southern Plains, and Pacific regions.

The Northeast, Appalachian, Southeast, and Lake States regions lost cropland between 1945 and 1992 (table 1.1.4). Eastern regions lost cropland because of climatic and geographic constraints; inability to capture economies of scale (that is, prevalence of small farms); and increased urbanization, which drives up land prices and reduces agricultural profit margins. Western increases resulted in part from federally subsidized irrigation water.

Eight of the 10 regions lost grassland pasture and range between 1945 and 1992. These losses ranged from 2.3 million acres in the Pacific region to 35.7 million acres in the Mountain region (table 1.1.4). The Northeast region lost more than 70 percent of its grassland pasture and range, the Appalachian and Corn Belt regions more than 50 percent. The Northeast and Appalachian regions saw the natural reforestation of grassland on abandoned small farms, loss of grassland to urbanization, and concentration of the dairy industry. Decreases in the Corn Belt, Northern Plains, and Mountain regions were likely associated with the conversion of some grassland pasture or range to cropland as demand for grain intensified.

In most regions, the changes in forest-use land were relatively small. The Northeast and Appalachian regions gained 7 million and 8 million acres of forest land, mainly from farm fields reverting to forest. The Pacific and Mountain regions lost forest-use land to recreation and wildlife areas. One-quarter of forest-use lands were grazed in 1992, down from over half in 1945. The proportional decline was greatest in the more heavily forested Northeast, Lake States, Appalachian, and Southeast regions. The decline in grazing derives from an increased emphasis on improving and managing farm woodlands. In the 1940's and 1950's, the Cooperative Extension Service encouraged farmers to fence livestock out of farm woodlands and to manage these areas for increased productivity of timber and other wood products. In some areas, such as the Appalachian region, many small farms ceased crop and livestock production and became forested. These reforested areas were generally not grazed.

The reduced grazing of forest-use land also reflects major changes in livestock production, including increased emphasis on improved grassland pastures; greater use of controlled, rotation grazing; and increased concentration and specialization in the dairy and beef cattle industry (as opposed to earlier general farming practices). Byproducts of other industries—such as beet and citrus pulp—now substitute for forage. Also, some of the larger, more concentrated dairy farms have moved to confined animal operations, where the cows are not pastured during their production cycle.

The location of special-use lands shifted considerably during 1945-92. Urban-use lands expanded most rapidly in the warmer Sunbelt States of the South and Southwest. Land in rural transportation uses increased in 8 of the 10 farm production regions, while land in recreation and wildlife areas increased in all regions. In contrast, land in national defense areas and miscellaneous farm uses declined in all regions.

Cropland Use and Programs

Total cropland consists of cropland used for crops, cropland idled, and cropland used for pasture (tables 1.1.2-1.1.4). While total cropland has varied up and down and generally declined since 1969, even greater shifts have occurred between cropland used for crops and cropland idled, mostly because of Federal programs. Cropland used for pasture has shown less variation.

Table 1.1.5—Major uses of cropland, United States, 1986-96[1]

Cropland	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	19962
					Million acres						
Cropland used for crops[3]	357	331	327	341	341	337	337	330	339	332	346
Cropland harvested[4]	316	293	287	306	310	306	305	297	310	302	314
Crop failure	9	6	10	8	6	7	8	11	7	8	10
Cultivated summer fallow	32	32	30	27	25	24	24	22	22	22	22
Cropland idled by all Federal programs[3]	48	76	78	61	62	65	55	60	49	55	34
Annual programs	46	60	53	31	28	30	20	23	13	18	0
Conservation Reserve Program[5]	2	16	25	30	34	35	35	36	36	36	34
Total, specified uses[3,6]	405	407	405	402	403	402	392	389	388	388	380

[1] Includes the 48 contiguous States. Fewer than 200,000 acres were used for crops in Alaska and Hawaii.
[2] Preliminary, subject to revision.
[3] Breakdown may not add to totals due to rounding.
[4] A double-cropped acre is counted as 1 acre.
[5] Numbers are gross before subtracting CRP terminations which, by the end of 1996, totaled approximately 1.5 million acres.
[6] Does not include cropland pasture or idle land not in Federal programs that is normally included in the total cropland base.
Source: USDA, ERS, based on a variety of published and unpublished data from FSA (formerly ASCS), ERS, and NASS.

Table 1.1.6—Selected crops harvested, 1996

Selected crops harvested[1]	Area	Proportion of total
	1,000 acres	*Percent*
Principal crops harvested:		
Corn for grain	73,147	22.4
Sorghum for grain	11,901	3.6
Oats	2,687	.8
Barley	6,787	2.1
Total, feed grains[2]	94,522	29.0
All wheat	62,850	19.3
Rice	2,799	.9
Rye	347	.1
Total, food grains[2]	65,996	20.2
Soybeans for beans	63,409	19.4
Peanuts for nuts	1,392	.4
Sunflower	2,499	.8
Dry edible beans	1,718	.5
Sugarbeets	1,323	.4
Sugarcane	845	.3
Potatoes	1,425	.4
Tobacco	734	.2
Cotton	12,833	3.9
All hay	61,029	18.7
Corn silage	5,395	1.7
Sorghum silage	371	.1
Total, all principal crops[2]	313,491	96.1
Citrus fruits[3]	1,104	.3
Noncitrus fruits[4]	1,934	.6
Tree nuts[5]	671	.2
Principal vegetables and melons for the fresh market[6]	1,821	.6
Principal vegetables for processing[7]	1,476	.5
Other crops[8]	5,577	1.7
Estimated total of crops harvested in 1996, including double-cropping[2]	326,074	100.0

[1] Sum of indicated crops for contiguous 48 States.

[2] Percentage distributions may not add to totals due to rounding.

[3] Bearing acreage of oranges, grapefruit, K-early citrus, lemons, limes, tangelos, tangerines, and temples.

4 Bearing acreage of apples, apricots, berries, cherries, cranberries, dates, figs, grapes, kiwifruit, nectarines, olives, peaches, pears, plums, prunes, and strawberries.

[5] Bearing acreage of almonds, hazelnuts, pistachios, and walnuts.

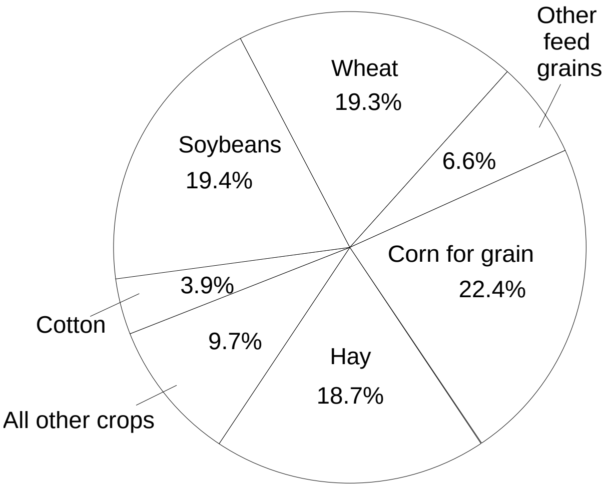
6 Area harvested of artichokes, asparagus, lima beans, snap beans, broccoli, brussels sprouts, cabbage, cantaloups, carrots, cauliflower, celery, sweet corn, cucumbers, eggplant, escarole/endive, garlic, honeydews, lettuce (head, leaf, romaine), onions, bell peppers, spinach, tomatoes, and watermelons. Includes processing total for dual-usage crops (asparagus, broccoli, and cauliflower).

7 Area harvested of lima beans, snap beans, beets, cabbage, carrots, sweet corn, cucumbers, green peas, spinach, and tomatoes.

[8] Determined as a residual.

Source: USDA, ERS, based on NASS, 1996a, 1997a, 1997b, 1997c.

Figure 1.1.2--Harvested crops, 1996



Source: USDA, ERS, based on NASS, 1996b, 1997a, 1997b, 1997c.

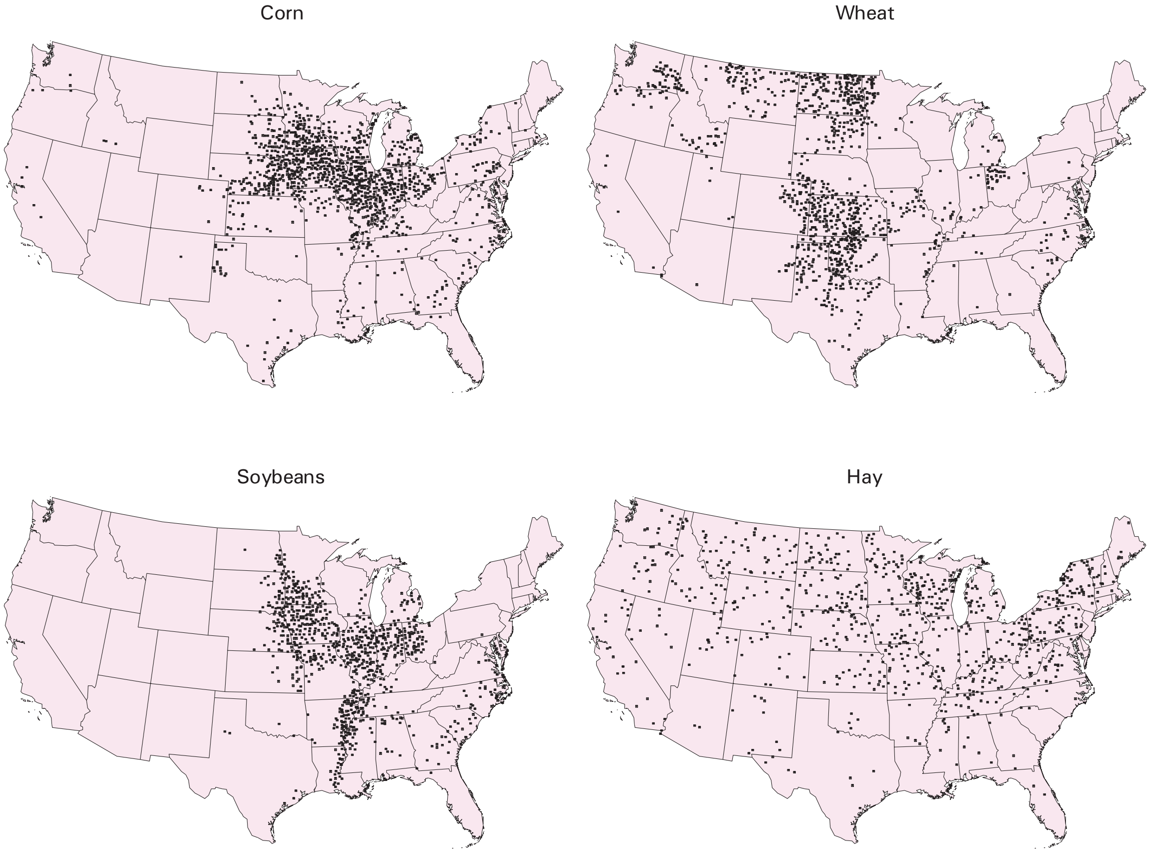
Cropland Used for Crops

Most cropland used for crops is harvested, but typically 2-3 percent experiences crop failure and 7-10 percent is cultivated summer fallow (table 1.1.5). In 1996, farmers harvested an estimated 326 million acres of crops (314 million acres of principal crops). About 12 million acres of the total harvested were double-cropped. When double-cropped land is counted only once, the *cropland harvested* estimate rounds to 314 million acres, up 12 million acres from 1995 as a result of no land idled in annual Federal programs and a larger acreage planted.

The 346 million cropland acres estimated to have been used for crops (cropland harvested, crop failure, and summer fallow) in 1996 were up about 14 million (just over 4 percent) from 1995 (table 1.1.5). This is the largest area used for crops since 1986, the year in which the Conservation Reserve Program (CRP) began. The increase in cropland used for crops reflects higher plantings and less land idled in Federal programs. The decrease of about 21 million acres in cropland idled in Federal programs from 1995 was a result of elimination of annual commodity prgrams and of changes to the CRP.

Four crops—corn for grain, wheat, soybeans, and hay—accounted for nearly 80 percent of all crop acres harvested in 1996 (table 1.1.6 and figs. 1.1.2, 1.1.3). The additional 15 "principal" crops accounted for another 16 percent of harvested area. Vegetables,

Figure 1.1.3 -- Geographic location of corn, wheat, soybean, and hay production, 1992



One dot = 75,000 acres

Source: USDA, ERS, based on NRCS 1992 National Resources Inventory.

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fruits, nuts, melons, and all other crops accounted for just 4 percent of crop area harvested in 1996.

In 1996, harvested acreage of corn, sorghum, barley, wheat, and soybeans increased, while the acreage of oats, rice, and cotton decreased (table 1.1.7). Total cropland harvested was up nearly 12 million acres from 1995. The increase in harvested acreage was due to the decrease in land idled in Federal programs.

Food crop acres have tended to increase over the past 30 years, while feed and other crops have declined (Daugherty, 1995). Wheat acreage is higher now than in the 1960's, but down from the early 1980's. Soybean and rice production followed a similar pattern. Peanuts have increased throughout the period while rye has decreased. Sunflower production increased until the early 1980's, declined for a few years and has been increasing again in the 1990's. Sugarcane, while still accounting for less than 1 million harvested acres, has increased consistently since the 1960's. Several other principal crops—dry edible beans and peas, potatoes, and sugarbeets—occupy comparatively small acreages and have exhibited no major trends.

Table 1.1.7—Harvested area of major crops, by region, 1990-96

Crop and period	Northeast	Lake States	Corn Belt	Northern Plains	Appalachian	Southeast	Delta States	Southern Plains	Mountain	Pacific	United States[1]
						Million acres					
Corn:[2]											
1990-94 avg.	2.2	11.1	34.3	13.1	3.1	1.2	0.5	1.8	1.1	0.3	68.7
1995	2.2	11.4	31.3	12.6	2.7	0.9	.6	2.0	1.0	0.3	65.0
1996[3]	2.4	12.2	34.1	15.1	3.1	1.3	1.4	2.0	1.2	0.4	73.1
Sorghum:[2]											
1990-94 avg.	-	-	0.8	4.6	0.1	0.1	0.5	3.4	0.4	[4]	9.8
1995	-	-	0.7	4.2	[4]	[4]	0.3	2.7	0.3	-	8.3
1996[3]	-	-	0.8	5.8	[4]	[4]	0.4	4.3	0.5	-	11.9
Barley:											
1990-94 avg.	0.2	0.8	-	3.0	0.1	[4]	-	[4]	2.4	0.8	7.3
1995	0.2	0.7	-	2.4	0.1	[4]	-	[4]	2.3	0.6	6.3
1996[3]	0.2	0.6	-	2.8	0.1	[4]	-	[4]	2.3	0.8	6.8
Oats:											
1990-94 avg.	0.3	1.2	0.8	1.6	[4]	0.1	[4]	0.2	0.2	0.1	4.6
1995	0.3	0.8	0.5	0.9	[4]	0.1	[4]	0.1	0.2	0.1	3.0
1996[3]	0.2	0.6	0.4	0.9	[4]	[4]	[4]	0.1	0.2	0.1	2.7
Wheat:											
1990-94 avg.	0.6	3.3	4.7	27.6	1.6	0.9	1.5	9.1	9.7	3.9	62.8
1995	0.6	3.0	4.5	27.0	1.7	0.7	1.2	8.0	10.2	4.0	61.0
1996[3]	0.7	3.2	4.4	27.3	1.8	0.7	1.6	7.8	10.9	4.4	62.8
Soybeans:											
1990-94 avg.	1.2	7.2	30.1	7.2	4.0	1.6	6.5	0.5	-	-	58.2
1995	1.2	8.1	32.5	8.2	3.8	1.1	6.2	0.5	-	-	61.6
1996[3]	1.1	8.4	33.2	8.5	4.0	1.3	6.3	0.6	-	-	63.4
Cotton:											
1990-94 avg.	-	-	0.3	[4]	1.0	1.2	3.1	5.2	0.5	1.1	12.4
1995	-	-	0.4	[4]	1.6	2.5	3.6	6.1	0.5	1.3	16.0
1996[3]	-	-	0.4	[4]	1.3	2.3	3.0	4.3	0.4	1.2	12.8
Rice:											
1990-94 avg.	-	-	0.1	-	-	-	2.1	0.3	-	0.4	3.0
1995	-	-	0.1	-	-	-	2.2	0.3	-	0.5	3.1
1996[3]	-	-	0.1	-	-	-	1.9	0.3	-	0.5	2.8

- = None reported.

[1] Includes the 48 contiguous States. Because of rounding, regional acres may not sum to U.S. totals.

[2] Corn and sorghum for grain.

[3] Preliminary, subject to revision.

[4] Less than 50,000 acres.

Source: USDA, ERS, compiled from USDA, NASS, *Crop Production*, Annual Summary and monthly reports.

Among feedgrains, corn increased from the 1960's to the early 1980's, decreased for a few years, and has trended upward again since the late 1980's. Sorghum and barley fluctuated year-to-year until the mid-1980's when they increased to 30-year highs. Both crops have declined since 1986. Oats has trended down over the last 30 years, while acreage of all hay has changed very little.

Harvested acreage of cotton hit a low of less than 8 million acres in 1983 and has trended upward since. Tobacco has indicated little trend in acreage harvested.

The demand for vegetable oils has led to increased production of some special oilseed crops. Special oilseeds currently reported by NASS include canola, rapeseed, safflower, and mustard seed (USDA, NASS, 1997a). In addition, the Federal commodity programs until 1996 promoted the production of industrial and other crops by allowing these crops to be planted on acreage diversion program lands (see box, "Cropland Programs and Definitions"). The crops allowed in

1995 included castor beans, chia, crambe, crotalaria, cuphea, guar, guayule, hesperaloe, kenaf, lesquerella, meadowfoam, milkweed, plantago ovato, and sesame. Deficiency payments were not reduced when these crops were planted on diverted acreage.

Cropland Idled Under Federal Programs

The Federal Agriculture Improvement and Reform Act of 1996 (the 1996 Farm Act) eliminated the authority of USDA to implement an annual Acreage Reduction Program (ARP) and other annual acreage diversions. As a result, no land was idled under annual commodity programs in 1996. This, combined with the expiration of some CRP contracts, reduced total land idled under Federal programs to about 34 million acres in 1996 (table 1.1.5, table 1.1.9) down from 1995 and well below the 1983 peak of 78 million acres (fig. 1.1.4, table 1.1.14). The extent of idled acres from participation in the CRP varied by farm production region (fig. 1.1.5). In 1995, land idled in annual programs totaled 18 million acres, compared with a range of 13 to 60 million acres idled since 1986.

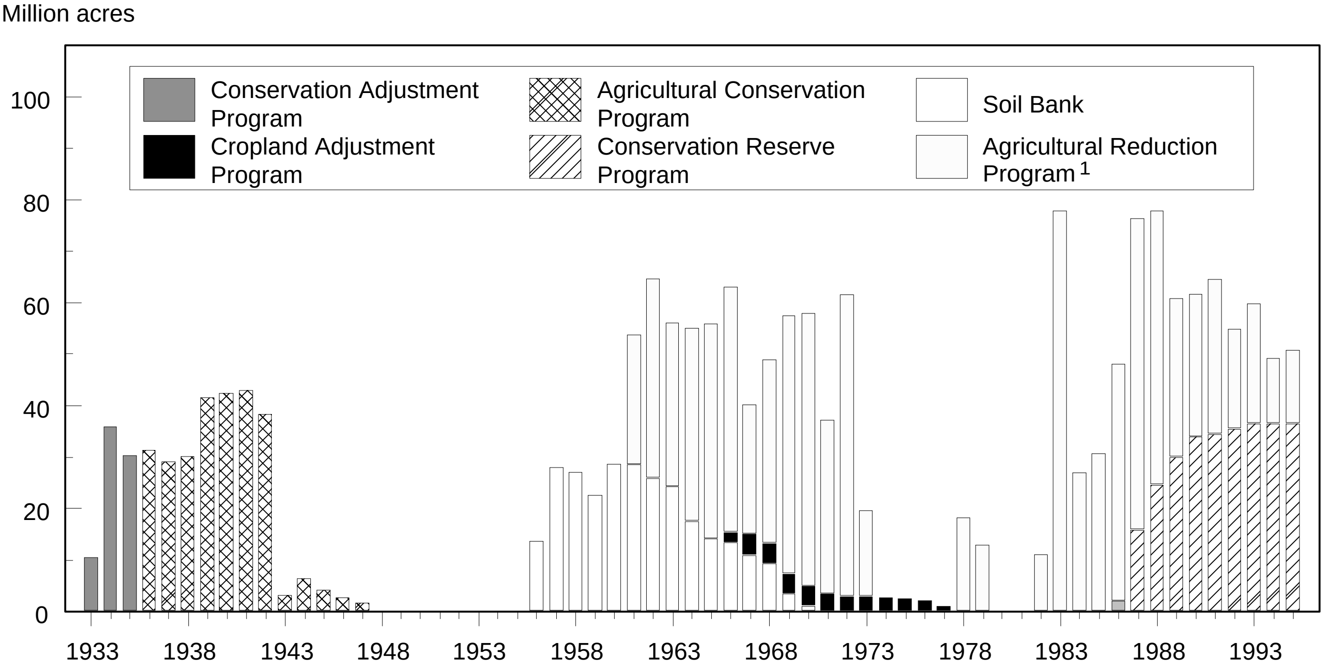
The CRP was initiated in 1986 to help owners and operators of highly erodible cropland conserve and improve the soil and water resources on their farms and ranches through long-term land retirement. CRP pays farmers to retire highly erodible and other environmentally sensitive lands from crop production for 10-15 years and to convert them to perennial vegetation. Since its authorization, 37 million acres of cropland have been enrolled in the CRP. With some producers opting lands out of the CRP in 1995-96 and some terminating prior to early-out, the program in December 1996 stood at just under 33 million acres (for more detail on the CRP, see chapter 6.3).

Prior to 1996, producers of corn, rice, sorghum, oats, barley, wheat, and cotton under USDA commodity programs had to idle a proportion of the crop acreage base and place it in the Acreage Reduction Program (ARP) (see box "Cropland Programs and Definitions," p. 12). These proportions (ARP requirements) varied by crop and year from 0 to 35 percent (table 1.1.8).

Agricultural Land Use Issues

Agricultural uses of land are being affected, and in some cases challenged, by factors other than changing demand for agricultural products and changing agricultural programs. Some continuing or emerging

Figure 1.1.4--Cropland acreage reductions by type of program, 1933-95



For yearly detail of programs since 1974, see table 1.1.14.

[1] Includes Acreage Conservation Reserve, 0,50/85-92 Programs, Paid Land Diversion, and Payment-in-Kind programs in applicable years (see table 1.1.14).

Source: USDA, ERS, based on various published and unpublished data from FSA (formerly ASCS).

Table 1.1.8—Acreage Reduction Program (ARP) requirements for participation in major program crops, 1985-96

Program crop	Proportion of crop acreage base to be idled from program crop and placed in a conserving use											
	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
	Percent											
Feed grains:												
Corn	10	17.5	20	20	10	10	7.5	5	10	0	7.5	*
Sorghum	10	17.5	20	20	10	10	7.5	5	5	0	0	*
Oats	10	17.5	20	5	5	5	0	0	0	0	0	*
Barley	10	17.5	20	20	10	10	7.5	5	0	0	0	*
Wheat	20	22.5	27.5	27.5	10	5	15	5	0	0	0	*
Upland cotton	20	25	25	12.5	25	12.5	5	10	7.5	11	0	*
Rice	20	35	35	25	25	20	5	0	5	0	5	*

*Authority for ARP eliminated by the 1996 Farm Act.
Source: USDA, ERS, based on unpublished material from the FSA (formerly ASCS).

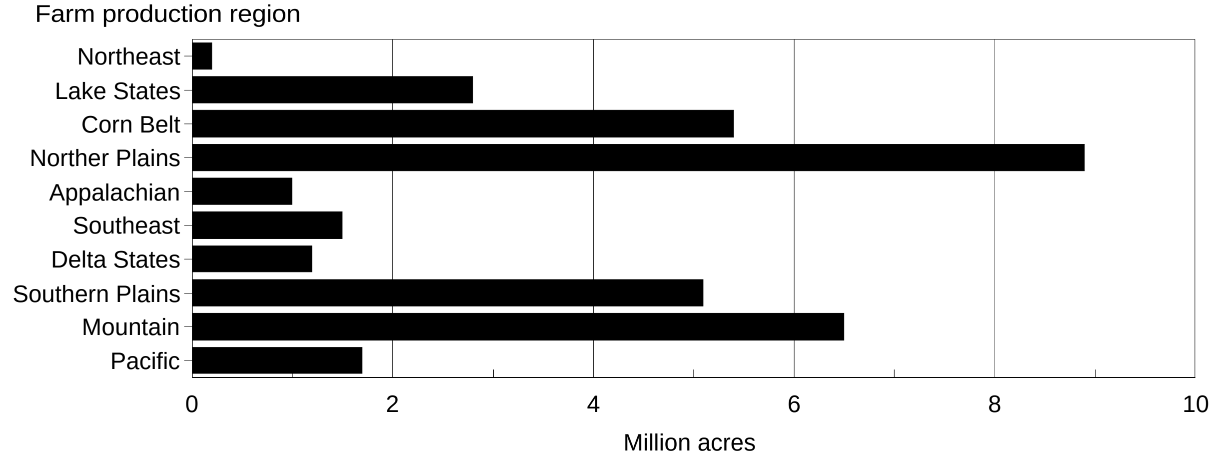
issues include farmland preservation from urbanization, conflicts with other uses of Federal lands, conflicts with environmental preservation, the use of agricultural lands for fuel and biomass production, and potential impacts of global climate change.

Preservation of Agricultural Lands

Preservation of agricultural lands for future food and fiber production and for open space is a concern because conversion, particularly to urban and other special uses, is largely irreversible. Urban and builtup land in the United States constitutes less than 3.5 percent of total land area. However, 75 percent of the U.S. population lives in urban areas (table 1.1.10). Even with large increases in urban area, percentage decreases in rural area are small because rural area is much larger than urban area. The rate of expansion in urban area has decreased from 39 percent during the 1950's to 18 percent during the 1980's (The Natural Resources Inventory (USDA, SCS, 1994) shows a 26-percent increase from 1982-92.)

Land converted to urban uses comes from several different major land uses. From 1982 to 1992, 46 percent of new urban development came from cropland and pasture (fig. 1.1.6). The average annual expansion in urban area was about 1.3 million acres

Figure 1.1.5--Cropland idled under the Conservation Reserve Program, by region, 1996



Source: USDA, ERS, based on various published and unpublished data from FSA (formerly ASCS).

Cropland Programs and Definitions

Conservation Reserve Program (CRP) was designed to voluntarily retire from crop production about 40 million acres of highly erodible or environmentally sensitive cropland for 10-15 years. In exchange, participating producers receive annual rental payments up to $50,000 and 50 percent cost-share assistance for establishing vegetative cover on the land. The Federal Agriculture Improvement and Reform Act (1996 Farm Act) of 1996 limited CRP enrollment to 36.4 million acres.

Acreage Reduction Program (ARP) was a voluntary land retirement program in which farmers reduced their planted acreage of a program crop by a specified proportion of that crop's acreage base to become eligible for deficiency payments, loan programs, and other USDA commodity program benefits. Crops under this program included corn, sorghum, oats, barley, wheat, cotton, and rice. The 1996 Farm Act eliminated the authority of USDA to implement an annual ARP.

0/85-92 Provision, an optional, Federal acreage diversion program, allowed wheat and feedgrain producers to devote all or a portion of their permitted acreage to conservation uses or to a minor oilseed crop, sesame, or crambe and, under some conditions, receive deficiency payments. At least 8 but no more than 15 percent of the producer's maximum payment acres had to be maintained in conserving uses or other allowable crop use. Eliminated by the 1996 Farm Act.

50/85-92 Provision, an optional, Federal acreage diversion program, allowed upland cotton and rice producers to underplant their permitted acreage and, under some conditions, receive deficiency payments on part of the underplanted acreage. At least 50 percent of the crop's maximum payment acreage had to be planted. An additional 8 percent but no more than 15 percent had to be designated for conserving use. Minor oilseeds could not be planted on the 50/92 conservation-use acres but sesame or crambe could be planted, with producers still qualifying for deficiency payments. Eliminated by the 1996 Farm Act.

Crop acreage base, for 1995 wheat and feedgrains, was the average of the acreage planted and considered planted to each program crop in the 5-year-period, 1990-94. For upland cotton and rice, the crop acreage base in 1995 was the average acreage planted and considered planted for 1992-94, with no adjustment for years with zero planted or considered planted acreage. The 1996 Farm Act used crop acreage base only in determining eligible production flexibility contract acreage.

Deficiency payments were payments made to farmers who participated in feedgrain (corn, sorghum, oats, or barley), wheat, rice, or upland cotton programs up to 1996. The payment rate per unit crop production was based on the difference between a target price and the market price or loan rate, whichever difference was less. The total payment a farm received was the payment rate multiplied by the eligible production. Eliminated by the 1996 Farm Act and replaced by production flexibility contract payments in 1996.

Production flexibility contract payments are authorized under provisions of the 1996 Farm Act as a replacement for deficiency payments, and cover the 1996 through 2002 crops of wheat, feed grains, upland cotton, and rice of landowners or producers with eligible cropland. In exchange for a series of annual contract payments for the 7-year period based on a predetermined total dollar amount for each year, the owner or producer agrees to comply with specified conservation requirements concerning the use of highly erodible cropland and wetlands; to comply with planting flexibility requirements of the Act; and to use contract acreage for agricultural or related activities, not for nonagricultural commercial or industrial use.

Production flexibility contract acreage is equal to a farm's crop acreage base for 1996 calculated under the provisions of the previous farm program, plus any returning CRP base acreage and less any new CRP acreage enrollment. A landowner or producer can enroll less than the maximum eligible acreage. In 1996, contracted acreage totaled just over 207.5 million acres, 98.8 percent of the eligible 210.2 million acres (USDA, FSA, 1996).

Table 1.1.9—Cropland idled under Federal acreage reduction programs, 1986-96

Program and crop	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
					Million acres						
Annual programs, base acres:											
Corn	14.2	23.2	20.5	10.8	10.7	7.4	5.2	10.7	2.0	7.5	0
Sorghum	2.9	4.1	3.9	3.3	3.3	2.4	2.0	2.2	1.6	1.6	0
Barley	2.0	3.0	2.8	2.3	2.9	2.1	2.3	2.2	2.1	2.4	0
Oats	0.5	0.8	0.3	0.3	0.2	0.5	0.6	0.8	0.5	0.7	0
Wheat	21.0	23.9	22.5	9.6	7.5	15.6	7.3	5.4	4.6	5.5	0
Cotton	4.0	3.9	2.2	3.5	2.0	1.2	1.7	1.4	1.7	0.2	0
Rice	1.5	1.6	1.1	1.2	1.0	0.9	0.4	0.7	0.3	0.5	0
Total, annual programs[1]	46.1	60.5	53.3	30.9	27.7	30.1	19.5	23.4	12.8	18.4	0
CRP base acres:[2]											
Corn	0.2	2.3	2.8	3.4	3.8	3.9	4.1	4.3	4.3	4.3	4.0
Sorghum	0.2	1.2	1.9	2.2	2.4	2.4	2.4	2.5	2.5	2.5	2.4
Barley	0.1	1.1	1.9	2.4	2.7	2.8	2.8	2.8	2.8	2.8	2.7
Oats	0.1	0.5	0.9	1.1	1.3	1.3	1.4	1.4	1.4	1.4	1.3
Wheat	0.6	4.2	7.1	8.8	10.3	10.4	10.6	10.8	10.8	10.8	10.5
Cotton	0.1	0.7	1.0	1.2	1.3	1.3	1.4	1.4	1.4	1.4	1.4
Rice	[3]	[3]	[3]	[3]	[3]	[3]	[3]	[3]	[3]	[3]	[3]
Total CRP-idled base acres[1,2]	1.2	10.0	15.5	19.0	21.8	22.0	22.6	23.3	23.3	23.3	22.3
Total base acres idled[1,2]	47.4	70.5	68.8	49.9	49.5	52.1	42.1	46.7	36.1	41.7	22.3
Total CRP-idled nonbase acres[2]	0.7	5.7	8.9	10.9	12.1	12.4	12.8	13.2	13.2	13.2	12.1
Total cropland idled under Federal programs[1,2]	48.1	76.2	77.7	60.8	61.6	64.5	54.9	59.8	49.2	54.8	34.4

[1] Because of rounding, crop acreages may not sum to totals. Base acreages idled under 0/92 and 50/92 programs from 1986 through 1992 are included in annual program data. However, base acres of feed grains and wheat enrolled in 0/92 and planted to oilseeds or other permitted crops in 1991 (0.5 million acres), in 1992 (0.7 million acres), in 1993 (1.0 million acres), in 1994 (1.6 million acres), and in 1995 (1.5 million acres) are not included.

[2] CRP began in 1986. Small acreages of peanut and tobacco base were bid into CRP in addition to the crops listed. Numbers are gross before subtracting CRP terminations which, by the end of 1996, totaled approximately 1.5 million acres.

[3] Less than 50,000 acres.

Source: USDA, ERS, based on various published and unpublished data from FSA (formerly ASCS).

(table 1.1.11). Even so, losing farmland to urban uses does not threaten total cropland or the level of agricultural production, which should be sufficient to meet food and fiber demand into the next century (Vesterby, Heimlich, and Krupa, 1994).

Land use change is dynamic. With the exception of urban land, changes occur to and from major land uses (table 1.1.11). For example, 26.4 million acres (of prime and nonprime land) left cropland and pasture from 1982 to 1992 but 16.3 million acres came into the category, resulting in a net loss of 10.1 million acres. Forestland lost 14.2 million acres, but gained 15.2 million acres for a net gain of 1 million acres.

Prime agricultural land has the growing season, moisture supply, and soil quality needed to produce sustained high yields when treated and managed according to modern farming methods (Heimlich, 1989). About 24 percent of rural non-Federal land is prime. Of land converted to urban, 28 percent is prime, so that urban conversion takes prime land in a slightly greater proportion than its occurrence. Of total cropland and pasture, 48 percent is prime and prime cropland is converted to urban uses at about the same rate as nonprime cropland.

Concerns about preserving agricultural lands and open areas have resulted in the use of a variety of instruments, including property, income, and estate tax incentives; and the use of easements and land

Table 1.1.10—Population and urban area, contiguous 48 States, 1950-90

Year	U.S. population			Urban area[1]	Urban area increase[2]
	Total	Urban	Portion urban		
	--Million--		*Percent*	*Million acres*	*Percent*
1950	151	97	64	18	--
1960	178	124	70	26	39
1970	202	149	74	35	36
1980	225	165	74	47	37
1990	247	185	75	56	18

[1] Data differ somewhat from table 1.1.11 due to different data sources and different time periods.

[2] Percent increase over that of 10 years past.

Source: USDA, ERS, based on USDC, 1991; Frey, 1983.

Table 1.1.11—Land-use changes from 1982 to 1992, contiguous 48 States

Land use[1]	1982 land use totals	In 1992--					
		Cropland and pasture[2]	Range-land	Forest-land	Other[3]	Urban and built-up	Federal land
				Million acres			
1992 land use totals[3,4]	1,891.1	542.3	398.9	395.0	81.6	65.4	408.0
Prime land in 1982:[5]							
Cropland and pasture	267.8	**259.2**	0.7	2.7	1.7	2.9	.6
Rangeland	20.0	1.4	**18.2**	.1	.1	.1	--
Forest land	45.6	1.1	--	**43.3**	.2	.7	.2
Other[2,3]	6.2	.7	--	.2	**5.3**	--	--
Nonprime land in 1982--							
Cropland and pasture	284.3	**266.4**	2.8	8.7	2.4	3.2	.7
Rangeland	388.6	7.4	**373.5**	1.4	1.3	1.8	3.3
Forest land	348.3	3.3	1.1	**336.3**	1.4	4.4	1.8
Other[2,3]	73.0	1.7	.3	1.4	**69.0**	.2	.3
Urban and built-up	51.9	--	--	--	--	**51.9**	--
Federal land	404.7	.7	2.0	.7	.2	--	**401.1**

[1] Numbers in bold indicate the acres that remained in the same use. Nonbold numbers across rows represent land moving out of the 1982 land uses. Nonbold numbers down columns represent land moving into the 1992 land uses.

[2] Includes land in the CRP.

[3] Includes rural transportation, marshland, and barren land.

[4] Distribution by use may not add to totals due to rounding.

[5] Prime land is land that has the growing season, moisture supply, and soil quality needed to sustain high yields when treated and managed according to modern farming methods.

Source: USDA, ERS, based on USDA, SCS, 1994.

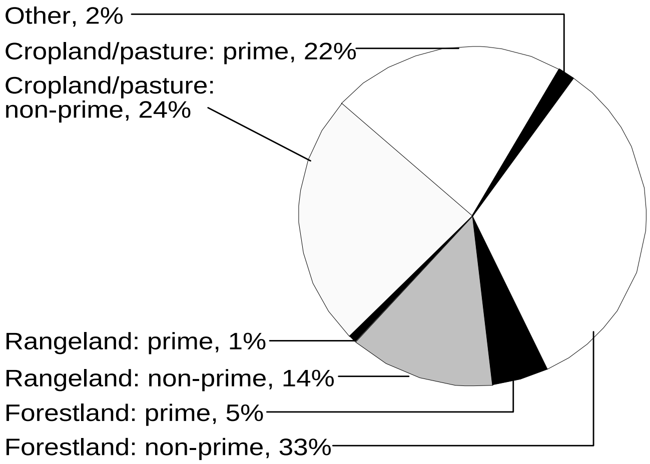
trusts (see chapter 1.2, *Land Tenure*, for more discussion).

Conflicts Among Uses of Federal Lands

Nearly 29 percent of the Nation's surface area, some 650 million acres, is owned by the Federal Government (U.S. General Services Administration, 1995). Most of this land is administered by USDA's Forest Service (FS) and the Department of the Interior's Bureau of Land Management (BLM), with lesser amounts by the Fish and Wildlife Service (FWS) and National Park Service.

National Forest System (NFS) lands total 191.6 million acres (table 1.1.12 and USDA, FS, 1996). By law, NFS lands are managed to promote multiple uses. Logging and grazing are the principal commercial activities. The NFS includes about 85 million acres of timberland and 96 million acres of rangeland. FY 1995 production from these resources included 3.9 billion board feet of timber (about 13 percent of the national harvest) and almost 9.3 million animal-unit months (AUM's—1 AUM is forage for a 1,000 lb. cow, or the equivalent, for 1 month) of livestock grazing. Other commercial activities include oil, gas, and mineral production. Recreation and conservation are also major uses. The Forest Service manages over 18,000 recreational facilities within the NFS, along with over 125,000 miles of trails and 4,385 miles of wild and scenic rivers. FY 1995 recreational use of NFS lands exceeded 4 billion visitor hours (USDA, FS, 1996). The NFS also includes 35 million acres of designated wilderness. Within the continental United States, NFS lands provide habitat for 113 animal species and 87 plant species listed by the Federal Government as threatened or endangered (BioData, Inc., 1995). The NFS also accounts for about one half of the West's water supply (USDA, FS, 1996).

Figure 1.1.6--Land urbanized, by prior land use, 1982-92



Source: USDA, ERS, based on USDA, SCS, 1994.

Bureau of Land Management (BLM) lands total 264 million acres, most of which are in Alaska and 11 Western States (table 1.1.12 and USDI, BLM, 1996). BLM lands are managed for multiple uses, primarily commercial production. The main commercial activity is grazing, with 19,048 grazing permits or leases covering 166.9 million acres in FY 1993 (USDI, BLM, 1996). About 8 million acres of BLM land are classified as timberland. BLM's recreation management efforts target high-use areas that cover about 10 percent of agency lands. These areas contain 4,869 miles of trails and about 2,000 miles of wild and scenic rivers. FY 1995 recreational use of BLM lands was about 880 million visitor hours. As with the Forest Service, BLM has given increasing importance to conservation uses—protecting wetlands and riparian areas, endangered species, and important wildlife habitat. Within the 48 States, BLM lands provide habitat for 61 federally listed threatened or endangered animal species and 77 listed plant species (BioData, Inc., 1995). BLM lands include 5.2 million acres of designated wilderness and 17.4 million acres that are being studied for future designation.

Debate over the use of public lands, particularly those under FS and BLM jurisdiction (that is, those explicitly managed under multiple-use objectives), has become increasingly contentious over the last 20-30 years. Critics argue that FS and BLM give grazing, logging, and mining priority over other land uses (primarily environmental uses but also, to a lesser extent, recreational uses). Federal grazing fees, for example, are generally well below fees charged by private landowners in nearby areas. In 1995, the Federal grazing fee was $1.61 per AUM. For the 11 Western States where BLM and FS lands are concentrated, private land grazing fees (for cattle) averaged $10.30 per AUM (USDA, NASS, 1995a). (See chapter 1.4, *Farm Real Estate Values, Rents, and Taxes*, for more detail on grazing fees and recent proposals to raise fees on public lands.) Similarly, the FS often pays for construction of access roads, which is a major cost component in bringing NFS lands into timber production. With respect to mining, Federal law allows prospectors to take title to public lands, and the minerals they contain, for as little as $2.50 per acre.

Table 1.1.12—Land-use changes on Bureau of Land Management (BLM) and Forest Service (FS) lands, FY 1983-95

Land use	1983	1985	1987	1989	1991	1993	1995
BLM land (million acres)	341	337	334	270	269	268	264
Grazing - all livestock:							
Number of operators	20,644	19,880	19,532	19,625	19,482	19,048	NR
Acres (1,000)	174,441	165,459	164,458	158,790	166,844	166,922	NR
AUM's authorized (1,000)	10,336	11,218	11,178	11,043	9,602	9,758	9,941
Timber sales:							
Number of sales	1,016	2,277	22,144	23,433	18,925	20,200	NR
Volume (MBF)[1]	240,099	1,042,917	1,264,981	795,729	602,006	87,402	NR
Recreation:							
Number of developed sites	406	375	368	554	726	908	NR
Visitor days (1,000)	27,834	20,384	41,388	41,101	44,982	35,735	73,359
Trails (miles)	2,000	1,600	1,600	1,600	2,300	4,869	NR
High-use areas:							
Number of areas	150	150	150	150	355	521	NR
Percent of BLM lands	5	5	5	5	10	10	NR
Wildlife and Nature:							
Wildnerness areas (number)	6	23	23	25	66	67	136
Wilderness acres (1,000)	19	369	369	469	1,611	1,654	5,227
Wild/scenic Rivers (number)	12	15	15	15	32	32	33
FS land (million acres)	191	191	191	191	191	191	192
Grazing - all livestock:							
Number of paid permittees	14,211	15,029	13,996	11,983	10,491	9,113	8,962
AUMs authorized (1,000)	10,074	10,124	9,953	9,566	9,554	9,195	9,290
Timber:							
Number of sales	235,585	366,874	289,043	275,895	271,963	255,825	216,272
Volume sold (MMBF)[2]	11,061	10,819	11,318	8,415	6,395	4,515	2,885
Volume harvested (MMBF)[2]	9,244	10,941	12,712	11,951	8,475	5,917	3,866
Recreation:							
Visitor days (1,000)	227,708	225,407	238,458	252,495	278,849	295,473	345,083
Trails (Miles)	101,847	99,468	102,507	108,381	116,585	121,059	125,422
Nature and Wildlife:							
Wilderness areas (number)	163	327	348	354	380	397	398
Wilderness acres (1,000)	25,228	32,102	32,457	32,534	33,586	34,584	34,577
Wild and scenic rivers (miles)	1,722	1,919	2,404	3,338	3,417	4,316	4,385

NR = Not reported.

[1] Thousand board feet.

[2] Million board feet.

Sources: USDA, ERS, based on U.S. Department of the Interior, Bureau of Land Management, Public Land Statistics (various years) and USDA, Forest Service, Report of the Forest Service (various years).

Commercial users of Federal lands defend existing policies on a number of grounds. Ranchers argue that Federal rangelands are, on average, of lower quality than private rangeland. Ranchers also fear that raising Federal grazing fees would reduce ranch land values because the value of access to Federal lands is capitalized into the value of ranches. Loggers argue that roads into previously inaccessible areas of the NFS provide a stream of future recreation and logging benefits and that these benefits justify their construction by the Federal Government. The economies of many rural communities, particularly in the West, are heavily dependent on access to Federal lands; reducing this access, it is argued, would increase unemployment in these areas.

In 1995 and 1996, a number of administration and congressional efforts attempted to effect changes in the management of federally owned lands. Whether designed to encourage economic development or promote conservation objectives, these efforts generally met with stiff opposition, and no major reforms affecting commercial or conservation activities on Federal lands were signed into law.

While the debate over the use of Federal lands is unlikely to be resolved in the near future, elements of the debate have been reflected in land-use patterns. Both NFS and BLM lands saw a marginal decrease in the amount of grazing allowed during 1983-95 (table 1.1.12). Both agencies also sharply decreased their timber sales, largely due to court injunctions brought to address environmental issues, but also reflecting changes in forest management objectives and policy within BLM and FS. Recreation and conservation uses of BLM and FS lands increased significantly between 1983 and 1995. For the two agencies combined, the number of recreational visitor days rose almost 64 percent while the area of designated wilderness expanded 14.6 million acres. There were also significant increases in the number of trail miles and wild and scenic river miles on both FS and BLM lands.

Conflicts With Environmental Preservation

Virtually all of the Nation's 460 million acres of cropland and much of its 591 million acres of grassland pasture and range were once wetlands, forest, native grassland, or some other natural ecosystem. In converting these lands to agricultural uses, many of their environmental goods and services have been damaged or lost. Additionally, incidental consequences of crop and livestock production, such as soil erosion and farm chemical runoff, can stress connected ecosystems. Conservation has become a recurring issue in agricultural policy for two reasons. First, government policies have often encouraged the conversion of natural areas to agriculture and the use of production practices with negative environmental impacts (for example, chemical-intensive monoculture systems). Second, the private benefits of conservation are often insufficient to induce farmers and ranchers to protect natural resources at levels that are optimal from a social perspective. This section briefly discusses five areas where conflicts between agricultural and environmental uses of land are likely to become important policy issues.

Endangered Species. As of September 30, 1995, 663 plant and animal species inhabiting the contiguous 48 States (during at least some part of their life cycle) were listed by the Federal Government as threatened or endangered. Of these species, 380 are listed, at least in part, due to activities typically associated with agriculture (table 1.1.13). Agricultural development (that is, the conversion of land to agricultural production) and grazing threaten the most species, 272 and 171. Exposure to fertilizers and pesticides is a factor in the listing of 115 species. While farm production accounts for the large majority of such listings, some listings are due to nonfarm uses of these chemicals. Of the species listed due to the use of fertilizers and pesticides, 28 have been linked to fertilizers, 85 to herbicides, and 80 to other pesticides.

Competition between agriculture and endangered species for land has heightened due to the Endangered Species Act (ESA) of 1973. The stated purpose of the ESA is to provide a means for protecting ecosystems upon which threatened and endangered (T&E) species depend and to provide a program for the conservation of such species. Several sections of the ESA have important implications for agriculture.

Section 6 prohibits State laws protecting federally listed T&E species from being less restrictive than the ESA. Hence, States have limited ability to grant exemptions to ESA restrictions regardless of compliance costs. Section 7 requires Federal agencies to ensure that actions they fund, authorize, or carry out are not likely to jeopardize the survival of T&E species. Potentially, this brings commodity program participants, users of federally supplied irrigation water, and holders of Federal grazing permits and leases within reach of the ESA. Additionally, Section 11 allows private agents to sue Federal agencies to force their compliance with ESA provisions. This has caused concern that the ESA may be used to restrict pesticide use because these products can be distributed in the United States only if they have been registered or exempted from registration by the Environmental Protection Agency. Finally, Section 9 makes it illegal to take, possess, transport, or traffic in listed animals except by permit; for plants it is illegal to collect or maliciously damage endangered species on Federal lands. For listed animal species then, the ESA can affect land-use decisions on both public and private lands; for listed plant species, it can affect land-use decisions only on Federal lands.

Wildlife Habitat. Agriculture affects the welfare of wildlife populations beyond endangered species. While a few species have adapted well to farm systems (for example, white-tail deer, Canada geese, raccoons, and coyotes), agriculture has negatively impacted most species. Over the last 30 years, habitat loss due to conversion of land to agriculture has reduced wild species numbers more than any other human activity (McKenzie and Riley, 1995). In prairie regions between 1980 and 1989, for example,

Table 1.1.13—Federally listed threatened and endangered (T&E) species in the contiguous 48 States by source of agricultural threat as of September 30, 1995[1]

Species	All T&E species	Source of agricultural threat						
		Agriculture[2]	Agricultural development[3]	Grazing	Fertilizers	Herbicides	Other pesticides[4]	Fertilizers and pesticides[5]
	Number of species							
All species	663	380	272	171	28	85	80	115
Vertebrates:	240	138	106	57	9	18	34	39
Amphibians	10	6	6	3	1	2	2	2
Birds	42	26	20	16	0	3	8	9
Fish	107	64	47	23	6	9	14	17
Mammals	55	27	23	9	1	3	6	7
Reptiles	26	15	10	6	1	1	4	4
Invertebrates:	129	79	63	18	18	37	40	43
Arachnids	5	0	0	0	0	0	0	0
Clams	57	42	39	1	15	30	31	32
Crustaceans	17	11	9	1	2	4	2	4
Insects	29	18	11	11	0	2	5	5
Snails	21	8	4	5	1	1	2	2
Plants:	294	163	103	96	1	30	6	33
Angiosperms	286	160	102	94	1	30	6	33
Gymnosperms	2	1	1	0	0	0	0	0
Ferns	6	2	0	2	0	0	0	0

[1] Table excludes listed marine species and domestic species found only outside the contiguous United States. Some species threatened by nonfarm uses of pesticides and fertilizers are included.

[2] Column 2 does not represent the sum of columns 3-7 because many species face more than one threat from agriculture.

[3] Conversion of land use to cropland.

[4] With respect to agricultural production, the term "pesticides" generally refers to a wide range of chemical compounds that include herbicides, insecticides, fungicides, nematicides, rodenticides, and fumigants. Herbicides, insecticides, and fungicides account for the large majority of pesticide applications in agriculture.

[5] Column 8 does not represent the sum of columns 5-7 because many species are threatened by more than one type of chemical.

Source: USDA, ERS, based on data supplied by BioData, Inc., 1995.

populations of grassland-nesting birds declined 25 to 65 percent. Many duck populations have also fallen dramatically. Mallard, winged teal, and pintail populations, for example, have declined 43, 45, and 71 percent since the 1970's.

At the same time, agriculture must be a key component of any national wildlife conservation program. Within the 48 States, the farm sector owns vast quantities of valuable wildlife habitat, including over 60 percent of all wetlands and 38 percent of all forests and woodlands. Agricultural producers also have senior use rights to millions of acre-feet of surface water in the West. Finally, tens of millions of acres of cropland and pasture have high wildlife producing potential and are thus prime candidates for habitat restoration. Additionally, the success of the Conservation Reserve Program (CRP) in enhancing many wildlife populations is promising (see chapter 6.3, *Conservation Reserve Program*).

Wetlands. In 1780, there were an estimated 221 million acres of wetlands in what is now the contiguous 48 States; a recent estimate is less than 124 million acres (see table 6.5.1 in chapter 6.5, *Wetland Programs*). Bringing land into agricultural production accounts for more than 80 percent of all wetlands lost since colonial times (U.S. Congress, OTA, 1993). Nearly a third of all wetlands losses have occurred in the farm-intensive States of Illinois, Indiana, Iowa, Michigan, Minnesota, Ohio, and Wisconsin (Dahl, 1990).

In recent years, the full range of ecological functions and economic benefits associated with wetlands has become much better understood; these include critical wildlife habitat, temporary stormwater storage, groundwater recharging, pollution control, sport hunting and fishing opportunities, wildlife viewing, and breeding grounds and nurseries for many commercially important fish, fur, and game species. As a result, Federal wetlands policy has increasingly emphasized conservation, and much of this policy shift has been directed at agriculture. Swampbuster provisions of the Food, Agriculture, Conservation, and Trade Act of 1990, for example, denied crop subsidy payments to farmers who converted wetlands to boost commodity program acreage—even if the converted wetlands were not directly used to produce program crops (U.S. Congress, OTA, 1993). Violation of Swampbuster regulations can mean the loss of eligibility for all farm program benefits—including commodity program participation, crop insurance, and disaster payments—until the violation is remedied. The Wetlands Reserve Program and the Emergency Wetlands Reserve Program pay farmers to preserve their wetlands and offer cost shares to encourage wetlands restoration.

Agriculture's role in converting wetlands to other uses has been declining. Between 1954 and 1974, agriculture accounted for 81 percent of all gross wetlands losses; between 1982 and 1992, it accounted for only 20 percent (see table 6.5.2 in chapter 6.5, *Wetlands Programs*). Furthermore, this percentage change reflects a decrease in conversions of land to agriculture rather than an increase in wetlands losses due to other activities.

About 90 percent of the 124 million acres of wetlands remaining in 1992 in the 48 States was on rural nonfederal lands. Given its ownership of these land resources, the farm sector will likely remain a primary target of wetlands conservation efforts. (See chapter 6.5, *Wetlands Programs*, for more detail.)

Water Quality. Agriculture threatens many wetland and aquatic ecosystems via the discharge of runoff laden with sediments and chemical residues. Nationally, runoff from agricultural land accounts for 60 percent of the sediment and about half of the phosphorus and nitrogen reaching freshwater systems (Crutchfield and others, 1993). This can create a variety of environmental problems in aquatic ecosystems. Nutrients from fertilizer applications can increase algae and plant growth, which in extreme cases can promote eutrophication of streams, lakes, and estuaries. Residues from pesticide applications can have toxic effects on freshwater and marine species as well as their predators. Soil sediments can decrease sunlight penetration in water bodies, deteriorate spawning grounds, and reduce supplies of dissolved oxygen.

Because of the widespread nature of environmental problems associated with agricultural runoff, water quality will continue to be an important source of conflicts between the farm sector and the environment. (For more detail, see chapter 2.2, *Water Quality*, and chapter 6.2, *Water Quality Programs*).

Air Quality. Onfarm air pollution has recently received increased attention. Principal concerns include crop damage, noxious odors, particulate matter or dust, and wildfires. Crop damages occur due to off-farm pollution, such as ozone and other airborne pollutants, drifting into agricultural areas reducing growth and seed formation of field crops. These yield reductions of 5-10 percent are concentrated in areas near large population centers (Westenbarger and Frisvold, 1995). While airborne pollutants do not directly cause a severe reduction in yields, they can weaken plants and make them more susceptible to disease or insect damage.

Onfarm odors have brought about legal action by nearby property owners, who have seen their quality of life and property values suffer. These odors are generally a problem around large-scale livestock facilities, as well as near farms that fertilize with stored manure sludge. Anticipated odor problems have delayed or prevented construction of some livestock or poultry operations. The backlash against noxious odors has prompted some farmers to band together to create "right-to-farm" zones that protect farm operators against lawsuits by newcomers who were aware of the farms' existence before purchasing their property.

Particulate matter, or "fugitive dust," is a problem in dry areas where wind erosion is high. The Agricultural Research Service (ARS) and the Natural Resources Conservation Service (NRCS) are working with the Environmental Protection Agency (EPA) to study conditions that lead to excessive airborne particulate pollution.

Wildfires affect respiratory health in rural areas, and the Forest Service and other agencies manage controlled burning programs to reduce their incidence. In a controlled burn, dry brush and dead trees are removed by burning to remove the kindling that contributes to uncontrolled wildfires.

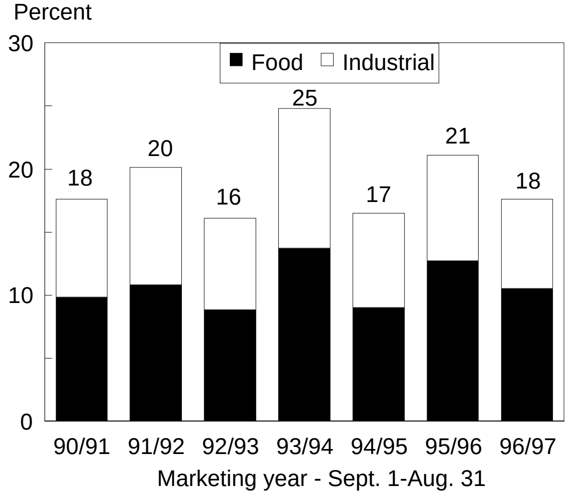
Using Agricultural Lands for Biomass and Fuel Production

New uses for existing crops have helped to stabilize demand for agricultural commodities. Corn, primarily considered a feedgrain, is increasingly being used in food and industrial products. Food uses—including high-fructose corn syrup, glucose and dextrose, cereals and other products, food starch, and beverage alcohol—will account for a forecasted 975 million bushels of corn in the 1996/97 (September 1-August 31) marketing year (Glaser, 1996). Corn used for industrial uses and fuel alcohol production is forecast to require an additional 661 million bushels (of the 9.3 billion bushels of corn expected to be produced in 1996/97) (USDA, NASS, 1997a).

As the nonfeed demand for corn has increased, a greater share of harvested corn acres has been devoted to food and industrial uses. Based on average yields, food and industrial uses of corn will account for 13 million of the 73 million acres of corn harvested in 1996/97 (USDA, NASS, 1997a). The share of total harvested corn devoted to all food and industrial uses is expected to be the same in 1996/97 as in 1990/91—nearly 18 percent. It has been as high as 25 percent in intervening years (fig. 1.1.7). Much of the increase in nonfeed uses of corn is a result of fuel alcohol production, which increased from about 900 million gallons in 1990/91 to an expected 1.4 billion gallons in 1995/96.

Little of the production from the estimated 23 million corn acres required for the food and industrial uses has come at the expense of other commodities. Since 1990/91, the total amount of acres planted to corn plus the acres set aside under annual programs has declined from 85 million acres to 79 million acres in 1996/97. For the most part, the added food and industrial demand for corn has been met through higher yields and stocks. Since 1990/91, ending corn stocks have averaged about 1.3 billion bushels per year while the food and industrial demand for corn has averaged 1.5 billion bushels per year. However, ending stocks for corn have fallen during the 1990's and added demand could soon have more noticeable impacts on acreage allocation and prices.

Figure 1.1.7--Share of harvested corn acres devoted to nonfeed uses



Source: USDA, ERS, based on Glaser, 1995.

Work on new commercial and industrial uses for crops, crop byproducts, and other renewable resources is continuous. Considerable applications are technically possible, but not economical compared with existing alternatives. For example, there is great interest in energy from biomass, which includes liquid and gaseous fuels as well as direct combustion of agricultural crops, crop and livestock byproducts, and herbaceous material and wood.

The use of cropland to produce biomass as a primary product will depend on returns to biomass crops exceeding the return to crops currently produced. This may occur through increases in prices, including scarcity of alternative energy sources, the need for the use of biofuels to meet environmental quality standards, or as a result of economic incentives. Cropland idled in the Conservation Reserve Program (CRP) might be used to produce herbaceous or tree crops as biomass energy sources through subsidies that would keep the land out of crop production yet protect and maintain the land resource. However, in early 1996, there was increasing concern with commodity scarcity, not excess stocks, and there was a call for releasing the CRP land for crop production. Thus, estimates of how much land might be used for biomass production require assumptions regarding the demands and supplies of agricultural commodities, types of energy needed, and environmental quality programs (including taxes and incentives). One recent analysis of biomass production in the United States in 2000, 2005, and 2020 concluded that, with the current estimates of the future price and yield relationships, "biomass-based electricity generation is likely to be more of a *niche* than a mass market where electricity is expensive and biomass fuel is cheap or incurs a disposal cost, e.g. waste wood, sawdust, etc." (Roningen and others, 1995). (For more discussion of energy from agricultural biomass, see chapter 3.3, *Energy*.)

Potential Impacts of Global Climate Change

The potential for emissions of greenhouse gases to change Earth's climate has been the subject of concerted Federal research since the late 1970's. The United Nations Framework Convention on Climate Change was signed by representatives from 155 countries, including the United States, at the United Nations Conference on Environment and Development (the Rio Earth Summit) in 1992. Ratification of the Convention by more than 50 nations occurred in late 1994, putting the agreement into force. The United States was among the early nations to ratify the Convention. The key provision for land use is Article 2: "The ultimate objective of this Convention ... is to achieve stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner."

Recent research conducted at ERS links world land and water resources with climate conditions and economic activity to analyze how four climate change scenarios might affect world agriculture and land use (Darwin and others, 1995). Under the scenarios, reduced productivity on Earth's existing agricultural lands, because of new temperature and precipitation patterns, would be more than offset by expanding agricultural production in new areas. Global food production would increase. However, if climate change were relatively severe, increased food production might not counter losses in other sectors and global economic activity could decrease. Only the effects of changes in atmospheric concentrations of CO_2 on climate were considered. The beneficial effects of greater atmospheric concentrations of CO_2 on plant growth and the effects of changes in the atmospheric concentrations of other gases like ozone and sulphur dioxide on both the climate and plant growth are still under study.

In the United States, all climate change scenarios result in land use changes on at least 48 percent of existing cropland. In two scenarios, more than half of all U.S. cropland ends up with a shorter growing season and 8-19 percent is abandoned (40-90 million acres). Some farm communities would be severely disrupted, particularly in areas where the only economically viable adaptation would be to abandon agriculture. Forest losses in some areas would be offset by gains in others. Likewise, net change in pasture could be negative or positive (from -0.1 to 7.4 percent). The environmental effects of such land use changes have yet to be determined, but will depend on the rate of change in the climate and the speed at which ecosystems migrate.

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1.2 Land Tenure

While most U.S. land was once held by the Federal Government, 60 percent (including virtually all farmland) is now privately owned. Most farms and most farmland are held by individuals or families, but leased land represents an increasing share of their operations as farm numbers decline and average farm size increases. Partial interests in land play a growing role in the conservation efforts of public agencies and private organizations.

Contents

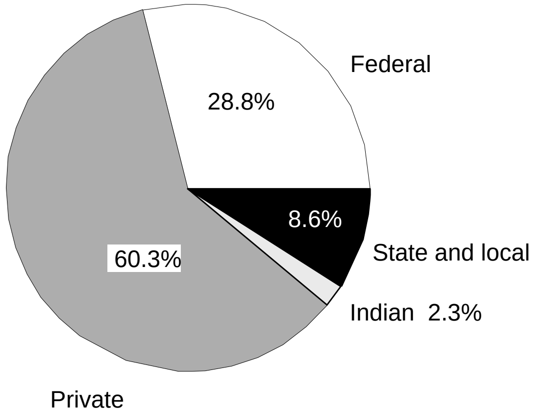
Land tenure is the system of rights and institutions that shapes access to land. Ownership and leasing are common features of land tenure in the United States. Less frequently recognized are zoning ordinances, subsurface mineral rights, conservation easements, and other instruments that arise out of law, custom, and the operation of private markets. Land tenure influences decisions about how land and other resources are used. These decisions, in turn, have important economic and environmental consequences for landowners and for other members of society.

Ownership of U.S. Land

The land surface of the United States covers 2.3 billion acres. Sixty percent (1.4 billion acres) is privately owned, 29 percent is owned by the Federal Government, 9 percent is owned by State and local governments, and 2 percent is on Indian reservations (fig. 1.2.1). Virtually all cropland is privately owned, as is over half of grassland pasture and range and forest land (table 1.2.1; cropland and other terms are defined in the Glossary, p. 38). Federal, State, and local government holdings consist primarily of forest land and other land.

While 60 percent of U.S. land is privately owned today, land tenure patterns were significantly different in the first century after independence. Between 1781 and 1867, through purchase, cession, and treaty, the Federal Government acquired lands totaling 81 percent of current U.S. area—the original “public domain” (table 1.2.2). The largest acquisition, the Louisiana Purchase, added 530 million acres in 1803.

Figure 1.2.1--Land ownership in the United States, 1992



Note: Includes all 50 States for a total of 2.3 billion acres.
Source: USDA, ERS, based on Daugherty, 1995.

Table 1.2.1—Ownership of land by major use, United States, 1992

Ownership	Cropland	Grassland pasture & range	Forest land[1]	Other[2]	Total[4]
	Million acres				
Federal	--	146	249	256	651
State & local	3	41	78	73	195
Indian[3]	2	33	13	5	53
Private	455	371	397	141	1,364
Total[4]	460	591	737	475	2,263

-- = less than 500,000 acres.

[1] Includes reserved forest land in parks and other special uses.

[2] Includes urban land, highways, and other miscellaneous uses; excludes an estimated 83 million acres in special uses that have forest cover and, therefore, are included with forest land.

[3] Managed in trust by the Bureau of Indian Affairs, U.S. Department of the Interior.

[4] Totals represent all 50 States.

Source: USDA, ERS, based on Daugherty, 1995.

Other large acquisitions included cessions from the original 13 States and from Mexico, as well as the Alaska Purchase. Acquisitions after 1867, including purchase of degraded forest and farmlands, added most of the Eastern United States' national forests (45 million acres) as well as 4 million acres of national grasslands (National Research Council, 1993; U.S. Department of Agriculture, Forest Service, 1993).

As of 1995, 1.1 billion acres of the original public domain (51 percent of total U.S. area) had been granted or sold by the Federal Government to States, corporations, and individuals (table 1.2.3). Grants to States totaled 329 million acres, including 65 million acres of wetlands granted on condition that proceeds from their subsequent sale to individuals be used to convert those acres to agricultural production. Another 288 million acres were granted or sold directly to homesteaders on condition that the land be settled and cultivated. Disposition of Federal lands had slowed by the 1930's, and in 1976 the Federal Land Policy and Management Act explicitly directed that most remaining Federal lands be retained in Federal ownership (National Research Council, 1993). Remaining Federal lands totaled 650 million acres in 1993 (table 1.2.4).

Most lands in Federal ownership are managed by four agencies: USDA's Forest Service; and the Department of the Interior's Bureau of Land Management (BLM), Fish and Wildlife Service (FWS), and National Park Service (NPS) (table 1.2.5). Federal lands are concentrated in Alaska and the West (fig. 1.2.2, table 1.2.6). Forest Service and BLM lands are managed for a variety of uses, including grazing, timber harvest, and wilderness preservation, while FWS and NPS lands are managed primarily for preservation and recreation. Controversies over public lands, for example with regard to grazing and timber harvests, have prompted proposals to transfer management, if not ownership, of some of these lands to States and

Table 1.2.2—Acquisition of the original public domain, 1781-1867

Acquisition	Year(s)	Land area	Water area	Total area	Percent of total U.S. land	Cost
		----------------*Million acres*---------------			*Percent*	*$ million*[3]
State cessions	1781-1802	233.4	3.4	236.8	10.5	6.2
Louisiana Purchase[1]	1803	523.4	6.5	529.9	23.4	23.2
Red River Basin	1782-1817	29.1	0.5	29.6	1.3	--
Cession from Spain	1819	43.3	2.8	46.1	2.0	6.7
Oregon Compromise	1846	180.6	2.7	183.4	8.1	--
Mexican Cession	1848	334.5	4.2	338.7	15.0	16.3
Purchase from Texas	1850	78.8	0.1	78.9	3.5	15.5
Gadsden Purchase	1853	19.0	0.0	19.0	0.8	10.0
Alaska Purchase[2]	1867	365.3	12.9	378.2	16.7	7.2
Total	1781-1867	1,807.5	33.2	1,840.7	81.3	85.1

[1] Excludes areas eliminated by the treaty of 1819 with Spain.

[2] Adjusted for the recomputation of the areas of the United States that was made for the 1980 decennial census.

[3] Nominal dollars.

Source: USDA, ERS, based on U.S. Department of the Interior, Bureau of Land Management, 1996.

Table 1.2.3—Disposition of the original public domain, 1781-1995

Disposition	Acres	Percent of total disposition
	Million	*Percent*
Granted to States for:		
Support of common schools	77.6	6.8
Reclamation of swampland	64.9	5.7
Construction of railroads	37.1	3.2
Support of miscellaneous institutions[1]	21.7	1.9
Canals and rivers	6.1	0.5
Construction of wagon roads	3.4	0.3
Other[2]	117.6	10.3
Total granted to States	328.5	28.7
Granted or sold to homesteaders[3]	287.5	25.1
Granted to railroad corporations	94.4	8.2
Granted to veterans as military bounties	61.0	5.3
Confirmed as private land claims[4]	34.0	3.0
Sold under timber and stone law[5]	13.9	1.2
Granted or sold under timber culture law[6]	10.9	1.0
Sold under desert land law[7]	10.7	0.9
Other[8]	303.5	26.5
Total dispositions, 1781-1995	1,144.4	100.0

[1] Universities, hospitals, asylums, etc.

[2] Construction of unspecified public improvements, reclamation of desert lands, etc.

[3] The homestead laws generally provide for the granting of lands to homesteaders who settle upon and improve vacant agricultural public lands.

[4] The Government has confirmed title to lands claimed under valid grants made by foreign governments prior to the acquisition of the public domain by the United States.

[5] The timber and stone laws provided for the sale of lands valuable for timber or stone but unfit for cultivation.

[6] The timber culture laws provided for the granting of public lands to settlers on condition that they plant and cultivate trees on the lands granted.

[7] The desert land laws provide for sale of arid agricultural public lands to settlers who irrigate them and bring them under cultivation.

[8] Chiefly public, private, and pre-emption sales, but includes mineral entries, strip locations, and sales of townsites and townlots.

Source: USDA, ERS, based on U.S. Department of the Interior, Bureau of Land Management, 1996.

Table 1.2.4—Federal land acquisition, disposition, and holdings as of 1993

Item	Million acres
Public domain acquisitions	1,840.7
- Public domain dispositions	1,144.4
- Water area	33.2
- Lands held in trust	52.0
+ Net other Federal acquisitions[1]	39.2
= Federal landholdings, 1993[2]	650.3

[1] This figure reconciles BLM data on public domain acquisitions, dispositions, and waters with GSA data on lands held in trust and Federal landholdings in 1993. GSA reports net Federal acquisitions of 59.9 million acres as of 1993.

[2] This total reflects a 0.8-million acre decline in Federal ownership from the 1992 total reported in table 1.2.1.

Source: USDA, ERS, based on U.S. Department of the Interior, Bureau of Land Management, 1996; U.S. General Services Administration, 1995.

Table 1.2.5—Federal landholdings by agency, 1993

Department/Agency	Million acres	Percent of total
Department of Agriculture	184.9	28.4
Forest Service	184.5	28.4
Other Agencies	0.4	0.1
Department of Defense	20.8	3.2
Department of the Interior	443.4	68.2
Bureau of Land Management	271.2	41.7
Fish and Wildlife Service	90.4	13.9
National Park Service	73.2	11.3
Other Agencies	8.6	1.3
Other Departments	1.2	0.2
Total[1]	650.3	100.0

[1] Reflects a 0.8-million acre decline in Federal ownership from the 1992 total reported in table 1.2.1.

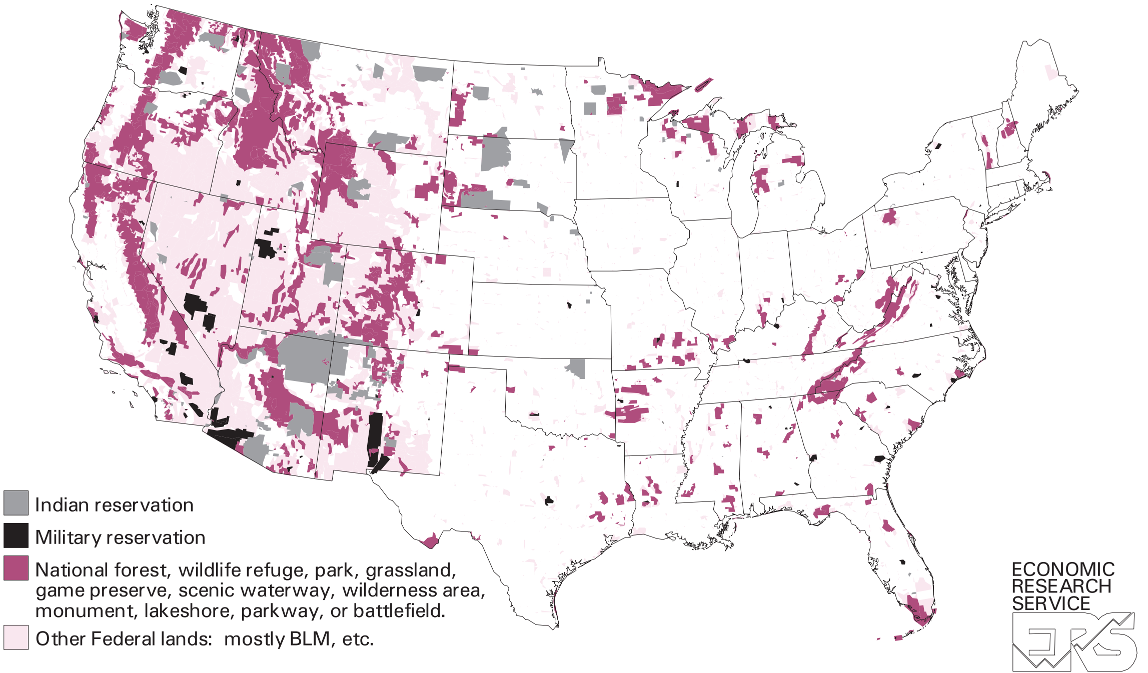
Source: USDA, ERS, based on U.S. General Services Administration, 1995.

counties. Federal land uses and conflicts are described in greater detail in chapter 1.1; Federal lands subject to conservation restrictions are discussed later in this chapter.

Even on lands remaining in Federal ownership, tenure is complicated by the fact that private individuals and corporations hold a variety of partial interests, including rights of way, mineral leases, and oil and gas leases (Laitos and Westfall, 1987). By contrast, grazing permits and livestock-use permits are revocable licenses, and “convey no right, title, or interest held by the United States in any land or resources” (U.S Department of Agriculture, Forest Service, 1991).

The principal source of funding for Federal land acquisitions today is the Land and Water Conservation Fund (LWCF), created by Congress in 1964 (National Research Council, 1993). LWCF appropriations have fallen from about $800 million in 1978 to $100-$400 million per year since the early 1980’s; appropriations for fiscal year 1997 are $149 million (fig. 1.2.3).

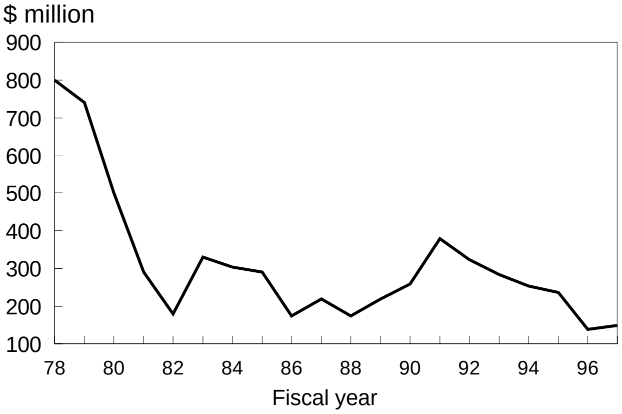
Figure 1.2.2--Federal lands, by type, 1992



Source: USDA, ERS, based on data from USGS and NRCS 1992 National Resources Inventory.

As of 1992, State and local governments in the 48 contiguous States owned a total of 107 million acres (table 1.2.6), or 6 percent of the total area of the 48 States. (The differences between these data and the data in table 1.2.1 and figure 1.2.1 are accounted for primarily by Alaska, where large State holdings continue to grow as Federal land is transferred to State ownership.) State holdings were highest in the Mountain States, and local government holdings were highest in the Lake States.

Figure 1.2.3--Land and Water Conservation Fund appropriations, 1978-97



Source: USDA, ERS, compiled from National Research Council, 1993 and "Land Letter" (various years).

Foreign individuals and corporations owned 15 million acres (or 1.2 percent) of the 1.3 billion acres of privately owned agricultural land (see Glossary, p. 38) as of December 31, 1995, over half of it in the Northeast, Mountain, and Pacific States (table 1.2.7). Foreign holdings in 1995 were up slightly over 1994 and 1981 (table 1.2.8). In 1995, foreign holdings exceeded 2 percent of privately owned agricultural land in nine States, led by Maine with 16 percent. Forest land accounted for 49 percent of all foreign holdings, pasture and other noncropped agricultural land for 32 percent, cropland for 16 percent, and nonagricultural land for 3 percent. Individuals and corporations from Canada held the largest share of foreign-owned agricultural land (32 percent), followed by owners from the United Kingdom (19 percent) and Germany (11 percent) (Krupa and others, 1996).

Farmland Tenure

On private land, decades-long trends in farm size and organizational structure continued between 1987 and 1992. Land in farms (see Glossary) totaled 946 million acres in 1992, down 19 percent from a peak of 1.2 billion acres in 1940 (Wunderlich, 1995; fig. 1.2.4). Over about the same period, the number of farmland owners declined by half, farm numbers fell by nearly three quarters to 1.9 million, and average farm size nearly tripled, to 491 acres. Farms of 500 acres or more continue to represent an increasing percentage of total farm numbers (fig. 1.2.5). Meanwhile, the percentages represented by farms of 1-49 acres and 50-499 acres have moved in opposing directions since the turn of the century, indicating a shift from the former to the latter in the 1950's and 1960's followed by a reversal in the late 1970's and early 1980's. Of the 1.9 million farms in 1992, over half were still smaller than 180 acres (table 1.2.9). Farms of 500 acres or more, representing 19 percent of all farms, accounted for 79 percent of land in farms and 55 percent of total sales. Nearly half of all farms sold less than $10,000 worth of agricultural products in 1992, while the 2 percent of farms with sales over $500,000 accounted for nearly half of total sales (fig. 1.2.6).

Table 1.2.6—Land ownership by farm production region, 48 contiguous States, 1992[1]

Region	Federal	State	Local	Indian	Private	Total
			Million acres			
Northeast	2.7	10.5	2.4	0.1	94.9	110.6
Appalachian	8.6	2.5	0.9	0.1	110.7	122.7
Southeast	8.0	4.4	1.2	0.2	108.4	122.1
Delta States	6.2	2.2	0.9	0.0	81.1	90.4
Corn Belt	3.6	2.8	2.2	0.0	154.8	163.4
Lake States	8.4	6.5	12.7	1.1	93.4	122.0
Northern Plains	6.2	3.8	1.4	4.7	177.3	193.5
Southern Plains	4.4	5.1	1.7	0.3	199.0	210.5
Mountain States	267.9	35.4	1.5	35.7	206.2	546.8
Pacific	91.6	6.7	1.9	3.7	99.6	203.5
Total	407.5	79.8	26.9	45.9	1,325.3	1,885.5

[1] All land, including urban land.

Source: USDA, ERS, based on 1992 National Resources Inventory.

Table 1.2.7—U.S. agricultural landholdings of foreign owners, 1995

Region	Acres foreign-owned	Percent of private land	Percent of total foreign holdings
Northeast	3,522,260	4.2	23.3
Lake States	744,100	0.8	4.9
Corn Belt	596,338	0.4	3.9
Northern Plains	215,055	0.1	1.4
Appalachian	669,381	0.6	4.4
Southeast	1,677,943	1.7	11.1
Delta States	1,282,343	1.6	8.5
Southern Plains	1,265,983	0.7	8.4
Mountain States	2,959,690	1.5	19.6
Pacific	1,987,972	2.1	13.2
Alaska, Hawaii, & Puerto Rico	180,972	7.2	1.2
U.S. total	15,102,037	1.2	100.0

Source: USDA, ERS, based on Krupa and others, 1996.

Table 1.2.8—Proportion of foreign-owned to privately owned agricultural land, 1981-95[1]

Selected States[2]	1981	1987	1993	1994	1995
			Percent		
Arizona	2.1	2.5	3.2	3.2	3.2
California	1.8	1.9	2.1	2.1	2.2
Florida	1.8	2.0	2.6	2.6	2.6
Hawaii	2.8	2.7	9.0	9.0	9.0
Louisiana	0.6	2.5	2.8	2.7	2.8
Maine	14.1	9.0	13.4	11.4	16.4
Nevada	0.7	0.6	3.5	3.5	4.7
New Mexico	1.9	1.6	2.2	2.2	2.2
Oregon	2.0	3.4	2.6	2.3	2.3
Total U.S.	1.0	1.0	1.2	1.1	1.2

[1] As defined by 7 USC 3508, includes both farm and forest lands.

[2] States with at least 2 percent foreign ownership in 1995.

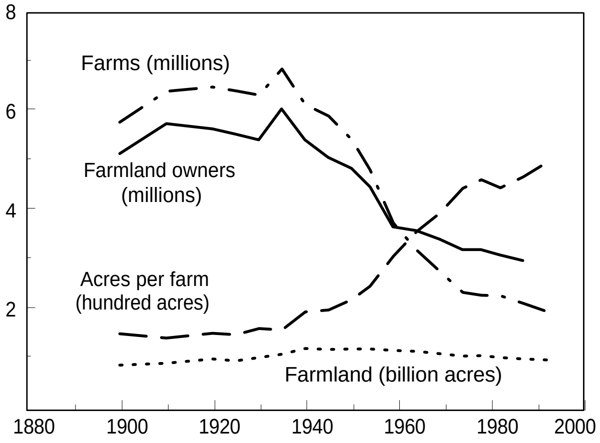
Source: USDA, ERS, based on DeBraal, 1993, and Krupa and others, 1996.

Concentration is receiving closer attention in the case of livestock production, with its associated waste management, water quality, and odor concerns (see chapter 2.2, *Water Quality*). Since 1959, for example, the number of farms on which hogs or pigs were sold has fallen by more than 85 percent (fig. 1.2.7), while the number of hogs and pigs sold has risen by 38 percent (*1992 Census of Agriculture*).

Despite the changing scale of farm operations, sole proprietorship continued to be the dominant organizational structure for farm businesses in 1992, accounting for 86 percent of farms and 64 percent of farmland, and generating 54 percent of the value of agricultural production (table 1.2.10). Even among farm corporations, nearly 90 percent were family-held in 1992. While fewer in number and smaller in total acreage than sole proprietorships, partnerships and corporations were larger on average, in terms both of acreage and of value of production.

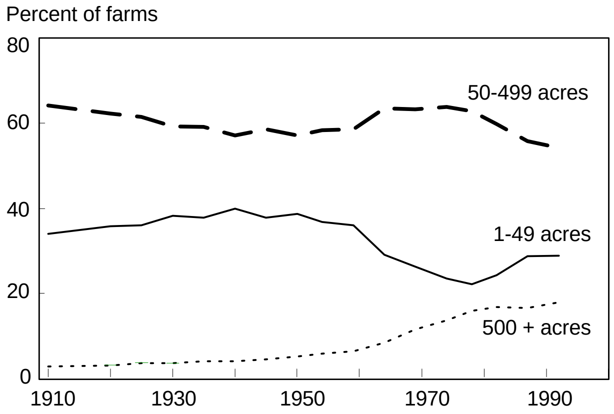
While most farm businesses are still operated as sole proprietorships, declining numbers of owners and increasing farm sizes have resulted in changing farmland ownership patterns. About 58 percent of all farms are now operated by full owners (who own all of the land they farm), 31 percent are operated by part owners (who own part of the land they farm), and 11

Figure 1.2.4--Farms, farmland, farm owners, and average acres per farm, 1900-92



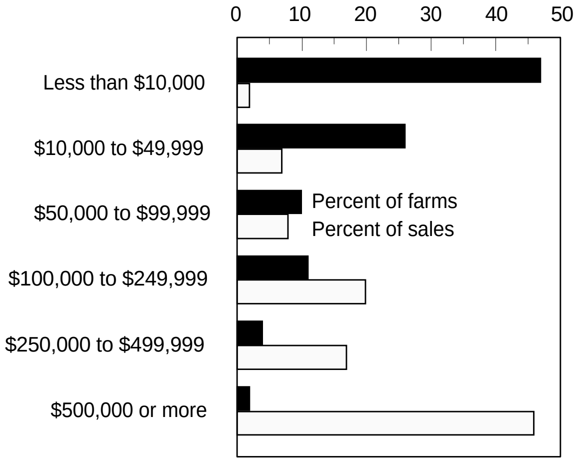
Source: USDA, ERS, based on Census of Agriculture,1954 and 1992.

Figure 1.2.5--Changing size and concentration in U.S. agriculture, 1900-92



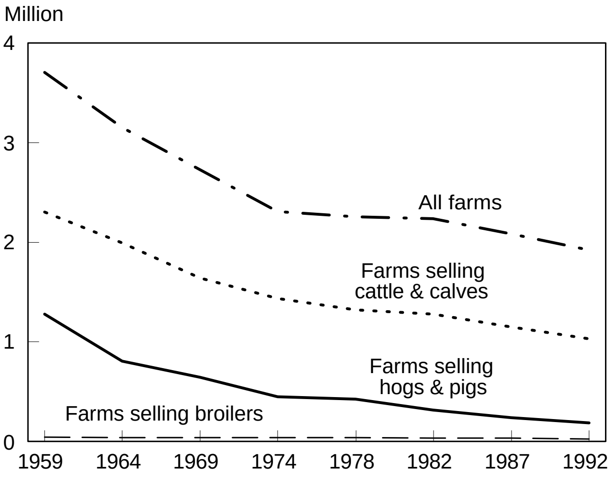
Source: USDA, ERS, based on Census of Agriculture, 1954 and 1992.

Figure 1.2.6--Distribution of farms by sales, 1992



Source: USDA, ERS, based on 1992 Census of Agriculture.

Figure 1.2.7--Livestock farm numbers, 1959-92



Source: USDA, ERS, based on 1992 Census of Agriculture.

Table 1.2.9—Size structure of U.S. farms, 1992

	Number of farms operated by				Land in farms (acres)	Total sales ($ billion)
	Full owners	Part owners	Tenants	Total		
Total	1,111,738	596,657	216,905	1,925,300	945,531,506	162.6
				Percent of total		
1-9 acres	7.2	0.4	1.0	8.6	0.1	3.0
10-49 acres	15.9	2.6	1.7	20.1	1.1	6.8
50-99 acres	10.6	2.8	1.3	14.7	2.2	5.6
100-179 acres	9.9	3.9	1.7	15.6	4.3	7.8
180-259 acres	4.6	3.2	1.1	8.9	3.9	6.2
260-499 acres	5.2	6.3	1.8	13.3	9.7	15.2
500-999 acres	2.5	5.8	1.4	9.7	13.7	19.8
1,000-1,999 acres	1.0	3.5	0.7	5.3	14.7	16.3
2,000+ acres	0.8	2.4	0.5	3.7	50.4	19.3
All farms	57.7	31.0	11.3	100.0	100.0	100.0

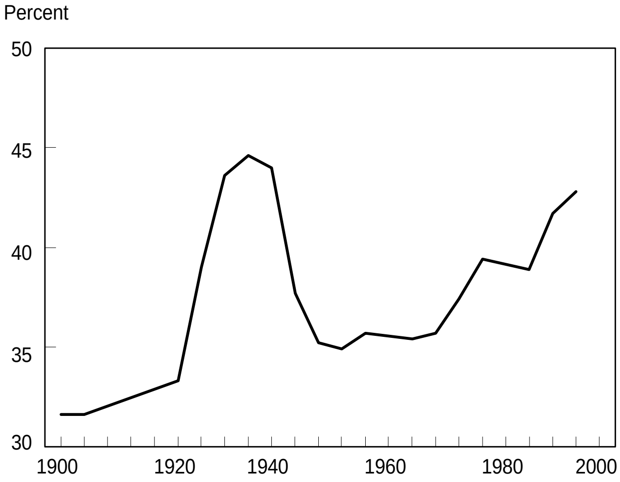
Source: ERS, USDA, based on 1992 Census of Agriculture.

percent are operated by tenants (who rent all of the land they farm) (table 1.2.9). While full owners outnumbered part owners and tenants in 1992, part owners operated larger farms on average (883 acres) than either full owners (266 acres) or tenants (566 acres) (*1992 Census of Agriculture*). Three-quarters of full owners operate farms smaller than 180 acres, while two-thirds of part owners operate farms of 180 acres or more. Between 1987 and 1992, part owners increased both as a share of total farm operators (29 to 31 percent) and in terms of the share of total land in farms they operated (54 to 56 percent).

The growth in part ownership reflects the increasing importance of leasing as a means of access to farmland. Farmland may be rented *out* for a variety of reasons, for example, as an investment by a nonoperating owner or as a reduction in the scale of operation by a farmer approaching retirement. Farmland may also be rented *in* for a variety of reasons. For example, it allows farmers to avoid tying up equity capital in land, reduces risk associated with asset depreciation, increases management flexibility in overall size of operation and combination of land types, and provides a means of entering agriculture (Rogers, 1991). Of the 946 million acres of farmland in 1992, nearly 43 percent (405 million acres) were rented by farm operators, up from 35 percent in 1954 and the highest proportion since 1940 (Wunderlich, 1995; fig. 1.2.8). About 282 million acres were rented by part owners, and 123 million acres were rented by tenants.

The increase in farmland leasing has occurred alongside an increase in land ownership by nonfarmers. Land owned by nonfarming landlords increased to 37 percent of all farmland in 1992, or 350 million acres, up from 36 percent in 1987 (Wunderlich, 1995). The importance of nonfarming landlords is evident in the nature of lease arrangements: nonfarming landlords may be less involved in farming decisions than are landlords who are farmers themselves, and this lesser degree of

Figure 1.2.8--Leased farmland as a percentage of total farmland, 1900-92



Source: USDA, ERS, based on Wunderlich, 1995.

Table 1.2.10—Farms, land in farms, and value of production by type of business organization, 1992

Type of organization	Farms		Land in farms			Value of production		
	Number	*Percent*	*Acres (million)*	*Percent*	*Acres per farm*	*Total sales ($ billion)*	*Percent*	*Sales per farm ($1,000)*
Sole proprietorship	1,653,491	85.9	604.3	63.9	365	87.9	54.0	53.2
Partnership	186,806	9.7	152.8	16.2	818	29.3	18.0	157.0
Corporation	72,567	3.8	122.7	13.0	1,692	44.2	27.1	608.8
Family-held	64,528	3.4	110.8	11.7	1,718	34.4	21.1	533.0
Other	8,039	0.4	11.9	1.3	1,484	9.8	6.0	1217.7
Other	12,436	0.6	65.7	6.9	5,280	1.2	0.7	97.7
Total	1,925,300	100.0	945.5	100.0	491	162.8	100.0	84.5

Source: USDA, ERS, based on 1992 Census of Agriculture.

involvement may favor cash leases rather than crop-share leases. In 1992, cash rents were paid on 65 percent of rented farms, or 27 percent of all farms.

The simultaneous growth in farm size, farmland leasing, and part ownership—particularly the predominance of part ownership among larger farms—suggests that tenure arrangements may be evolving to accommodate larger operational holdings necessary for viable farming. The resulting decline in landowner participation in farming decisions may have important implications for conservation since owner-operators may differ from renter-operators in their incentives to use and conserve land.

Research on the relationship between tenure and adoption of conservation practices has produced mixed findings. Conventional expectations that owner-operators are more likely than renter-operators to adopt conservation practices are supported in some circumstances but not in others. Recent Cropping Practices Survey data show that the impact of tenure on adoption varies with the nature of particular conservation practices as well as by crop, HEL (highly erodible land) designation, and farm program participation (table 1.2.11).

Table 1.2.11—Adoption of selected conservation practices in major producing States, 1994[1]

Practice	Corn (10 States)		Soybeans (8 States)		Seven crops (28 States)	
	Owner-operator	Renter-operator	Owner-operator	Renter-operator	Owner-operator	Renter-operator
Number of observations	2,084	2,612	1,246	1,891	5,296	6,812
			Percent of observations			
Highly erodible land	20.3	18.1	18.7	16.8	24.0	21.0
Mulch tillage, 30% residue	22.0	23.2	27.7	23.1	21.7	19.9
No till	14.9	18.8	23.8	24.3	12.6	15.0
Ridge till	2.2	2.7	0.5	0.5	0.9	1.1
Row crops & small grains[2]	4.5	3.8	4.6	4.9	9.6	8.3
Hay, pasture, other[1]	10.1	4.5	2.5	3.3	5.5	3.1

[1] For States and crops included, see "Cropping Practices Survey" in the appendix.

[2] As part of a 3-year crop rotation.

Source: USDA, ERS, 1994 Cropping Practices Survey data.

Federal Restrictions on the Use of Public and Private Land

Land tenure involves more than land ownership. To balance landowners' rights with the rights of other members of society, rights to use land may be limited by government regulations, zoning ordinances, conservation easements, contracts, or other instruments that arise out of law, custom, and the operation of private markets (see box, "The Private Property Rights Issue"). This holds true whether the landowner is a private individual or the Federal Government.

For example, as of 1993, 96 million acres of Forest Service, BLM, FWS, and NPS land had been designated as wilderness by Congress, restricting the use of motorized equipment, construction of buildings and roads, development of commercial enterprises, and other activities (U.S. General Accounting Office, 1995). Another 33 million acres had been designated as wilderness study areas, providing interim protection until Congress makes a final decision on their status. In all, 44 percent of Federal lands (271 million acres, including all 164 million acres managed by FWS and NPS) are encumbered for conservation purposes by legislative or administrative restrictions.

Federal programs also seek to encourage conservation on privately owned land through both regulatory and nonregulatory means. Through Conservation Reserve Program (CRP) contracts and Wetlands Reserve Program (WRP) easements, the Federal Government acquires cultivation rights from willing farmers and farmland owners in an effort to reduce soil erosion, protect wildlife habitat, and improve water quality. The Endangered Species Act and the Clean Water Act regulate the ways in which landowners may use their land. (These instruments, as well as other policy tools, are discussed further in chapters 6.1-6.5) Most CRP contract holders own the land on which they hold CRP contracts. In 1993, 72 percent of CRP contract holders (controlling 70 percent of CRP acres) were owner-operators, 16 percent (controlling 15 percent of CRP acres) were owner-nonoperators, and 5 percent (controlling 7 percent of CRP acres) were renter-operators (Osborn, Schnepf, and Keim, 1994). WRP participation is limited to landowners. In addition, Federal tax code provides income and estate tax benefits for landowners who donate interests in environmentally valuable land to qualified conservation organizations.

The Private Property Rights Issue

Property rights are the building blocks of land tenure. Property rights may be held publicly, as in federally owned national forests; held privately, as in most U.S. farmland; or held in combination, as when a government agency acquires a conservation easement on private land. A particular landowner may hold the rights to use his or her property for various purposes and to receive benefits or profits from those uses. Those rights generate value. Because a landowner's actions on his or her land may also generate adverse effects beyond the parcel's boundaries, however, the rights of each landowner are generally limited by the rights of other landowners and the rights of other members of society. These limitations take the form of local, State, and Federal restrictions on land use.

Private property is protected by the Constitution's Fifth Amendment, which states that private property shall not be taken for public use without just compensation. Only physical appropriations of property were viewed as "takings" until 1922, when the Supreme Court ruled that regulation could also be considered a taking if it went "too far" (*Pennsylvania Coal Company v. Mahon*). Even so, the courts have considered a regulation's impact on a property's value as only one among several criteria—such as the nature of the public purpose accomplished by the regulation—in determining whether a taking has occurred.

Legislation recently considered by Congress would require the Federal Government to compensate landowners whenever Federal restrictions on land use cause property values to fall by more than a threshold percentage (Wiebe, Tegene, and Kuhn, 1995). Such legislation would have established diminution in value as a sufficient criterion by which takings could be determined, regardless of other economic and legal criteria. Most States have also considered takings legislation in recent years, and 20 States have now enacted takings bills. Most of the bills passed by State legislatures require "takings impact assessments" rather than compensation for diminished property values, but six States (Florida, Louisiana, Mississippi, Oregon, Texas, and Washington) passed compensation bills in 1995 (*Land Use Law Report*, 1995). Oregon's bill was vetoed by the Governor in July 1995, and Washington's was defeated in a referendum in November 1995, a year after voters defeated a similar measure in Arizona (American Resources Information Network, 1997).

Table 1.2.12—State farmland preservation programs, 1996

State	Year established	Acres preserved	Number of farms	Average cost per acre[2]
Maryland	1977	122,068	837	$877
Massachusetts	1977	37,445	409	$2,718
Connecticut	1978	25,192	165	$2,951
New Hampshire[1]	1979	8,469	127	n.a.
Rhode Island[1]	1982	2,428	30	$5,766
New Jersey	1983	28,713	195	$3,236
Pennsylvania	1988	76,360	611	$2,113
Vermont	1988	36,580	111	$598
Maine[1]	1990	307	1	$1,238
Delaware	1991	8,500	31	n.a.
Kentucky	1994	0	0	--
Total	1977-94	346,062	2,517	n.a.

n.a. means not available; -- means not applicable.

[1] Data as of July 1995.

[2] Current dollars.

Apart from its treatment of conservation easements in the tax code, the Federal Government's role in farmland preservation consists of three pieces of legislation. The Farmland Protection Policy Act, part of the 1980 Farm Act, requires Federal agencies to identify and minimize adverse effects of their programs on farmland preservation and to ensure compatibility with State, local, and private farmland preservation programs. The Farms for the Future Act, part of the 1990 Farm Act, authorizes the establishment of an Agricultural Resource Conservation Demonstration Project, which provides Federal loan guarantees and interest rate assistance for State trust funds through the Farmers Home Administration. So far only Vermont has been given authority to participate. In 1996, the Federal Agriculture Improvement and Reform Act increased direct Federal participation in farmland protection by establishing a Farmland Protection Program at the Federal level. This program is to protect 170,000-340,000 acres of prime, unique, or other farmland through USDA acquisition of easements or other interests in farmland, with funding of up to $35 million from the Commodity Credit Corporation. About $14 million has been spent so far to help acquire easements on 76,000 acres in 17 States.

Non-Federal Programs to Preserve Land

State and local government agencies and nongovernmental organizations also acquire partial interests in private land for conservation purposes, including the preservation of farmland, wetlands, and wildlife habitat. Farmland preservation programs, which seek to retain land in agricultural use when land values rise due to urban pressure, operate primarily at the State and local levels.

One method used by State governments is to tax agricultural, forest, and open lands based on their current-use value rather than on their market value (which might reflect development pressure). Beginning with Maryland in 1956, all 50 States have now established programs that provide preferential property tax treatment for agricultural land (Malme, 1993; Aiken, 1989). Twenty States have "pure preferential programs," which provide special treatment while land remains in agricultural use but extract no penalty when land use changes. Other States impose deferred or "roll-back" taxes plus penalties when land is converted in order to recover at least a portion of the difference between the taxes paid and the taxes that would have been due without preferential treatment. Preferential property tax treatment programs have generally had a limited effect in preventing conversion of farmland to more intensive uses because the tax benefits offered have not matched the profits available from conversion in areas experiencing development pressure (Malme, 1993).

In addition to property, income, and estate tax incentives for farmland preservation, public and private agencies also prevent farmland conversion through acquisition of agricultural conservation easements. Conservation easements are restrictions on land use voluntarily negotiated between landowners and conservation organizations (both

Table 1.2.13—County farmland preservation programs, 1995[1]

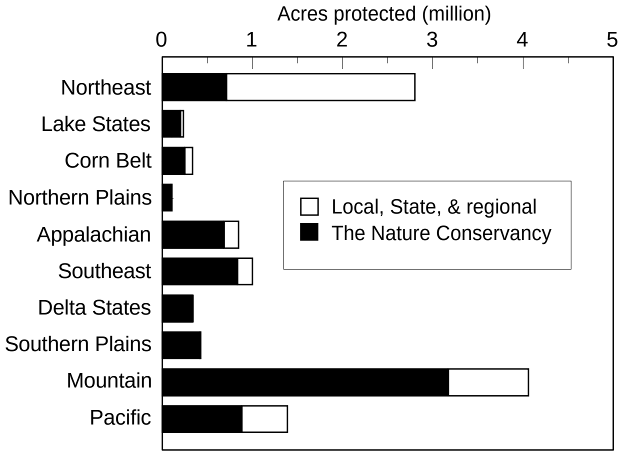
County	Farms preserved to date	Acres preserved to date
Montgomery (MD)	n.a	46,813
Marin (CA)	38	25,504
Carroll (MD)	184	24,604
Lancaster (PA)	260	22,000
Sonoma (CA)	48	21,000
Howard (MD)	142	20,119
Caroline (MD)	131	18,350
Harford (MD)	n.a.	16,861
Baltimore (MD)	107	11,714
Queen Anne's (MD)	53	10,411

n.a. means not available.

[1] These data overlap to an undetermined extent with the State data in table 1.2.12.

Source: USDA, ERS, based on *Farmland Preservation Report*, 1996.

Figure 1.2.9--Land protected by land trusts as of 1994



Source: Compiled by ERS from Wiebe (1995).

public and private) that are binding on current and future landowners over a specified period of time. State and county programs generally acquire farmland preservation easements at fair market value, defined as the difference between the fair market value of the land unencumbered by an easement and the value of the land in agricultural use (Wiebe, Tegene, and Kuhn, 1996). Farmland preservation programs using easement acquisition have been established in 11 States to date, beginning with Maryland in 1977 (table 1.2.12). Maryland's is the largest program, protecting over 122,000 acres on over 800 farms so far. The State programs together have protected over 346,000 acres on over 2,500 farms, at average costs ranging from $598 per acre in Vermont to $5,766 per acre in Rhode Island. County farmland preservation programs are also active in many States, although the Nation's 10 largest county programs are concentrated in Maryland, California, and Pennsylvania (table 1.2.13).

Farmland preservation is also a goal of many land trusts, nonprofit conservation organizations that protect land from more intensive uses through direct involvement in voluntary land transaction activities (Wiebe, 1995). Over 1,000 land trusts operate at the local, State, or regional level, protecting 4 million acres through land ownership, conservation easements, and land transfers to government agencies. A few land trusts operate nationwide. The largest of these, The Nature Conservancy, specializes in the preservation of biodiversity, protecting 8 million acres in the United States. Other national land trusts had protected 2 million acres as of 1994. Acreage protected by The Nature Conservancy was highest in the Mountain States, at 3.2 million acres (fig. 1.2.9). Acreage protected by local, State, and regional land trusts was highest in the Northeast, at 2.1 million acres.

The number of local, State, and regional land trusts grew by 30 percent between 1990 and 1994, to 1,145. Acreage protected grew by 49 percent over the same period. About 0.6 million acres were owned by such land trusts, 0.9 million acres were transferred to other private or government conservation agencies, 0.8 million acres were protected by conservation easements, and 1.8 million acres were protected by other means. Acreage protected by The Nature Conservancy increased by 51 percent between 1990 and 1994. About 0.7 million acres were owned, 2.6 million acres had been transferred to other conservation agencies, 0.6 million acres were protected by conservation easements, 1.8 million acres were protected under lease or management agreements, and 2.1 million acres were protected by other means.

The ultimate success of public agencies and private organizations in using easements and other partial interests in land to protect environmentally sensitive areas depends on the specific land-use restrictions that individual agreements contain. These restrictions may vary widely from one agreement to the next. Program success also depends on the strictness with which these restrictions are monitored and enforced.

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Glossary

Cropland—Farmland in crop rotations, including cropland used for crops, idle cropland, and cropland used for pasture only, totaling 460 million acres in 1992 (Daugherty, 1995; table 1.2.1).

Family farm—A variety of characteristics have been used to describe family farms, but none has gained widespread acceptance. Among these characteristics are the extent to which a single family owns or controls farm assets, provides management and labor, and accepts risk, as well as the extent to which the farm business is the family's principal source of income. The relative emphasis placed on each criterion varies widely and has been the subject of some controversy (for example, in debates over who should receive farm program benefits). Only the Farmers Home Administration currently uses a family farm definition as a qualifier for a government program, based very broadly on farm income and family contributions to management and labor (*Code of Federal Regulations,* §1941.4).

Farm—The *Census of Agriculture* defines a farm as any place from which $1,000 or more of agricultural products were sold or normally would have been sold during a year. There were 1.9 million such farms in 1992 (*1992 Census of Agriculture*, 1994; table 1.2.9; fig. 1.2.4).

Farmland—Land in farms (see above) as determined by the *Census of Agriculture*, totaling 946 million acres in 1992 (table 1.2.9; fig. 1.2.4).

Land in farms is used interchangeably with farmland (see above).

Privately owned agricultural land—All private lands (table 1.2.1) less transportation and urban lands (Krupa and others, 1996). Includes cropland, pastureland, forest land, and rangeland, and totaled 1.3 billion acres in 1995.

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Recent ERS Reports on Land Tenure Issues

Partial Interests in Land: Policy Tools for Resource Use and Conservation. AER-744, Nov. 1996 (Keith Wiebe, Abebayehu Tegene, and Betsey Kuhn). Partial interests in land, such as conservation easements, are increasingly used by public and private agencies to balance resource use and conservation objectives on environmentally sensitive land without incurring the political costs of regulation or the financial costs of outright land acquisition. Examples described in this report include the Conservation Reserve Program, the Wetlands Reserve Program, and State and local farmland protection programs.

Land Trusts Protected 14 Million Acres as of 1994, AREI Update, 1995, No. 13 (Keith Wiebe). The Nature Conservancy and other national land trusts protected about 10 million acres as of 1994 through ownership, easements, and other means. Local, State, and regional land trusts protected an additional 4 million acres. Data are reported by State and region.

Foreign Ownership of U.S. Agricultural Land Through December 31, 1995, SB-931, Oct. 1996 (Kenneth Krupa, Charles Barnard, and Jacqueline Ross). Foreign persons or U.S. corporations in which foreigners held a significant interest owned 15.1 million acres of U.S. agricultural land in 1995, about 1 percent of all privately owned agricultural land in the United States. Data are reported by State and by foreign country.

"Farmland Rentals: Central to Farming," *Agricultural Outlook*, July 1995 (Bob Hoppe, Bob Green, and Gene Wunderlich). Data from the 1992 Farm Costs and Returns Survey indicate that about 40 percent of land in farms is rented, most through cash leases. Renting helps young farmers gain access to land and helps spread some of the risks of farming.

1992 Census Documents More Farmland Leasing, AREI Update, 1995, No. 7 (Gene Wunderlich). Data from the 1992 Census of Agriculture indicate that farmers leased 43 percent of the land they operated in 1992, the highest proportion since 1940. Most leased land was rented from nonfarmers, and cash rents were paid on 65 percent of leased farms.

Purchase of Development Rights and the Economics of Easements, AER-718, June 1995 (Henry Buist, Carolyn Fischer, John Michos, and Abebayehu Tegene). By the end of 1992, State or county governments in 15 States had developed programs to purchase development rights from farmland owners, primarily in the Northeast. Program goals, procedures, and achievements are discussed, along with the role of private land trusts and of Federal tax incentives for donation of conservation easements.

Structural and Financial Characteristics of U.S. Farms, 1991: 16th Annual Family Farm Report to Congress, AIB-712, June 1995 (Judith Kalbacher, Victor Oliveira, Susan Bentley). Farmers operated 854 million acres in the 48 contiguous States in 1991, according to Farm Costs and Returns Survey data. The average farm generated sales of $69,298, of which 44 percent came from crop sales, 42 percent from livestock sales, and 5 percent from government payments.

"Farm Numbers Continue to Drop," *Agricultural Outlook*, Jan.-Feb. 1995 (Fred Gale). The 1992 Census of Agriculture reports a total of 1.9 million farms in 1992, down from 2.1 million in 1987 and 6.8 million in 1935. Exits from farming exceeded entries in all regions, but productivity and sales continued to grow. Farms averaged 491 acres in 1992, with sales of $84,459 per farm.

(Contact to obtain reports: Keith Wiebe, (202) 501-8283 [kdwiebe@econ.ag.gov])

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1.3 Land and Soil Quality

Maintaining and improving the quality of the Nation's soils can provide economic benefits in the form of increased productivity, more efficient use of nutrients and pesticides, improvements in water and air quality, and the storage of greenhouse gases. Economic measures of soil quality are needed to monitor and assess the effects of agricultural activities on soil properties. While measures of land capability, productivity, and erodibility are well known, there is an increasing emphasis on soil quality measures that incorporate properties more fully reflecting a soil's potential for long-term agricultural production without negative environmental impacts.

Contents

Maintaining and improving the quality of the Nation's soils can increase farm productivity, minimize use of nutrients and pesticides, improve water and air quality, and help store greenhouse gases. Developing economic measures of soil quality requires a better understanding of the multiple functions of soils and of the interaction between agricultural activities and soil quality. For example, productivity measures reflect the private concerns surrounding soil quality, but other concerns, such as surface-water pollution from runoff, soil productivity for future generations, and the health of agricultural and rural ecosystems, are of broader national interest—and greater economic importance—and need to be reflected in new measures of land and soil quality. Combining the many physical attributes of land and soil quality into meaningful indicators is difficult, as is assigning economic values to these indicators. But only when economic values are generated for these indicators can we fully assess the trade-offs associated with alternative private and public actions.

Traditional Measures of Quality

Soil quality definitions currently follow two concepts (Karlen and others, 1997; Seybold and others, 1997). The first is the "capacity of the soil to function" (Doran and Parkin, 1994). The second is "fitness for use" (Pierce and Larson, 1993; Acton and Gregorich, 1995). "Capacity of the soil to function" refers to the inherent properties of soil formation, which include climate, topography, vegetation, and parent material. These are measured in soil surveys by characteristics such as texture, slope, structure, and soil color (USDA, 1993). "Fitness for use" is a dynamic concept and relates to soils as influenced by human use and management. This concept is often termed soil health or condition. Measures of soil quality such as Land Capability and Prime Farmland are thought to reflect the inherent properties of soil and are based on crop production. Other criteria are needed for other uses of land. The potential capacity of a soil to function must be assessed before a soil's fitness for use can be measured (Mausbach, 1997). Measures of land and soil quality should also account for scale, both spatial and temporal (Halvorson, Smith, and Papendick, 1997). Scale is important

Table 1.3.1—Cropland and soil quality, selected measures, 1992[1]

Measure	Cultivated cropland	CRP	Total	Cultivated cropland	CRP	Total
	1,000 acres			*Percent of acres*		
Land capability class in 1992:						
I (highest land quality)	26,945	214	27,159	7.0	0.6	6.5
II	177,337	7,584	184,921	46.4	22.3	44.4
III	116,687	14,240	130,927	30.5	41.8	31.4
IV and above (lowest quality)	61,349	12,001	73,350	16.1	35.3	17.6
Total	382,317	34,040	416,357	100.0	100.0	100.0
Prime farmland in 1992	215,731	9,688	225,419	56.4	28.5	54.1
Erodibility in 1992:[2]						
Highly erodible from water only	51,924	na	na	13.5	na	na
Highly erodible from wind only	48,933	na	na	13.0	na	na
Highly erodible from both	3,516	na	na	0.9	na	na
Subtotal highly erodible	104,373	19,796	124,169	27.4	58.2	29.8
Not highly erodible	277,944	14,244	292,188	72.3	41.8	70.2
Total	382,317	34,040	416,357	100.0	100.0	100.0

[1] Includes cultivated cropland and land enrolled in the Conservation Reserve Program (CRP) in the contiguous States, Hawaii, and the U.S. Caribbean islands (less than 0.75 million acres).

[2] Highly erodible land has an erodibility index for sheet and rill erosion or for wind erosion greater than or equal to 8.

Source: USDA, ERS, analysis of NRCS 1992 National Resources Inventory data.

because soil quality changes over time and is different by region. Some traditional measures of land quality are discussed in this section.

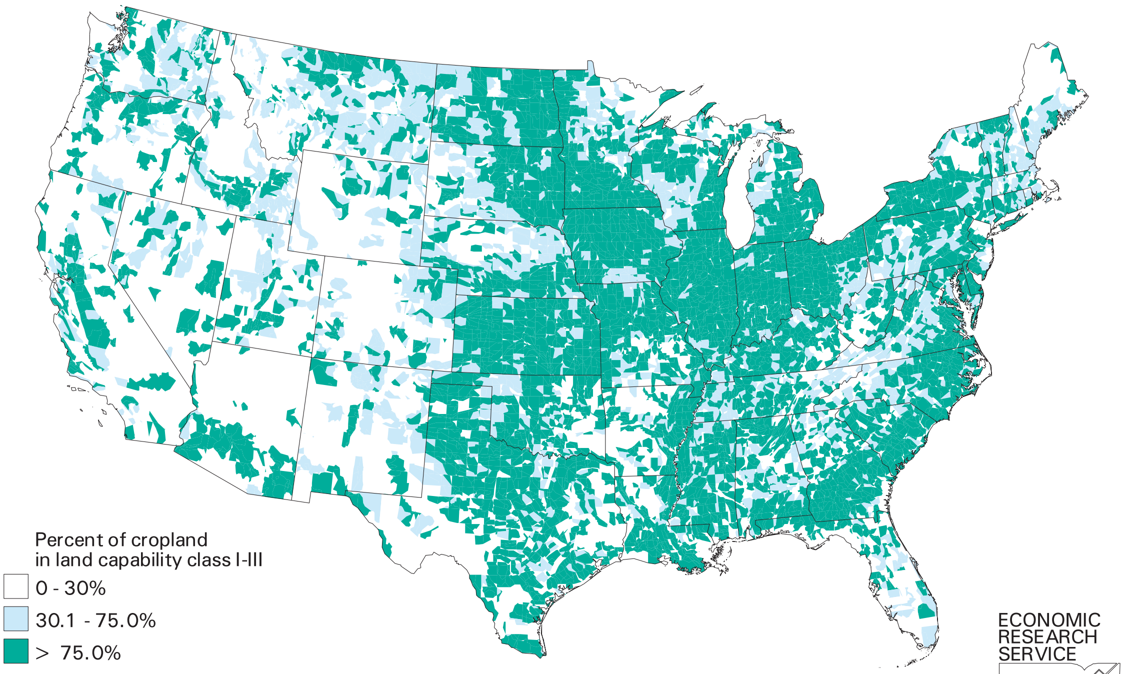
Land Capability and Suitability. Some measures of land quality are used to monitor the capability or suitability of land for a particular purpose, such as growing crops or trees, grazing animals, or nonagricultural uses. Data on two commonly used measures—land capability classes (LCC) and the prime farmland designation—have been collected in the National Resources Inventory (NRI), conducted by USDA's Natural Resources Conservation Service (NRCS) every 5 years (USDA, 1994 and 1989b). (See appendix for a description of the NRI.)

Land capability classes range from I to VIII. Class I, about 7 percent of U.S. cropland, has no significant limitations for raising crops (table 1.3.1). Classes II and III make up just over three-fourths of U.S. cropland and are suited for cultivated crops but have limitations such as poor drainage, limited root zones, climatic restrictions, or erosion potential. Class IV is suitable for crops but only under selected cropping practices. Classes V, VI, and VII are best suited for pasture and range while Class VIII is suited only for wildlife habitat, recreation, and other nonagricultural uses (USDA, 1989a). Land capability classes I-III total 343 million acres, or 82 percent of U.S. cropland including land in the Conservation Reserve Program but excluding Alaska (fig. 1.3.1, table 1.3.1).

Prime Farmland. Another measure of land suitability is USDA prime farmland, which is based on physical and morphological characteristics such as depth of the water table in relation to the root zone, moisture-holding capacity, the degree of salinity, permeability, frequency of flooding, soil temperature, erodibility, and soil acidity. Land classified as prime farmland has the growing season, moisture supply, and soil quality needed to sustain high yields when treated and managed according to modern farming methods (USDA, 1989a). Prime farmland totals 225 million acres, or 54 percent of U.S. cropland, excluding Alaska (fig.1.3.2, table 1.3.1).

These measures of land quality are often confused with the capability of land to produce economic returns. Land in capability classes I-III or prime farmland does not necessarily have the highest value of crop production per acre (see Vesterby and Krupa, 1993). Alternatively, lands earning high economic returns may not be classified as prime farmland or in LCC I-III. For example, prime and LCC are based on characteristics that reflect suitability for row crop production. Florida and Arizona have little prime

Figure 1.3.1--Distribution of cropland in land capability classes I,II and III on rural nonfederal land



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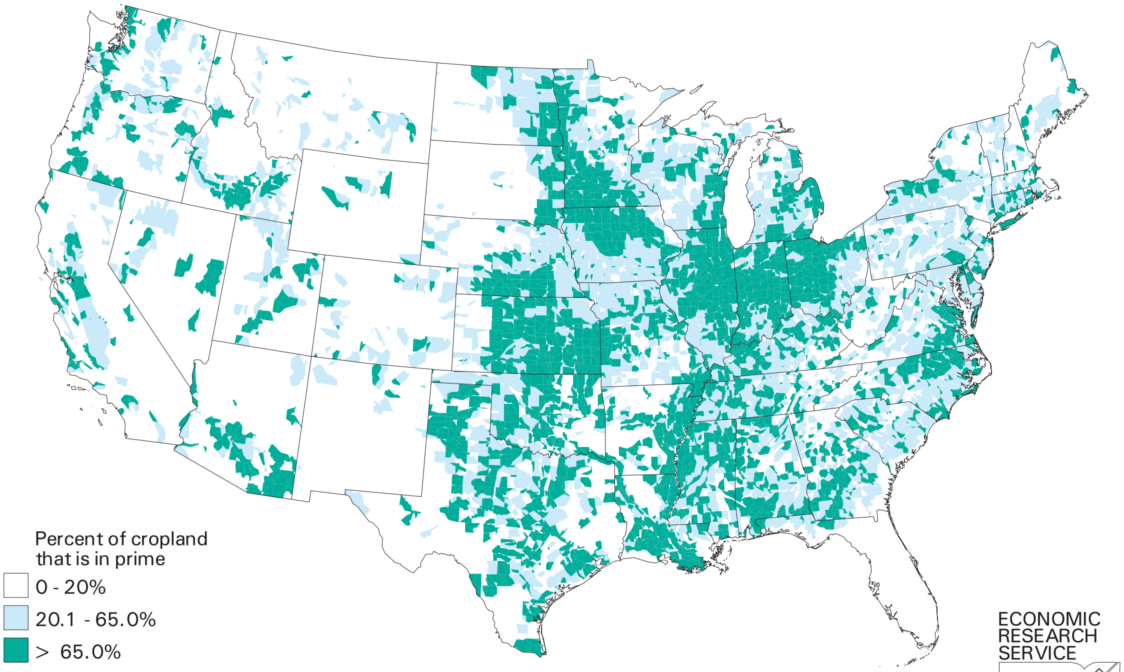
Source: USDA, ERS, based on NRCS 1992 National Resources Invertory and Soils-5 databases.

Figure 1.3.2--Distribution of prime cropland on rural, nonfederal land



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Source: USDA, ERS, based on NRCS 1992 National Resources Invertory and Soils-5 databases.

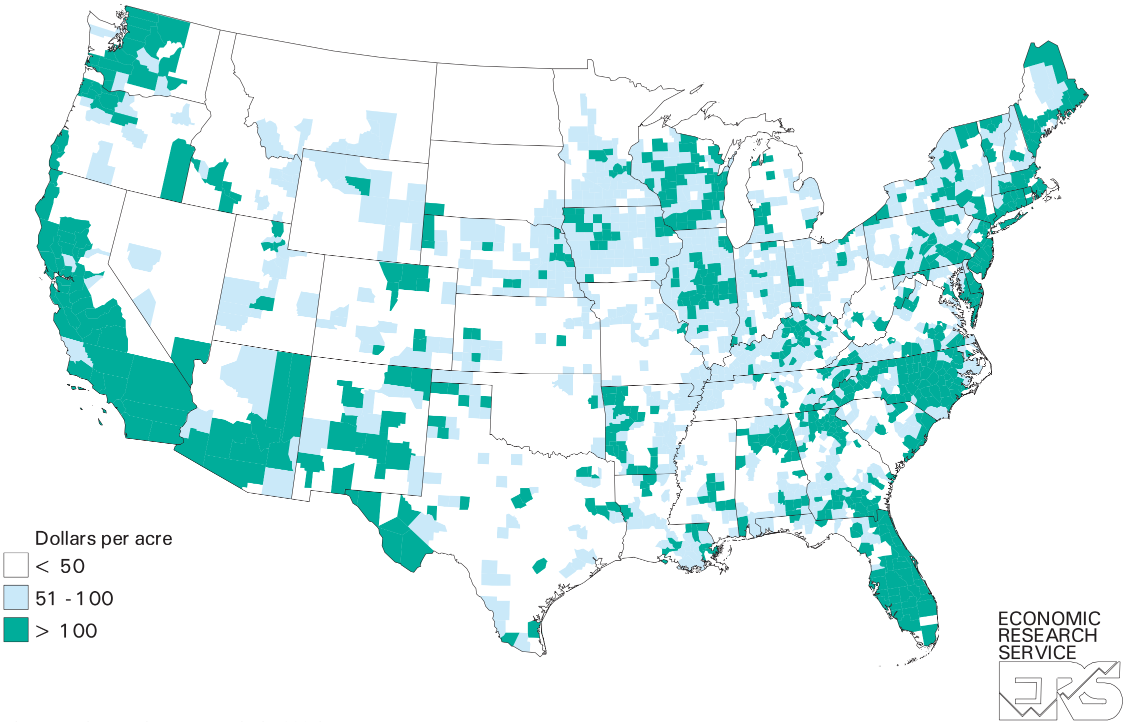


Figure 1.3.3--County average net cash return per acre of cropland

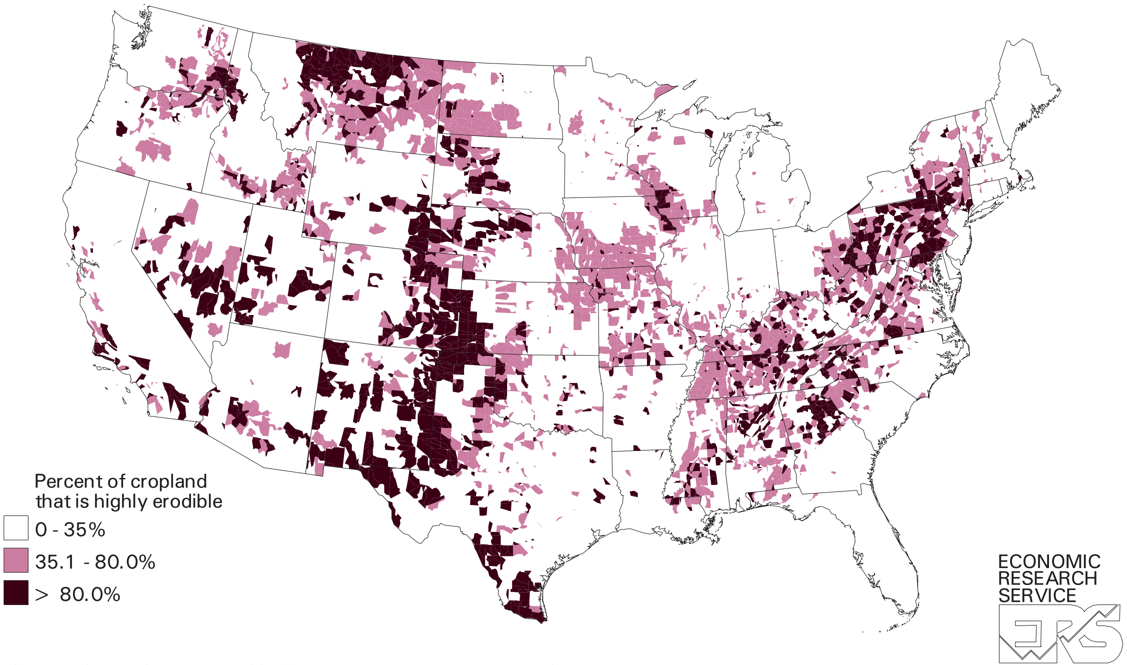
Source: USDA, ERS, based on USDC 1992 Census of Agriculture.

farmland or land in LCC I-III, but these areas rank among the most economically productive in the Nation. (New irrigation will sometimes change a classification from nonprime to prime if other soil characteristics needed for a prime classification are present.)

Productivity. Soil productivity, which measures output per unit of input, is often the primary reason for monitoring soil erosion (or other degradation processes) and is itself a measure of soil quality. Productivity is often measured as crop yield per acre**.** Another indicator of land quality is the expected net returns per acre from production (dollar returns to production net of cash production costs). Highest values are in coastal areas where climate, soil, location, and irrigated conditions favor production of perishable crops (fruits and vegetables), or where integrated livestock operations draw from an extended cropping area (fig. 1.3.3). The next most productive lands are in the Corn Belt, Lake States, the Northeast, and Southern Coastal Plain. The least productive lands, by this net returns measure, are in bands across the Northern Plains and Central Plains. Productivity can reflect soil degradation if yields decline as soils become degraded or if input use increases to compensate for declines in soil quality. However, productivity often masks environmental or health components of soil quality; lands of poor physical quality (as measured by erosion, texture, organic matter) can sometimes produce very high yields without large increases in input use (Vesterby and Krupa, 1993).

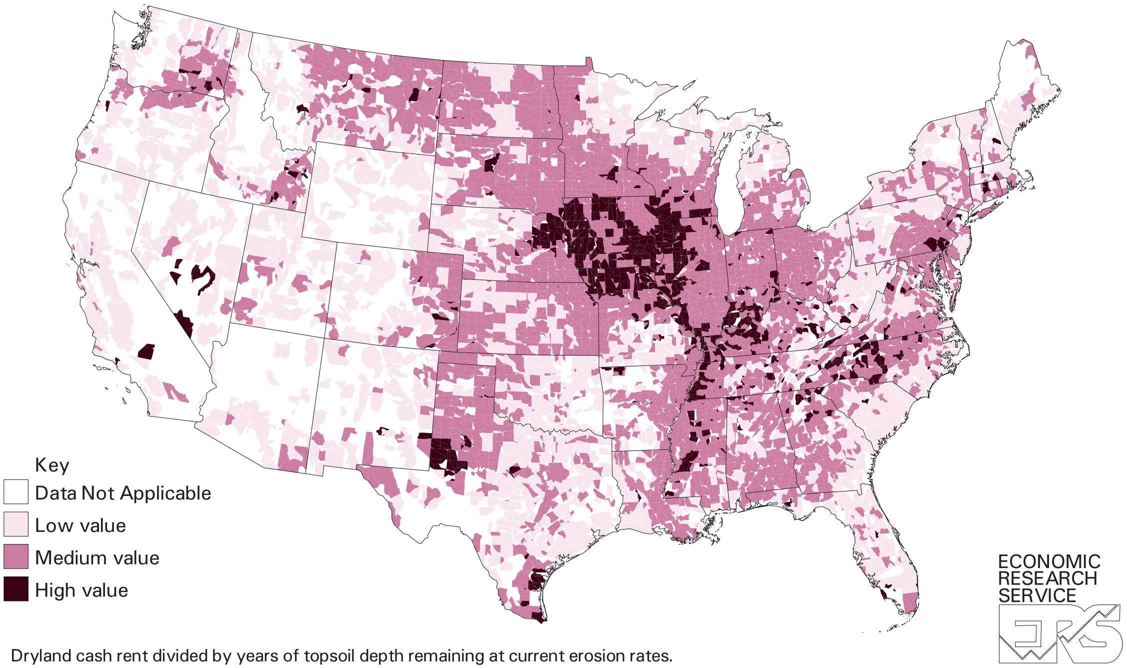
Erodibility. A commonly used measure of soil quality is highly erodible land (HEL), which is of particular importance for USDA conservation policy (see chapter 6). Because the actual tons of wind- and water-eroded soil do not usefully measure the erosion potential on particular soils, USDA uses the erodibility index (EI) to inventory and classify erosion potential and to determine conservation program eligibility. Highly erodible soils have the potential for erosion because of relatively unchanging physical attributes. Associated with sheet and rill erosion are rainfall pattern, soil texture, and topography; associated with wind erosion are climatic and soil erodibility factors. Erosion rates can be reduced if hay or close-grown crops are grown, if tillage methods are used with appropriate crop residue management, and if conservation practices are employed. An assessment of erosion needs to consider both the physical potential for erosion and the erosion rates resulting from management choices.

Figure 1.3.4--Distribution of highly erodible cropland on rural, nonfederal land



Source: USDA, ERS, based on NRCS 1992 National Resources Inventory and Soils-5 databases.

Figure 1.3.5--Value of onsite soil productivity loss



Dryland cash rent divided by years of topsoil depth remaining at current erosion rates.
Source: USDA, ERS, based on NRCS 1992 National Resources Inventory.

Highly erodible lands are more vulnerable to soil quality problems, but if erosion is controlled, they may be productive soils. Any soils that are eroding are considered to have lower quality than similar soils that are protected from erosion. Soil quality suffers on eroding soils, but simply controlling erosion does not necessarily translate to high-quality soils since compaction, acidity, salinization, and biological factors play a part in the quality of the soil (Mausbach, 1997).

The EI divides potential erosion (sheet and rill, or wind) by the soil loss tolerance factor (T-level, the rate of soil erosion above which long-term soil productivity may be depleted) to reflect erosion potential relative to vulnerability to productivity loss. (Heimlich and Bills, 1989; McCormack and Heimlich, 1985). Highly erodible land (HEL) is defined by USDA as cropland with a natural erosion potential of at least eight times its T-level. According to the 1992 NRI, 124 million acres of cultivated cropland and CRP land are highly erodible from water, wind, or both (table 1.3.1). However, for purposes of administering the conservation compliance provision of the 1985, 1990, and 1992 Farm Acts, USDA's NRCS has classified 146 million acres as HEL, which includes some 22 million acres of other soils in fields that are primarily highly erodible soils (for more information on Conservation Compliance, see chapter 6.4). Highly erodible soils are found in all States (fig. 1.3.4).

Another measure of productivity loss due to erosion converts total erosion from tons per acre per year to inches per year. The rate of expected soil loss in inches is divided into the topsoil depth (the A horizon) recorded in the Soil Interpretation Record (SOILS 5) (USDA, 1983). This measures how many years it would take to remove the topsoil at the current rate of erosion (on the extreme assumption that all the eroded soil is removed from the field). Multiplying the inverse of this measure by the cash rental rate for cropland reflects the relative economic value of soil productivity loss due to erosion. Three factors are reflected in this measure: erosion rates, soil depth, and rental values of land. Low erosion rates or deep, long-lasting topsoils are given less weight, and highly productive (high rental rate) but vulnerable soils (thin topsoil, high erosion rate) are given more weight (fig. 1.3.5). This indicator suggests four regional concentrations of vulnerable soils, the largest centered on Iowa, Illinois, and Missouri in the Corn Belt. This region's index values are largely driven by the region's relatively high rental rates. While erosion rates are moderate in this region, the soil is relatively valuable. A second concentration is the eastern bluffs of the Mississippi River in western Kentucky, Tennessee, and along the eastern edge of the Mississippi Delta. A third concentration is the irrigated cotton area of the Texas Panhandle, stretching up to the eastern edge of Colorado. The final concentration is a band of highly erodible and highly valued land in eastern Washington and Oregon around the Palouse and Central Plateau.

The major onsite effect of soil erosion is the impact on soil productivity. Research conducted in the 1980's has improved our understanding of the long-term relationship between erosion and productivity (AAEA, 1986). The 1987 RCA estimated that, under 1982 management conditions, agricultural productivity would decline about 3 percent over the next 100 years, due to soil erosion. Productivity loss would be concentrated on soils eroding at high tolerance values or on very fragile soils where even slight erosion can result in large declines in yields (USDA, 1989a). Soil erosion also contributes to off-farm sediment damage, estimated at $2-$8 billion annually (Ribaudo, 1986).

Vulnerability. Interest in soil erosion and its associated costs has been coupled with an increasing interest in the loss of nutrients, pesticides, and salts from farming systems to surface and ground water (NAS, 1993). For example, indices to assess the potential for groundwater contamination related to agricultural chemical use (Kellogg, Maizel, and Goss, 1992) incorporate variables that reflect the propensity of soils to leach pesticides and nitrates. The Ground Water Vulnerability Indexes for Pesticides and Nitrogen are functions of soil leaching potential, pesticide and nitrogen properties, precipitation, and chemical use. The Corn Belt, Southeast, and Lake States have more acreage vulnerable to pesticide leaching, while the Northern and Southern Plains show more acreage with a potential for nitrate leaching (see figs. 2.2.2 and 2.2.4 in chapter 2.2, *Water Quality*).

Land capability classes, prime farmland, and highly erodible land designations are useful in determining how land might be used or the degree and location of erosion, but they are limited in that they exclude other important characteristics of soils and pertain mostly to cropland. Productivity measures, such as yields per acre, or profitability measures, such as cash rents, provide fairly direct indicators of the utility of land for producers wishing to maximize the return on their land investments. But, such measures are limited to private interests and do not reflect the environmental vulnerability or harm the land may face. Vulnerability indices are useful measures of potential environmental impacts and provide a needed link between soil characteristics and water quality. All these measures can provide policymakers and natural resource managers with information for beginning to design and target policies for resource management. But, as we broaden our understanding of land as a fundamental base for the environment, broader measures are needed to capture the multiple dimensions of soil and land quality.

Comprehensive Measures of Quality

Instead of focusing on the capability to support specific activities, such as crop production, or a single soil degradation process, such as erosion or chemical leaching, researchers are focusing on how a broad range of physical, chemical, and biological properties determine soil quality. Physical properties include soil tilth, and wind and water erosion; chemical properties include pH, total plant nutrients, and salinity; and biological properties include microbial and natural processes of respiration, mineralization, and denitrification. How do human activities, such as farming, affect the soil and its ability to function in the long run? Eventually, economic analysis could provide estimates of the on- and off-farm costs of soil degradation and the cost of maintaining soil quality.

Most definitions of soil quality include both environmental factors and measures of crop productivity. For example, soil quality has been defined as *the ability of a soil to produce safe and nutritious crops in a sustained manner over the long–term and to enhance human and animal health without impairing the natural resources base or harming the environment* (Parr and others, 1992). Similarly, soil quality can be defined as the *sustaining capacity of a soil to accept, store, and recycle water, minerals, and energy for production of crops at optimum levels while preserving a healthy environment* (Arshad and Coen, 1992). A National Academy of Sciences (NAS, 1993) report defines soil quality as *the ability of a soil to perform its three primary functions: to function as a primary input to crop production; to partition and regulate water flow, and to act as an environmental filter*. In addition, the NAS report recommends that *the concept of soil quality should be the principle guiding the recommendations for use of conservation practices and the targeting of programs and resources.* Currently, conservation compliance plans rely primarily on one soil quality indicator—soil erosion potential as measured by the EI.

A soil's quality is determined by many properties such as soil depth, water-holding capacity, bulk density, nutrient availability, potential capacity, organic matter, microbial biomass, carbon and nitrogen content, soil structure, water infiltration, and crop yield. Because of the correlation across these properties, a few key attributes can be selected as soil quality indicators (Olson, 1992; Hornsby and Brown, 1992; Alexander and McLaughlin, 1992; and Arshad and Coen, 1992). Parr and others (1992) suggest a soil quality index that includes such factors as soil properties, productivity potential, environmental factors, health (human/animal), erodibility, biological diversity, food quality/safety, and management inputs. Many of these factors, such as food quality or biological diversity, are complex indicators themselves but may be important contributors to the full breadth of soil quality. And while the components of soil quality appear quite complex, some soil properties can be estimated without collecting detailed information of attributes. For example, Larson and Stewart (1992) use crop residue data and a simple regression model to estimate changes in soil organic matter for several U.S. soils.

Soil quality is a function of many factors, including agroclimatic factors, hydrogeology, and cropping/production practices. Soil quality can be degraded through three processes: (1) physical degradation such as wind and water erosion and compaction; (2) chemical degradation such as salinization and acidification; and (3) biological degradation, which includes declines in organic matter, carbon from biomass, and the activity and diversity of soil fauna (NAS, 1993).

Physical Degradation. Erosion has long been considered the major agent of soil degradation worldwide (NAS, 1993). Erosion has been shown to reduce onfarm soil productivity and contribute to water quality problems as eroded soils carry agrichemicals and byproducts or residuals into waterways. Another form of soil degradation is compaction, typically caused by heavy machinery and cattle trampling. Soils with low organic matter are particularly vulnerable. Compaction can make tillage costly, impede emergence of seedlings, and decrease water infiltration, causing higher runoff of rainwater and increasing water erosion (WRI, 1992). Eradat and Voorhees (1990) show that the value of yield losses from compaction in Minnesota, Wisconsin, Iowa, Illinois, Indiana, and Ohio could be as high as $100 million annually.

Chemical Degradation. While salinity problems are often associated with irrigation, salinity problems can also occur in dryland areas where rainfall is insufficient to leach salts from the soil. More than 48 million acres of cropland and pastureland are affected by varying degrees of salinity (USDA, 1989a). Irrigated areas are particularly subject to salinization because irrigation water contains dissolved salts, which become more concentrated in the soil as water is consumed by crops or lost by evaporation (USDA, 1989a). Crops such as corn, soybeans, rice, and some fruits and vegetables, are quite sensitive to salinity—an increase in salinity can lead to a significant yield reduction. Acidification, another chemical degradation process, can occur when bases (such as calcium, magnesium, potassium, and sodium) are leached from the soil. Aluminum toxicity is also often a problem in acid soils. Acidity may be reduced by the application of basic material, such as limestone. Acidic soil conditions can limit plant growth by supplying insufficient calcium or magnesium, altering the decomposition rates of organic matter, and reducing the amount of nitrogen fixed by legumes (NAS, 1993).

Biological Degradation. According to the NAS (1993), biological degradation is *perhaps the most serious form of soil degradation because it affects the life of the soil and because organic matter significantly affects the physical and chemical properties of soils*. Currently, little is known about how agricultural activities change a soil's biological properties, and the potential cost to the food and fiber system.

It has been estimated that the number of bacterial species in a gram of soil may exceed 10,000 (Torsvik and others, 1990). Probably less than 1 percent of all bacterial species are presently known and there may be up to 1 million different species on earth (ASM, 1994). Biological degradation is important because if the soil food web is disrupted, the soil may not be able to cycle nutrients and transform harmful chemicals or substances to nontoxic waste or to combat plant pests and diseases (Mausbach, 1997).

The microbial community is continually adapting to the environment, and can function as indicators of changes in soil quality. Changes probably occur more rapidly in the microbial community than in other soil characteristics. Methods to assess soil microbial status need to be explored as indicators to further define and measure soil quality (Kennedy and Papendick, 1992).

Land Quality and Resource Policy

The Natural Resources Conservation Service has recognized the importance of soil quality and has established the Soil Quality Institute to acquire and develop soil quality technology. In addition, many Federal programs address specific soil quality factors such as wind and water erosion and nutrient loss (see chapter 6). USDA programs are directed at conducting research on the relationship between farming practices and soil quality, developing new technologies and practices that conserve and protect soil resources, providing technical and financial assistance to adopt soil conserving practices, and protecting farmland through land retirement and conservation easements.

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Recent ERS Reports on Land-Use Issues

Industrial Uses of Agricultural Materials, Situation and Outlook Report, IUS-6, Aug. 1996 (Lewrene Glaser, Coordinator). Research and market demand open new opportunities for agriculturally based industrial materials. Industrial uses of corn are expected to total 622 million bushels in 1995/96 (Sept./Aug.), down 18 percent from the previous year due to a lower use for ethanol. A special article examines possible biodiesel demand in three niche fuel markets that might be commercialized—Federal fleets, mining, and marine/estuary areas.

Agricultural Adaptation to Climate Change, AER-740, June 1996 (David Schimmelpfennig, Jan Lewandrowski, John Reilly, Marinos Tsigas, and Ian Parry). This report, which highlights ERS research on the effects of climate change on agriculture, focuses on economic adaptation and concludes there is considerably more sectoral flexibility and adaptability than found in other analyses. The report frames the discussion of economic adjustments within the context of global agricultural environmental sustainability.

Major Land Uses, Data Product Stock #890003, Feb. 1996 (Kenneth Krupa and Arthur Daugherty). This electronic data product contains 3 ASCII files containing explanatory and reference material and 16 Lotus 1-2-3 (.WK1) spreadsheet files containing State, regional, and national estimates for separate land uses for census of agriculture years 1945 through 1992. This product updates one with the same title and stock number prepared in 1990 covering the 1945-87 period.

Major Uses of Land in the United States, 1992, AER-723, Sept. 1995 (Arthur Daugherty). This report categorizes the Nation’s nearly 2.3 billion acres of land area into major uses by State and farm production region, with national totals for 1992. Similar geographic detail provided for a number of subcategories of cropland, grassland pasture and range, forest-use land, and special land uses.

1995 Cropland Use, AREI Update, 1995, No. 12 (Arthur Daugherty). This annual update of cropland use and Federal commodity program participation indicates that cropland use was down, crop failure and program-idled cropland up in 1995 from 1994. Nearly 3.7 million base acres of the 7 major program crops were “flexed” to non-program crops, of which 2.8 million acres were soybeans.

World Agriculture and Climate Change, Economic Adaptations, AER-703, June 1995 (Roy Darwin, Marinos Tsigas, Jan Lewandrowski, and Anton Ranses). Analysis of four popular climate change scenarios suggests that farmer adaptation and international trade will allow world agriculture to respond to global climate change without imperiling world food production. Regionally, agricultural production possibilities expand in arctic and mountainous areas and contract in tropical and some other areas. In the United States, soil moisture losses may reduce agricultural production possibilities in the Southeast and the Corn Belt.

Urbanization of Rural Land in the United States, AER-673, March 1994 (Marlow Vesterby, Ralph Heimlich, and Kenneth Krupa). Land conversion to urban use has remained constant at about a half acre per household in fast-growth counties since 1960. Urbanization of farmland poses no threat to U.S. food and fiber production in the near future.

Agricultural and Water-Quality Conflicts: Economic Dimensions of the Problem, AIB-676, July 1993 (Steve Crutchfield, LeRoy Hansen, and Marc Ribaudo). Off-farm effects of farm production practices impose costs on society, including damage to fish and wildlife resources, costs of avoiding potential health hazards and protecting natural ecosystems, and lost recreational opportunities. Policies that stress economic and technical assistance can encourage adoption of pollution-reducing farm practices.

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Glossary of Land Use Categories

Cropland—Total cropland includes five components: cropland harvested, crop failure, cultivated summer fallow, cropland used only for pasture, and idle cropland. ***Cropland harvested*** includes row crops and closely sown crops; hay and silage crops; tree fruits, small fruits, berries, and tree nuts; vegetables and melons; and miscellaneous other minor crops. Farmers double-cropped nearly 4 percent of this acreage. ***Crop failure*** consists mainly of the acreage on which crops failed because of weather, insects, and diseases, but includes some land not harvested due to lack of labor, low market prices, or other factors. The acreage planted to cover and soil-improvement crops not intended for harvest is excluded from crop failure and is considered idle. In recent years, crops have failed on 2-3 percent of acreage planted for harvest.

Cultivated summer fallow refers to cropland in subhumid regions of the West cultivated for one or more seasons to control weeds and accumulate moisture before small grains are planted. This practice is optional in some areas, but it is necessary for crop production in the drier cropland areas of the West. Other types of fallow, such as cropland planted to soil-improvement crops but not harvested and cropland left idle all year, are not included in cultivated summer fallow but are included as idle cropland. ***Cropland used only for pasture*** generally is considered to be in long-term crop rotation. However, some land classed as cropland pasture is marginal for crop uses and may remain in pasture indefinitely. This category also includes land that was used for pasture before crops reach maturity and some land used for pasture that could have been cropped without additional improvement. Cropland pasture and permanent grassland pasture have not always been clearly distinguished in agricultural surveys.

Land idled under annual Federal crop programs could have been pastured except during a consecutive 5-month period between April 1 and October 31 designated by the State Agricultural Stabilization and Conservation Committee. If such acreage conservation reserve or conservation use acres were pastured at any time during the year, the Census requested that they be reported as cropland pasture. Land in the CRP could not be pastured. Idle cropland includes land in cover and soil-improvement crops and cropland on which no crops were planted. Some cropland is idle each year for various physical and economic reasons. Acreages diverted from crops to soil-conserving uses (if not eligible for and used as cropland pasture) under Federal farm programs are included in this component.

Cropland used for crops—Three of the cropland acreage components—cropland harvested, crop failure, and cultivated summer fallow—are collectively termed cropland used for crops, or the land input to crop production.

Grassland pasture and range—Grassland pasture and range comprise all open land used primarily for pasture and grazing, including shrub and brushland types of pasture, grazing land with sagebrush and scattered mesquite, and all tame and native grasses, legumes, and other forage used for pasture or grazing. Because of the diversity in vegetative composition, grassland pasture and range are not always clearly distinguishable from other types of pasture and range. At one extreme, permanent grassland may merge with cropland pasture, or grassland may often be found in transitional areas with forested grazing land. This category does not include any land currently in the CRP.

Forest land grazed—Forested pasture and range consist mainly of forest, brushgrown pasture, arid woodlands, and other areas within forested areas that have grass or other forage growth. The total acreage of forested grazing land includes woodland pasture in farms plus rough estimates of forested grazing land not in farms. For many States, the estimates include significant areas grazed only lightly or sporadically.

Forest land—As defined by the Forest Service, forest land is "land at least 10% stocked by trees of any size, including land that formerly had such tree cover and that will be naturally or artificially regenerated. Forest land includes transition zones, such as areas between heavily forested and nonforested lands that are at least 10% stocked with forest trees and forest areas adjacent to urban and built up lands. Also included are pinyon-juniper and chaparral areas in the West and afforested areas" (Powell and others, 1993, p. 117).

Forest-use land—A modified total used in this inventory of 648 million acres of forest land that excludes an estimated 89 million acres in parks, wildlife areas, and similar special-purpose uses. To eliminate all overlap with other uses is not feasible, but this reduced area is a more realistic approximation of the land that may be expected to serve normal forest uses as opposed to having forest cover. Forest-use land includes forested grazing land in this report.

Special-use areas—Special uses in this report include urban areas; highway, road, and railroad rights-of-way and airports; Federal and State parks, wilderness areas, and wildlife refuges; national defense and industrial areas; and miscellaneous farmland uses.

Miscellaneous other land—Includes miscellaneous special uses such as industrial and commercial sites in rural areas, cemeteries, golf courses, mining areas, quarries, marshes, swamps, sand dunes, bare rocks, deserts, tundra, and other unclassified land.

Table 1.1.14—Cropland idled by Federal program and commodity, 1978-95[1]

Item	1978	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
	Million acres																	
Acreage Conservation Reserve:																		
Corn	3.2	1.7			2.1	4.4	3.9	5.4	10.4	14.7	14.4	6.3	6.1	4.7	3.1	6.6	0.0	4.7
Sorghum	1.1	0.9			0.7	0.8	0.6	0.9	2.1	2.4	2.2	1.1	1.0	0.8	0.5	0.6	0.0	0.0
Barley	0.6	0.3			0.4	0.5	0.5	0.7	1.6	2.2	1.9	0.8	0.7	0.7	0.4	0.0	0.0	0.0
Oats	0.0	0.0			0.1	0.1	0.1	0.1	0.3	0.5	*	0.1	*	0.0	0.0	0.0	0.0	0.0
Feed grains[2]	4.9	2.9			3.3	5.9	5.1	7.2	4.5	19.8	18.6	8.2	7.9	6.2	4.1	7.2	0.0	4.7
Wheat	8.3	7.4			5.8	8.8	10.4	11.9	15.8	20.2	19.2	6.1	2.2	10.1	3.3	0.0	0.0	0.0
Cotton	0.0	0.0			1.6	2.5	2.5	2.3	3.3	3.2	1.5	3.1	1.5	0.6	1.3	1.0	1.5	0.0
Rice	0.0	0.0			0.4	0.6	0.8	0.7	1.3	1.3	0.9	0.9	0.7	0.2	0.0	0.2	0.0	0.2
Total[2]	13.1	10.3			11.1	17.8	18.7	22.1	34.8	44.5	40.3	18.4	12.3	17.1	8.6	8.4	1.5	4.9
0,50/85-92 Programs:[3]																		
Corn									0.6	1.4	2.9	4.5	4.6	2.7	2.2	4.3	2.4	3.0
Sorghum									0.4	0.5	1.1	2.2	2.3	1.7	1.5	1.7	1.6	1.7
Barley									0.2	0.3	0.6	1.5	2.2	1.5	1.9	2.5	2.7	2.9
Oats									0.1	0.1	0.2	0.3	0.2	0.6	0.7	0.8	0.6	0.8
Feed grains[2]									1.3	2.3	4.8	8.5	9.3	6.5	6.3	9.3	7.2	8.4
Wheat									1.3	3.7	3.2	3.5	5.3	5.8	4.0	5.7	0.2	6.1
Cotton									0.8	0.7	0.6	0.4	0.5	0.6	0.4	0.4	0.2	0.2
Rice									0.2	0.2	0.1	0.2	0.3	0.7	0.4	0.5	0.3	0.3
Total[2]									3.5	7.0	8.8	12.6	15.3	13.6	11.2	15.9	12.9	15.0
Long-term programs:[4]																		
Corn									0.2	2.3	2.8	3.4	3.8	3.9	4.1	4.3	4.3	4.3
Sorghum									0.2	1.2	1.9	2.2	2.4	2.4	2.4	2.5	2.5	2.5
Barley									0.1	1.1	1.9	2.4	2.7	2.8	2.8	2.8	2.8	2.8
Oats									0.1	0.5	0.9	1.1	1.3	1.3	1.4	1.4	1.4	1.4
Feed grains[2]									0.6	5.1	7.4	9.0	10.2	10.3	10.6	11.0	11.0	11.0
Wheat									0.6	4.2	7.1	8.8	10.3	10.4	10.6	10.8	10.8	10.8
Cotton									0.1	0.7	1.0	1.2	1.3	1.3	1.4	1.4	1.41	1.4
Rice									*	*	*	*	*	*	*	*	*	*
Non-base acres									0.7	5.7	8.9	10.9	12.1	12.4	12.8	13.2	13.2	13.2
Total[2]									1.9	15.7	24.4	29.9	33.8	34.4	35.4	36.4	36.4	36.4
Paid Land Diversion:																		
Corn	2,9	1.2				5.9	0.0	0.0	1.8	7.0	3.2							
Sorghum	0.3	0.3				1.3	0.0	0.0	0.4	1.2	0.6							
Barley	0.2	0.0				0.6	0.0	0.0	0.2	0.4	0.3							
Oats	0.0	0.0				0.2	0.0	0.0	0.1	0.2	0.0							
Feed grains[2]	3.4	1.5				8.0	0.0	0.0	2.4	8.8	4.1							
Wheat	0.0	0.0				3.5	5.7	6.9	3.9	0.0	0.0							
Cotton	0.3	0.0				*	0.0	1.3	0.0	0.0	0.0							
Rice	0.0	0.0				0.2	0.0	0.6	0.0	0.0	0.0							
Total[2]	3.7	1.5				11.7	5.7	8.8	6.4	8.8	4.1							
Payment-In-Kind:																		
Corn						21.9	0.0											
Sorghum						3.6	0.0											
Barley						0.0	0.0											
Oats						0.0	0.0											
Feed grains[2]						25.2	0.0											
Wheat						17.7	3.6											
Cotton						4.2	0.0											
Rice						1.1	0.0											
Total[2]						48.6	3.6											

See footnotes at end of table.

Table 1.1.14—Cropland idled by Federal program and commodity, 1978-95, continued[1]

Item	1978	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
									Million acres									
All programs:[2]																		
Corn	6.1	2.9			2.1	32.2	3.9	5.4	12.9	25.5	23.3	14.1	14.5	11.3	9.3	15.2	6.6	12.0
Sorghum	1.4	1.2			0.7	5.7	0.6	0.9	3.1	5.3	5.8	5.4	5.7	4.8	4.5	4.7	4.1	4.2
Barley	0.8	0.3			0.4	1.1	0.5	0.7	2.2	4.1	4.7	4.7	5.6	4.9	5.2	5.3	5.5	5.7
Oats					0.1	0.3	0.1	0.1	0.6	1.3	1.1	1.4	1.5	1.9	2.0	2.2	2.0	2.2
Feed grains[2]	8.3	4.4	0.0	0.0	3.3	39.4	5.1	7.2	18.8	36.1	34.9	25.6	27.3	22.9	21.0	27.5	18.2	24.1
Wheat	8.3	7.4			5.8	30.0	19.6	18.8	21.6	28.1	29.6	18.4	17.8	26.3	17.9	16.5	16.0	16.9
Cotton	0.3				1.6	6.8	2.5	3.6	4.1	4.5	3.2	4.7	3.3	2.6	3.1	2.8	3.1	1.6
Rice					0.4	1.8	0.8	1.3	1.5	1.6	1.1	1.2	1.0	0.9	0.4	0.7	0.3	0.5
Non-base acres					0.0	0.0	0.0	0.0	0.7	5.7	8.9	10.9	12.1	12.4				
Total [2]	16.8	11.8	0.0	0.0	11.1	78.0	28.0	30.9	46.6	76.0	77.7	60.8	61.5	65.1	55.2	60.7	50.8	56.3
Cropland used for crops	369	378	382	387	383	333	373	372	357	331	327	341	341	337	337	330	339	333

* = Less than 50,000 acres

[1] A blank cell indicates program was not in effect that year for that crop.

[2] Distributions may not add to totals due to rounding.

[3] Includes cropland participating in the 0,50/85-92 programs but planted to allowed minor oilseeds or industrial/other crops.

[4] Data represent the Conservation Reserve Program (CRP) from 1986-94. There was no long-term retirement program between 1977 and 1986.

Source: USDA, ERS, compiled from unpublished materials provided by the Farm Service Agency.

1.4 Farm Real Estate Values, Rents, and Taxes

Farm real estate values and cash rents are important indicators of the financial condition of the farm sector. Farm real estate values are influenced by net returns from agricultural production, capital investment in farm structures, interest rates, government commodity programs, and nonfarm demands for farmland. Values have been on the rise since 1987. By early 1995, the average value of U.S. farm real estate exceeded the previous high set in 1982 before values began to decline. Average value continued to increase through 1995. Cash rents also generally increased during 1995 and 1996.

Contents

Values of farm real estate (farmland and attached buildings and dwellings) are important to landowners, prospective buyers, lenders, tax assessors, agricultural producers, and local governments. Farm real estate is the major asset on the farm sector balance sheet (currently accounting for more than 75 percent of total U.S. farm assets), and its value provides an indicator of the general economic health of the agricultural sector. Farm real estate underlies the financial stability of many farm businesses whose portfolios derive a large proportion of their value from real estate. In addition to being the largest single investment item in a typical farmer's portfolio, farm real estate is the principal source of collateral for farm loans, enabling farm operators to finance the purchase of additional farmland and equipment or to finance current operating expenses. Some 52.5 percent of the total farm sector debt of $155 billion at the end of 1996 was real estate debt—either mortgages for purchase of farmland or short- or intermediate-term debt secured by farmland. Wide swings in farm real estate values alter the equity positions, creditworthiness, and borrowing capacity of those farm operators and landowners who hold large percentages of assets in the form of farmland.

Farm Real Estate Values

The rapid increase in farmland values during the 1970's and early 1980's was followed by a sharp decline during 1982-87, then a slow upward trend beginning in 1987 (fig. 1.4.1). Since 1987, average farmland values in the Nation have rebounded 48.6 percent, from $599 per acre to $890 in January 1996. In real or inflation-adjusted terms (1982 dollars), however, this amounts to only a 10.8-percent gain. It was not until January 1, 1995, that the average nominal value per acre surpassed the record high of $823 set in 1981. But even with continued increases in 1995, the January 1996 average, on a real (or inflation-adjusted) basis, was still 40 percent below the 1981 peak.

U.S. farm real estate values rose 7.0 percent during 1995 (table 1.4.1). This represents an

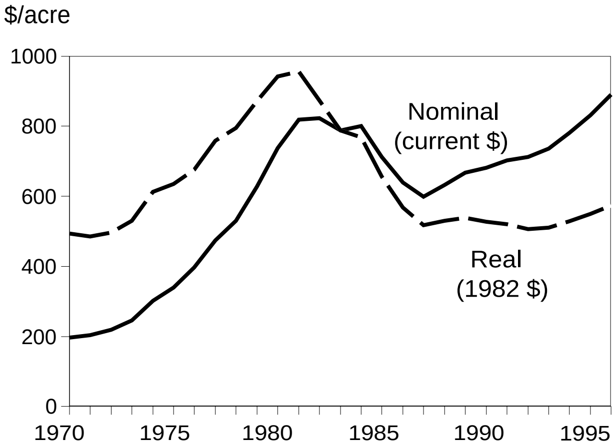
Table 1.4.1—Average per-acre nominal value of farm real estate, by State, January 1, 1989-96[1]

State	1989	1990	1991	1992	1993	1994	1995	1996	Change 1995-96
	Dollars								*Percent*
Northeast	1,825	1,848	1897	1,977	2,095	2,311	2,414	2,485	2.9
Maine	1,046	1,073	1,057	1,033	1,130	1,232	1,245	1,291	3.7
New Hampshire	2,253	2,269	2,194	2,103	2,256	2,459	2,486	2,578	3.7
Vermont	1,226	1,262	1,248	1,223	1,342	1,463	1,479	1,534	3.7
Massachusetts	3,988	4,227	4,301	4,340	4,898	5,339	5,398	5,597	3.7
Rhode Island	5,289	5,564	5,619	5,627	6,304	6,871	6,947	7,204	3.7
Connecticut	4,715	5,033	5,158	5,241	5,959	6,495	6,567	6,810	3.7
New York	1,045	1,014	1,095	1,139	1,237	1,383	1,380	1,333	-3.4
New Jersey	4,947	5,494	6,341	6,710	6,942	7,407	8,052	8,172	1.5
Pennsylvania	1,936	1,929	1,937	2,073	2,056	2,247	2,339	2,505	7.1
Delaware	2,037	2,214	2,181	2,042	2,246	2,511	2,689	2,907	8.1
Maryland	2,534	2,563	2,394	2,530	2,911	3,310	3,707	3,826	3.2
Lake States	820	843	909	920	956	986	1,048	1,126	7.5
Michigan	983	1,005	1,086	1,106	1,131	1,214	1,329	1,470	10.6
Wisconsin	845	801	849	865	925	968	1,065	1,175	10.3
Minnesota	747	810	881	884	910	914	936	976	4.2
Corn Belt	1,108	1,111	1,153	1,190	1,235	1,331	1,448	1,578	9.0
Ohio	1,298	1,273	1,323	1,396	1,456	1,593	1,800	1,989	10.5
Indiana	1,249	1,254	1,291	1,325	1,395	1,504	1,654	1,801	8.9
Illinois	1,391	1,405	1,459	1,536	1,548	1,694	1,863	2,064	10.8
Iowa	1,095	1,090	1,139	1,153	1,212	1,281	1,349	1,442	6.9
Missouri	684	701	723	734	774	825	880	948	7.7
Northern Plains	387	401	403	400	401	432	458	478	4.5
North Dakota	317	321	337	318	335	353	373	383	2.5
South Dakota	273	291	293	286	273	286	302	319	5.5
Nebraska	511	524	517	517	514	562	596	632	6.0
Kansas	429	450	449	460	463	503	535	553	3.3
Appalachian	1,110	1,178	1,154	1,223	1,300	1,336	1,436	1,597	11.2
Virginia	1,397	1,665	1,490	1,643	1,636	1,690	1,771	1,925	8.7
West Virginia	731	664	704	843	849	869	910	965	6.0
North Carolina	1,364	1,355	1,382	1,455	1,573	1,609	1,749	1,970	12.6
Kentucky	910	978	958	988	1,077	1,136	1,250	1,377	10.2
Tennessee	1,037	1,067	1,095	1,130	1,245	1,250	1,336	1,526	14.2
Southeast	1,216	1,300	1,319	1,301	1,345	1,427	1,533	1,631	6.4
South Carolina	990	1,011	1,112	1,152	1,137	1,204	1,337	1,363	2.0
Georgia	1,030	1,079	1,095	1,025	1,131	1,154	1,256	1,358	8.1
Florida	1,880	2,070	2,110	2,033	2,037	2,165	2,219	2,306	3.9
Alabama	847	890	864	936	1,000	1,117	1,262	1,387	9.9
Delta States	809	806	834	820	866	912	972	1,009	3.8
Mississippi	717	736	766	754	777	836	886	917	3.5
Arkansas	801	796	841	815	880	927	983	989	0.6
Louisiana	959	925	920	926	972	1,000	1,082	1,176	8.7
Southern Plains	520	504	494	487	498	521	550	562	2.2
Oklahoma	518	491	477	482	496	517	547	547	0.0
Texas	521	507	498	488	499	522	550	566	2.9
Mountain	259	265	283	283	290	319	346	379	9.8
Montana	202	222	219	219	227	254	277	289	4.5
Idaho	593	658	654	680	682	774	836	905	8.3
Wyoming	144	153	159	145	159	180	192	206	7.3
Colorado	375	374	437	400	426	479	520	558	7.3
New Mexico	185	185	210	212	194	208	225	258	15.0
Arizona	276	267	291	311	316	325	347	399	15.0
Utah	426	398	417	445	491	537	606	697	15.0
Nevada	242	207	241	262	252	268	289	332	15.0
Pacific	1,175	1,259	1,362	1,410	1,453	1,510	1,549	1,675	8.2
Washington	777	821	864	880	892	1,025	1,065	1,117	4.9
Oregon	536	573	586	607	663	747	844	928	9.9
California	1,742	1,884	2,077	2,157	2,213	2,213	2,215	2,404	8.5
48 States	668	682	703	713	736	782	832	890	7.0

[1] Value of farmland and buildings in nominal dollars

Source: USDA, ERS, based on Agricultual Land Value Survey, June Agricultural Survey; and 1992 Census of Agriculture data.

Figure 1.4.1--Average real and nominal values of U. S. farm real estate, 1970-96

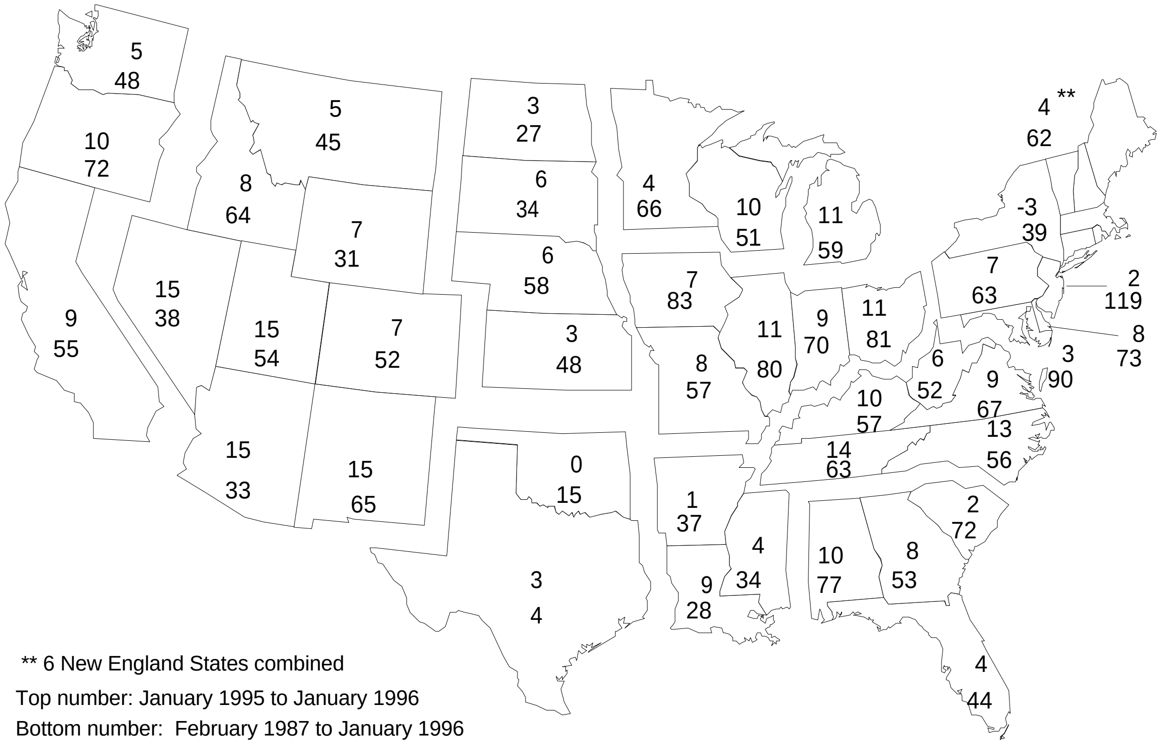


Source: USDA, ERS

inflation-adjusted increase of 4.4 percent (table 1.4.2). All States recorded increases except New York and Oklahoma. Several States in the Lake States, Corn Belt, Appalachian, and Mountain regions recorded double-digit increases in farm real estate values. The largest regional increases occurred in the Applachian, Mountain, and Corn Belt regions (11.2, 9.8, and 9 percent).

The 1995 increase was the strongest yearly gain since 1987. The 7.0-percent nominal increase during 1995 marked the 9th consecutive yearly increase since 1987. The largest State-by-State increases over the 1987-95 period occurred in several of the Northeast States, where most States never experienced the sharp declines in farm real estate value that characterized most other States during the early- to mid-1980's (fig. 1.4.2). Much of this increase can be attributed to strong nonfarm demand for farmland associated with population growth. Another set of relatively high increases since 1987 occurred in the Corn Belt, the region that also experienced the largest value declines between 1981 and 1986. The relatively small increase in Texas is largely a product of the beginning and end points of the time period being discussed. Texas farm real estate values continued to increase until the mid-1980's, before declining and then beginning a slow recovery later than most other States. The counter-cyclical pattern is partially attributable to changing conditions in the oil industry during the 1980's.

Figure 1.4.2--Percent change in farm real estate value per acre (nominal dollars), 1987-96 and 1995-96



** 6 New England States combined

Top number: January 1995 to January 1996

Bottom number: February 1987 to January 1996

Source: USDA, ERS.

Table 1.4.2—Average per-acre real (inflation-adjusted) value of farm real estate, by State, Jan. 1, 1989-96[1]

State	1989	1990	1991	1992	1993	1994	1995	1996	Change 1995-96
				1982 dollars					Percent
Northeast	1,473	1,430	1,408	1,410	1,454	1,563	1,596	1,603	0.6
Maine	844	830	783	736	784	833	823	833	1.1
New Hampshire	1,817	1,754	1,626	1,497	1,566	1,663	1,644	1,663	1.2
Vermont	989	976	925	871	931	989	978	990	1.2
Massachusetts	3,217	3,268	3,188	3,090	3,399	3,611	3,569	3,610	1.2
Rhode Island	4,266	4,302	4,165	4,007	4,375	4,648	4,593	4,647	1.2
Connecticut	3,803	3,891	3,823	3,732	4,135	4,393	4,342	4,393	1.2
New York	843	784	812	811	858	935	913	860	-5.8
New Jersey	3,990	4,247	4,700	4,778	4,818	5,010	5,324	5,271	-1.0
Pennsylvania	1,562	1,491	1,436	1,476	1,427	1,520	1,547	1,616	4.5
Delaware	1,643	1,712	1,617	1,454	1,559	1,698	1,778	1,875	5.5
Maryland	2,044	1,981	1,774	1,801	2,020	2,239	2,451	2,468	0.7
Lake States	662	652	674	655	663	667	693	726	4.8
Michigan	793	777	805	788	785	821	879	948	7.9
Wisconsin	682	619	629	616	642	655	704	758	7.6
Minnesota	603	626	653	629	632	618	619	630	1.7
Corn Belt	894	859	855	848	857	901	957	1,018	6.3
Ohio	1,047	984	981	994	1,010	1,077	1,190	1,283	7.8
Indiana	1,007	969	957	943	968	1,017	1,094	1,162	6.2
Illinois	1,122	1,086	1,081	1,094	1,074	1,145	1,232	1,331	8.1
Iowa	883	843	844	821	841	867	892	930	4.3
Missouri	552	542	536	523	537	558	582	612	5.1
Northern Plains	312	310	299	285	278	292	303	308	1.8
North Dakota	256	248	250	226	232	239	247	247	0.1
South Dakota	220	225	217	204	189	194	200	206	2.9
Nebraska	412	405	383	368	357	380	394	408	3.5
Kansas	346	348	333	328	321	340	354	357	0.8
Appalachian	895	910	855	870	902	904	949	1,030	8.5
Virginia	1,127	1,287	1,104	1,170	1,135	1,143	1,171	1,242	6.0
West Virginia	590	513	522	600	589	588	602	622	3.4
North Carolina	1,100	1,048	1,024	1,036	1,092	1,088	1,157	1,271	9.9
Kentucky	734	756	710	703	747	769	826	888	7.5
Tennessee	836	825	812	805	864	845	884	984	11.4
Southeast	980	1,005	978	926	934	965	1,014	1,052	3.8
South Carolina	799	782	824	820	789	814	884	879	-0.5
Georgia	831	834	812	730	785	780	830	876	5.5
Florida	1,516	1,600	1,564	1,448	1,414	1,465	1,467	1,488	1.4
Alabama	683	688	640	666	694	756	834	895	7.2
Delta States	653	623	618	584	601	617	643	651	1.3
Mississippi	578	569	568	537	539	566	586	592	0.9
Arkansas	646	615	623	580	611	627	650	638	-1.9
Louisiana	774	715	682	659	675	677	716	759	6.0
Southern Plains	420	389	366	347	346	353	363	363	-0.2
Oklahoma	418	380	354	343	344	350	362	353	-2.5
Texas	420	392	369	347	346	353	364	365	0.4
Mountain	209	205	210	202	201	216	229	244	6.9
Montana	163	172	162	156	158	172	183	186	1.8
Idaho	478	509	485	484	473	524	553	584	5.6
Wyoming	116	118	118	103	110	121	127	133	4.8
Colorado	302	289	324	285	296	324	344	360	4.7
New Mexico	149	143	156	151	135	141	149	166	11.9
Arizona	223	206	216	221	219	220	229	257	12.2
Utah	344	308	309	317	341	363	401	450	12.2
Nevada	195	160	179	187	175	181	191	214	12.1
Pacific	948	974	1,008	1,001	1,008	1,021	1,024	1,080	5.5
Washington	627	635	640	627	619	693	704	721	2.3
Oregon	432	443	434	432	460	505	558	599	7.3
California	1,405	1,457	1,540	1,536	1,536	1,497	1,465	1,551	5.9
48 States	539	528	521	507	511	529	550	574	4.4

[1] Nominal values as of Jan. 1 for farmland and buildings adjusted by the Gross Domestic Product implicit price deflator indexed to 1982 = 100.

Source: USDA, ERS, based on Agricultural Land Value Survey, June Agricultural Survey; and 1992 Census of Agriculture data.

In 1996, California, Florida, and the Northeast States continued to record the highest average per-acre values for farm real estate. Farm real estate values in the Northeast reflect continued pressure from nonagricultural sources for conversion to residential or other urban use. The relatively high values in California and Florida are the consequence of both urban pressures and the presence of intensive agriculture for the production of high-valued crops. Alternatively, the low average values in the Mountain States can be attributed to large amounts of arid rangeland and less productive cropland. Wyoming, New Mexico, and Montana recorded the lowest average per-acre values (table 1.4.1).

Variation among States in the 1995 rate of increase in value can be attributed to several factors. For the Mountain States, growing recreational use of rural land and population pressures related to urbanization appear to be the driving forces behind value gains. The Mountain region experienced the largest population growth of any region from 1990 to 1993 (8.2 percent) (U.S. Dept. Of Commerce, 1995) and contained six of the ten fastest-growing States. The increasing farmland values in the Corn Belt during 1995 can be attributed to increased net returns from corn and soybeans, the major agricultural products of the region, as well as continued improvements in yields.

As of January 1, 1996, the total value of U.S. farm real estate reached $860 billion, while the average per-farm value (total value divided by the number of farms) was $417,761 (tables 1.4.3 and 1.4.4). By State, the total value of farm real estate was greatest for California, Texas, and Illinois, and lowest for several of the New England States. State-level averages ranged from $178,497 per farm in West Virginia to $1,883,308 in Arizona. Variation among States in the per-farm average results from differences in per-acre values and differences in average size of operation. West Virginia farms averaged 185 acres per operation, compared with 4,780 acres in Arizona. These per-farm values are more appropriate as indicators of the value of land resources associated with typical farm operations than as indicators of the equity or wealth of typical individual farm operators. The land resource assets of most farm operations have multiple owners. Many operations lease significant proportions of the land they operate, others are organized as partnerships or corporations, and many operations use owned land as loan collateral, thus giving lenders an implicit interest in the land asset.

Cash Rents

A substantial proportion of U.S. farmland is operated under some form of lease, approximately 43 percent in 1992, according to the 1992 Census of Agriculture. The most common form of lease, the cash rental agreement, is characterized by a fixed payment negotiated before planting, whereas in share rental agreements, payment to the landowner varies with the amount of product harvested. Under cash rental arrangements, the tenant bears all of the production and market-price risk; share rental arrangements implicitly divide production and market risks between tenant and landlord.

The term “cash rent” refers to the amount of cash paid by a tenant to a landowner for use of a farmland parcel as an input in agricultural production. Cash rents are generally considered a shortrun indicator of the return to a landowner’s investment in the land, though to tenants, cash rents represent a major production expense. Because rents reflect the income-earning capacity of the land, they vary widely across the country. Cropland rents tend to be highest in States and regions where higher-value crops are grown. During 1996, the highest average rents were reported for irrigated land in California at $210 per acre (table 1.4.5). California produces large shares of high-value specialty crops, vegetables, fruits, and nuts. Cropland suitable for corn and soybean production in the Midwest also commands high rents. The highest rents for nonirrigated cropland in 1996 were reported in Illinois ($106 per acre) and Iowa ($105 per acre).

Average cash rents for cropland were higher in most States for the 1996 crop year than in 1995. This pattern was roughly similar for both irrigated and nonirrigated cropland. An upward pattern was evident in most regions.

During 1996, average cash rents for pasture varied from $40 per acre in Wisconsin to $5.40 per acre in Texas, but for many States, survey data were insufficient to make an estimate (table 1.4.6). Average cash rents for pasture were almost uniformly lower than in 1995 in the Northern Plains, Appalachian, Southeast, Delta, and Southern Plains. For the Corn Belt, Mountain, and Southeast regions, some States reported higher cash rents compared with 1995.

Table 1.4.3—Total value of farmland and buildings, by State, 1989-96[1]

State	1989	1990	1991	1992	1993	1994	1995	1996
				Million dollars				
Northeast	45,461	45,598	46,551	47,978	50,248	54,511	55,983	57,240
Maine	1,517	1,556	1,501	1,467	1,582	1,675	1,681	1,730
New Hampshire	1,036	998	965	925	993	1,082	1,094	1,109
Vermont	1,778	1,817	1,785	1,749	1,919	2,048	2,026	2,070
Massachusetts	2,592	2,705	2,710	2,734	2,988	3,203	3,077	3,190
Rhode Island	386	389	371	355	397	433	438	454
Connecticut	2,075	2,114	2,166	2,149	2,384	2,533	2,495	2,588
New York	8,778	8,518	9,089	9,340	10,020	10,925	10,628	10,266
New Jersey	4,353	4,780	5,580	5,905	6,040	6,370	6,844	6,865
Pennsylvania	15,875	15,625	15,690	16,584	16,242	17,528	18,013	19,292
Delaware	1,243	1,328	1,309	1,205	1,280	1,431	1,533	1,643
Maryland	5,828	5,767	5,387	5,566	6,404	7,282	8,155	8,034
Lake States	47,898	49,252	53,016	53,256	54,946	56,487	60,130	64,399
Michigan	10,616	10,854	11,729	11,948	12,102	12,985	14,219	15,579
Wisconsin	14,872	14,098	14,858	14,965	15,818	16,367	18,004	19,741
Minnesota	22,410	24,300	26,430	26,343	27,027	27,135	27,907	29,079
Corn Belt	137,982	138,026	142,588	146,624	151,684	163,227	177,204	192,996
Ohio	20,379	19,859	20,507	21,359	22,131	24,212	27,359	30,033
Indiana	20,484	20,440	20,656	21,200	22,320	24,061	26,302	28,642
Illinois	39,644	39,902	41,290	43,315	43,499	47,588	52,346	58,000
Iowa	36,683	36,515	38,157	38,510	40,360	42,532	44,786	47,876
Missouri	20,794	21,310	21,979	22,240	23,375	24,835	26,411	28,445
Northern Plains	69,550	72,127	72,423	71,827	71,941	77,456	81,994	85,567
North Dakota	12,839	13,001	13,615	12,847	13,534	14,278	15,041	15,417
South Dakota	12,094	12,891	12,951	12,641	12,067	12,658	13,306	14,038
Nebraska	24,068	24,680	24,351	24,351	24,209	26,485	28,074	29,695
Kansas	20,549	21,555	21,507	21,988	22,131	24,035	25,573	26,417
Appalachian	54,595	57,119	55,741	58,840	62,247	63,737	68,225	75,536
Virginia	12,573	14,819	13,112	14,294	14,070	14,534	15,232	16,557
West Virginia	2,705	2,457	2,605	3,119	3,141	3,217	3,368	3,570
North Carolina	13,640	13,144	13,267	13,823	14,786	14,965	16,092	18,120
Kentucky	12,922	13,790	13,508	13,931	15,186	16,021	17,498	19,283
Tennessee	12,755	12,911	13,250	13,673	15,065	15,000	16,035	18,006
Southeast	48,259	50,297	49,741	48,912	50,522	53,796	57,560	60,188
South Carolina	5,247	5,257	5,782	5,990	5,856	6,141	6,749	6,816
Georgia	12,978	13,488	13,250	12,403	13,685	13,959	15,076	16,025
Florida	21,056	22,563	22,155	21,347	20,981	22,303	22,860	23,752
Alabama	8,978	8,989	8,554	9,173	10,000	11,393	12,875	13,594
Delta	30,839	30,139	30,936	30,177	31,769	33,095	35,378	36,627
Mississippi	9,536	9,568	9,805	9,651	9,946	10,701	11,432	11,557
Arkansas	12,576	12,338	13,036	12,470	13,464	13,992	14,747	14,836
Louisiana	8,727	8,233	8,096	8,056	8,359	8,402	9,199	10,234
Southern Plains	85,866	83,127	80,979	79,828	81,734	84,969	89,578	90,503
Oklahoma	17,094	16,203	15,741	16,388	16,864	17,572	18,609	18,609
Texas	68,772	66,924	65,238	63,440	64,870	67,396	70,968	71,894
Mountain	63,075	64,372	68,463	68,259	69,791	76,501	82,908	90,773
Montana	12,241	13,431	13,206	13,140	13,575	15,165	16,529	17,273
Idaho	8,124	9,015	8,829	9,180	9,207	10,450	11,286	12,223
Wyoming	5,011	5,309	5,517	5,017	5,501	6,211	6,633	7,118
Colorado	12,563	12,379	14,334	13,120	13,973	15,658	17,020	18,150
New Mexico	8,233	8,233	9,303	9,370	8,575	9,184	9,883	11,287
Arizona	9,936	9,665	10,418	11,072	11,218	11,522	12,282	14,125
Utah	4,814	4,497	4,712	5,029	5,499	5,957	6,731	7,671
Nevada	2,154	1,842	2,145	2,332	2,243	2,355	2,543	2,925
Pacific	76,497	81,363	87,603	89,844	92,265	95,438	98,057	105,882
Washington	12,432	13,136	13,824	14,080	14,272	16,194	16,825	17,538
Oregon	9,541	10,199	10,431	10,623	11,603	13,076	14,776	16,239
California	54,525	58,027	63,349	65,141	66,390	66,169	66,456	72,105
48 States	660,022	671,419	688,042	695,545	717,147	759,217	807,017	859,711

[1] Value data as of Feb. 1, 1989, and Jan. 1 for 1990-96.

Source: USDA, ERS, based on Agricultural Land Value Survey, June Agricultural Survey; and 1992 Census of Agriculture data.

Table 1.4.4—Average per-farm value of farmland and buildings, by State, 1989-96[1]

State	1989	1990	1991	1992	1993	1994	1995	1996
				Dollars				
Northeast	307,024	314,162	321,043	331,340	354,360	390,480	405,088	415,086
Maine	207,767	216,090	211,400	200,940	216,712	220,409	221,195	233,834
New Hampshire	345,460	369,763	357,541	342,711	397,056	450,824	475,600	461,905
Vermont	269,348	279,582	278,850	273,264	299,853	330,305	337,675	345,057
Massachusetts	398,800	422,700	423,380	427,219	481,900	533,882	512,767	514,586
Rhode Island	501,425	526,324	529,791	506,430	567,360	618,422	625,225	648,358
Connecticut	518,650	542,015	555,477	537,203	627,263	666,624	656,676	680,973
New York	225,077	221,236	239,171	245,784	267,192	303,484	295,209	285,172
New Jersey	524,501	590,096	656,480	656,089	678,600	715,744	760,423	746,167
Pennsylvania	293,985	294,809	296,032	318,923	318,478	343,691	360,259	385,837
Delaware	414,190	458,069	451,241	446,215	512,088	572,514	613,163	657,015
Maryland	373,603	379,391	349,773	356,795	426,947	502,178	570,305	586,407
Lake States	211,940	220,859	239,893	240,977	252,047	261,516	272,081	294,059
Michigan	193,025	201,000	217,200	221,262	232,725	249,714	263,309	293,942
Wisconsin	183,605	176,220	188,070	189,424	200,222	207,180	225,049	249,884
Minnesota	249,000	273,034	300,341	299,355	310,655	319,237	320,772	334,244
Corn Belt	302,592	309,476	326,288	337,844	356,067	387,713	423,934	470,722
Ohio	239,748	239,263	256,331	273,831	291,200	322,820	369,717	417,123
Indiana	288,501	300,591	317,785	326,154	354,286	381,920	424,220	477,375
Illinois	460,971	480,747	503,533	534,756	550,618	618,022	679,824	763,156
Iowa	349,357	351,106	370,451	373,885	395,682	421,109	447,862	488,535
Missouri	190,767	197,319	205,413	207,852	220,517	236,524	251,533	273,506
Northern Plains	357,581	370,834	375,250	376,058	384,713	416,430	438,470	461,278
North Dakota	383,239	388,075	412,570	389,309	416,431	446,199	470,020	497,311
South Dakota	345,540	368,323	370,017	361,177	349,757	372,290	403,219	431,940
Nebraska	422,247	432,989	434,834	434,834	440,171	481,547	501,325	530,276
Kansas	297,813	312,391	311,697	328,179	340,483	369,765	387,469	400,255
Appalachian	172,223	185,152	185,187	195,480	208,185	215,326	231,270	256,925
Virginia	267,511	322,141	291,378	317,647	312,658	315,954	324,075	344,931
West Virginia	128,795	119,844	130,240	155,955	157,065	160,835	168,394	178,497
North Carolina	209,846	211,992	221,120	230,375	250,614	258,024	277,456	312,415
Kentucky	136,021	148,277	148,437	153,086	166,876	180,010	196,607	219,123
Tennessee	143,316	148,399	155,876	160,859	179,339	180,720	197,960	225,081
Southeast	298,819	312,402	317,831	314,548	325,947	351,607	376,209	402,593
South Carolina	205,765	210,288	236,016	244,506	243,981	266,992	306,795	317,038
Georgia	270,375	280,990	288,033	269,620	297,502	310,196	335,011	372,675
Florida	513,561	550,317	553,875	547,346	537,977	571,869	586,166	593,801
Alabama	191,026	191,255	185,948	199,409	217,391	247,683	273,926	302,095
Delta	250,721	253,265	266,692	267,052	281,140	298,156	315,878	321,293
Mississippi	232,588	239,200	245,120	247,467	255,015	274,397	272,195	262,662
Arkansas	261,994	262,511	283,380	277,100	299,200	318,006	342,965	345,022
Louisiana	256,674	257,266	269,867	277,800	288,248	300,056	340,694	379,048
Southern Plains	325,250	312,508	303,292	296,758	302,159	314,699	328,123	326,727
Oklahoma	244,200	231,471	224,871	230,817	239,206	251,033	262,099	258,459
Texas	354,495	341,449	331,157	320,404	324,350	336,982	351,329	350,704
Mountain	524,751	541,394	580,198	584,913	605,296	672,239	724,091	792,774
Montana	495,595	543,765	534,644	540,741	570,361	673,981	751,336	785,146
Idaho	367,606	413,514	412,570	437,143	449,122	509,753	524,927	555,576
Wyoming	563,056	596,528	613,033	545,326	597,978	675,117	721,025	782,162
Colorado	465,278	467,147	551,292	514,510	547,953	618,875	680,790	740,837
New Mexico	588,036	609,815	689,111	694,104	635,170	680,267	732,042	836,108
Arizona	1,242,000	1,239,154	1,370,763	1,476,213	1,515,946	1,557,026	1,659,790	1,883,308
Utah	370,292	340,712	354,293	380,947	423,015	458,228	502,341	572,487
Nevada	861,520	736,920	857,960	932,720	934,500	981,288	1,017,399	1,170,009
Pacific	481,116	513,329	557,983	574,082	605,013	623,780	634,676	676,560
Washington	327,158	355,027	373,622	380,541	396,444	449,821	467,364	487,162
Oregon	257,859	279,436	281,914	283,267	309,400	344,106	383,790	421,785
California	649,102	682,673	763,235	794,407	840,380	837,578	830,705	879,332
48 States	304,260	313,668	325,855	330,818	345,098	368,659	390,581	417,761

[1] Value data as of Feb. 1, 1989, and Jan. 1, for 1990-96. Average per-farm value is estimated by dividing total value of farm real estate by the number of farms.

Source: USDA, ERS, based on Agricultural Land Value Survey, June Agricultural Survey; and 1992 Census of Agriculture data.

Table 1.4.5—Cropland rented for cash: average gross cash rent per acre and rent as a percent of value, selected States, 1992-96

State and land type[2]		Rent per acre						Rent to value[1]					
		ALVS[3] 1992	ALVS 1993	ALVS 1994	JAS[4] 1994	ALVS 1995	JAS 1996	ALVS 1992	ALVS 1993	ALVS 1994	JAS 1994	JAS 1995	JAS 1996
		Dollars						*Percent*					
Northeast:													
New England[5]		na	na	na	31.50	35.20	30.70	na	na	na	.7	.7	1.0
New York		36.20	34.90	38.20	25.10	25.10	29.00	4.5	3.9	3.8	2.4	2.2	2.9
New Jersey		52.00	50.60	71.10	42.90	45.40	44.80	0.5	0.8	1.3	0.4	0.6	.4
Pennsylvania		42.40	44.10	41.90	37.70	38.80	38.50	1.8	2.0	1.5	1.4	1.5	1.3
Delaware		62.30	57.90	59.80	54.90	61.10	64.30	3.3	2.6	2.8	2.4	2.5	2.7
Maryland		*	55.40	60.80	41.40	44.70	48.00	*	2.3	2.2	1.3	1.6	1.6
Lake States:													
Michigan		47.40	45.60	49.00	48.00	49.70	52.20	6.2	5.7	5.5	4.8	4.9	4.3
Wisconsin		51.40	52.50	51.20	48.70	46.20	48.50	7.3	6.9	6.8	5.6	4.9	4.6
Minnesota		62.30	64.20	61.90	66.00	70.10	73.80	7.6	7.6	7.9	6.8	6.5	6.4
Corn Belt:													
Ohio		70.20	68.50	70.50	64.50	67.10	70.80	5.6	5.5	4.7	3.8	3.5	2.7
Indiana		85.70	88.30	90.40	83.40	88.40	94.80	7.5	6.8	6.3	5.7	5.6	5.2
Illinois		103.30	102.90	107.30	99.50	99.70	106.00	6.5	6.3	5.5	4.2	4.9	4.6
Iowa		104.60	108.00	107.00	98.60	99.60	105.00	8.0	7.9	7.4	6.5	6.3	5.8
Missouri	-All cropland	58.20	64.10	64.80	na	na	na	8.0	8.9	8.6	na	na	na
	-Nonirrigated	na	na	na	55.10	51.10	47.10	na	na	na	4.2	4.2	3.8
Northern Plains:													
N. Dakota		29.10	31.30	31.90	32.90	33.10	34.00	8.7	8.5	8.2	7.0	7.1	7.2
S. Dakota	-All cropland	30.40	30.50	32.20	na	na	na	8.3	8.0	8.2	na	na	na
	-Nonirrigated	na	na	na	30.00	30.20	31.90	na	na	na	6.6	6.9	6.9
Nebraska	-Nonirrigated	49.60	50.30	50.30	56.70	57.20	63.00	8.6	8.6	8.3	8.2	7.7	6.5
	-Irrigated	102.80	102.20	106.80	108.40	111.10	112.00	9.5	9.3	9.3	8.5	8.4	7.5
Kansas	-Nonirrigated	31.90	32.80	34.70	32.60	35.50	32.70	7.2	7.4	7.3	6.5	5.9	5.8
	-Irrigated	62.70	65.10	72.50	*	*		9.5	9.3	10.1	*	*	*
Appalachian:													
Virginia		34.40	33.80	37.40	35.80	35.70	37.70	2.1	2.4	2.4	2.2	1.9	2.0
West Virginia		30.40	30.10	36.90	31.00	30.00	32.00	3.4	3.5	4.3	2.7	2.3	2.1
North Carolina		37.70	41.00	38.10	32.50	33.60	39.00	2.8	2.8	2.5	2.2	2.0	2.2
Kentucky		52.60	55.30	59.00	49.10	52.80	64.00	5.4	5.2	5.7	4.4	3.8	4.9
Tennessee		48.80	50.20	49.50	46.70	43.00	48.30	5.1	4.8	5.8	3.6	3.1	3.0
Southeast:													
S. Carolina		21.70	22.50	23.40	23.90	23.50	23.80	2.5	2.8	2.6	2.6	2.5	2.5
Georgia	-All cropland	29.70	30.50	32.00	na	na	na	3.5	3.2	3.5	na	na	na
	-Nonirrigated	na	na	na	28.70	32.90	36.40	na	na	na	3.9	4.2	4.4
	-Irrigated	na	na	na	56.10	60.80	66.90	na	na	na	5.3	6.1	5.2
Florida	-All cropland	101.50	95.70	73.10	na	na	na	3.0	3.5	1.9	na	na	na
	-Nonirrigated	na	na	na	20.80	22.50	30.00	na	na	na	2.0	2.8	2.8
	-Irrigated	na	na	na	136.30	183.50	na	na	na	na	1.8	1.7	*
Alabama		28.10	30.70	36.50	31.60	36.20	42.20	4.1	4.3	4.8	2.8	3.4	4.0
Delta States:													
Mississippi	-All cropland	40.80	39.60	44.00	na	na	na	6.7	6.4	6.7	na	na	na
	-Nonirrigated	na	na	na	44.30	41.60	45.00	na	na	na	5.7	5.5	5.4
	-Irrigated	na	na	na	59.90	70.00	73.70	na	na	na	6.6	7.3	7.9
Arkansas	-All cropland	48.00	50.10	50.70	na	na	na	7.3	7.2	6.3	na	na	na
	-Nonirrigated	na	na	na	46.90	48.40	48.80	na	na	na	6.5	6.8	5.6
	-Irrigated	na	na	na	68.10	58.70	*	na	na	na	6.8	6.4	*
Louisiana	-All land	48.30	46.80	48.30	na	na	na	6.1	5.6	6.0	na	na	na
	-Nonirrigated	na	na	na	47.90	55.30	55.60	na	na	na	5.9	5.7	5.7
	-Irrigated	na	na	na	78.90	77.60	65.30	na	na	na	8.9	8.2	6.9
Southern Plains:													
Oklahoma	-Nonirrigated	26.10	26.20	25.20	25.50	25.10	25.60	5.6	5.5	5.1	4.5	4.0	4.7
	-Irrigated	39.10	39.10	41.70	*	*	*	5.9	6.4	6.9	*	*	*
Texas	-Nonirrigated	20.00	20.60	20.20	17.60	17.00	18.00	3.3	3.5	3.2	2.6	2.1	2.1
	-Irrigated	45.30	49.40	44.90	58.50	53.80	44.80	7.3	7.6	6.3	5.7	5.6	4.6

Continued--

Table 1.4.5—Cropland rented for cash: average gross cash rent per acre and rent as a percent of value, selected States, 1992-96—continued

State and land type[2]		Rent per acre						Rent to value[1]					
		ALVS[3] 1992	ALVS 1993	ALVS 1994	JAS[4] 1994	JAS 1995	JAS 1996	ALVS 1992	ALVS 1993	ALVS 1994	JAS 1994	JAS 1995	JAS 1996
		Dollars						*Percent*					
Mountain:													
Montana	-Nonirrigated	19.80	21.00	24.10	15.20	15.30	19.0	8.3	7.8	8.4	5.1	5.1	5.3
	-Irrigated	50.60	54.80	49.70	*	*	*	5.0	5.5	7.3	*	*	*
Idaho	-Nonirrigated	33.90	34.30	47.80	*	*	44.10	5.6	6.4	7.6	*	*	6.5
	-Irrigated	114.30	100.50	126.60	99.50	112.30	113.00	9.9	7.1	8.9	6.9	7.4	6.6
Wyoming	-Nonirrigated	9.60	13.40	16.10	*	*	*	5.7	6.7	6.3	*	*	*
	-Irrigated	49.40	54.00	51.20	*	*	*	8.7	8.2	7.7	*	*	*
Colorado	-Nonirrigated	20.40	24.80	28.80	*	*	*	5.6	7.6	8.8	*	*	*
	-Irrigated	72.70	76.20	75.50	*	*	*	7.2	7.1	7.8	*	*	*
New Mexico	-Irrigated	87.70	80.40	88.90	77.70	88.00	*	2.6	2.5	1.8	4.2	4.6	*
Arizona	-All land	na	na	na	80.60	87.40	94.60	na	na	na	3.0	2.8	2.2
	-Irrigated	128.10	136.70	150.10	na	na	na	3.8	3.6	3.0	na	na	na
Utah	-Nonirrigated	30.50	26.30	28.20	*	*	*	3.8	3.3	3.6	*	*	*
	-Irrigated	57.60	52.90	54.00	51.40	50.90	60.00	3.4	3.0	2.5	1.5	1.4	1.4
Nevada	-Irrigated	92.70	89.10	81.70	*	*	*	4.8	6.2	3.2	*	*	*
Pacific:													
Washington	-Nonirrigated	49.80	53.40	55.90	69.50	70.80	*	5.5	5.4	6.7	4.1	4.6	*
	-Irrigated	113.10	124.20	133.20	127.90	137.80	138.00	5.7	6.3	6.1	6.5	7.1	4.6
Oregon	-Nonirrigated	58.20	55.50	61.90	59.10	66.00	65.80	6.0	5.6	4.2	4.2	4.6	3.7
	-Irrigated	106.70	124.70	135.90	125.50	130.00	115.00	6.1	7.8	7.4	5.2	5.8	4.9
California	-Irrigated	179.60	191.50	223.00	176.00	189.60	210.00	3.4	3.6	4.4	4.4	4.6	3.6

* = Insufficient information; na = data not available.

[1] Cash rent as a percent of per acre value of rented cropland.

[2] Unless otherwise specified as irrigated or nonirrigated, data are for all cropland.

[3] ALVS is "Agricultural Land Values Survey."

[4] JAS is "June Agricultural Survey."

[5] Combines 6 States.

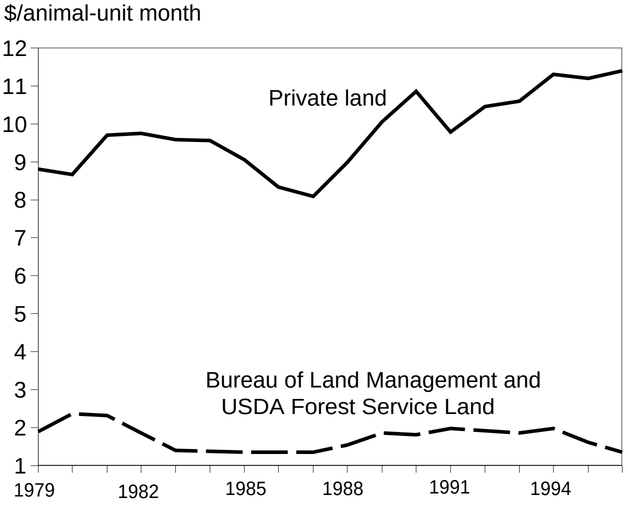
Source: USDA, ERS, based on ALVS and JAS data.

Grazing Fees

Grazing fees for use of pasture or rangeland are also a form of cash rent, except that payment is based on "grazing units" rather than tracts of land (acres). A grazing unit is defined on an animal-unit-month (AUM) basis, which is one cow (or an equivalent in terms of other livestock types) for 1 month. Grazing fees on privately owned nonirrigated land in 16 selected States averaged $11.40 per AUM in 1996, a 1.8-percent increase over 1995 (table 1.4.7). Fees ranged from $18 per AUM in Nebraska to $6.50 in Arizona. Private grazing fees have been relatively stable over the last decade (fig. 1.4.3).

Grazing fees on public lands administered by the Bureau of Land Management (BLM) of the Department of the Interior, and the Forest Service (FS) of the Department of Agriculture are set by law. The fees vary annually according to a legislated formula, which attempts to set the fees according to changes in the cost of production. As a result of the

Figure 1.4.3--Average grazing fees on private and public lands, 1979-96



Sources: USDA, ERS, based on NASS and USDI data.

Table 1.4.6—Pasture rented for cash: average gross cash rent per acre and rent as a percent of value, selected States, 1992-96

State	Rent per acre						Rent to value[1]					
	ALVS[2] 1992	ALVS 1993	ALVS 1994	JAS[3] 1994	JAS 1995	JAS 1996	ALVS 1992	ALVS 1993	ALVS 1994	JAS 1994	JAS 1995	JAS 1996
	Dollars						*Percent*					
Northeast:												
New England[4]	na	na	na	20.60	20.90	*	na	na	na	1.1	1.1	*
New York	19.90	17.00	17.60	14.70	14.50	14.50	4.2	2.2	2.8	2.3	2.7	2.2
New Jersey	*	27.10	*	*	*	*	*	0.5	*	*	*	*
Pennsylvania	21.80	25.40	20.70	20.70	29.80	37.00	1.5	2.0	1.1	2.1	1.9	2.3
Maryland	31.90	31.50	32.40	33.50	*	*	2.1	2.5	1.3	1.4	*	*
Lake States:												
Michigan	19.60	21.50	22.10	*	*	*	4.2	4.2	3.5	*	*	*
Wisconsin	25.60	24.90	22.50	25.50	31.40	40.00	7.6	7.2	6.6	4.3	5.8	5.8
Minnesota	18.60	19.60	22.30	16.20	16.50	16.00	6.3	5.7	7.5	5.3	5.1	4.8
Corn Belt:												
Ohio	26.50	25.60	25.50	*	*	*	4.3	3.4	3.3	*	*	*
Indiana	35.00	35.90	32.90	*	*	*	6.1	5.7	4.5	*	*	*
Illinois	34.90	31.80	34.60	31.00	27.65	29.40	5.6	5.2	5.2	5.6	4.0	4.1
Iowa	33.60	36.10	36.40	26.35	28.05	28.90	7.3	7.0	7.2	5.5	6.2	5.0
Missouri	23.70	22.60	24.70	18.50	16.40	20.00	5.4	4.7	5.1	2.6	2.7	2.8
Northern Plains:												
North Dakota	9.20	9.10	9.70	8.30	8.00	8.50	7.1	6.8	6.7	5.9	4.9	6.3
South Dakota	8.20	7.80	8.90	9.70	8.50	9.10	7.4	6.3	6.8	6.0	5.5	6.5
Nebraska	11.80	11.30	11.10	10.20	9.20	10.00	7.4	6.9	5.9	6.1	5.4	5.8
Kansas	12.00	12.80	12.80	12.20	11.70	11.90	5.0	5.1	4.8	3.7	4.1	3.8
Appalachian:												
Virginia	22.60	20.20	19.40	14.80	14.00[6]	13.80	2.2	1.9	1.7	1.2	1.1[6]	0.7
West Virginia	14.70	16.70	17.60	17.00	14.00	*	1.9	1.9	3.3	3.0	2.2	*
North Carolina	21.30	23.20	23.00	16.90	17.00[6]	22.20	2.1	1.8	1.9	0.9	1.0[6]	1.1
Kentucky	25.90	24.50	26.20	*	*	*	3.3	3.3	3.3	*	*	*
Tennessee	23.50	25.80	31.90	15.20	14.30	13.50	2.9	3.3	4.4	0.8	0.7	0.8
Southeast:												
South Carolina	15.30	16.40	18.80	*	16.11	*	2.2	1.8	2.2	*	1.7	*
Georgia	19.70	21.10	23.00	20.00	19.20	23.20	2.6	2.2	2.3	1.4	1.4	1.9
Florida	21.40	21.00	17.00	17.00	19.50	17.40	0.8	0.8	1.2	.7	.8	0.6
Alabama	18.80	19.40	19.10	13.10	12.50	15.80	3.2	3.6	3.1	2.4	2.0	1.9
Delta States:												
Mississippi	14.90	15.00	14.90	15.90	13.00	15.60	3.4	3.1	2.8	2.5	2.0	2.6
Arkansas	18.60	19.90	18.00	20.90	15.60	*	4.0	4.9	3.5	2.0	1.2	*
Louisiana	17.20	14.50	15.60	13.00	12.60	12.60	2.7	2.1	2.3	0.9	0.8	0.7
Southern Plains:												
Oklahoma	10.20	9.40	9.60	9.40	9.20	8.00	3.4	3.0	3.1	3.2	3.1	3.3
Texas	6.90	7.00	7.30	5.00	4.80	5.40	1.8	1.6	1.5	1.2	1.4	1.1
Mountain:[5]												
Montana	6.60	8.10	6.20	5.50	5.10	7.20	5.5	5.8	4.7	4.7	3.9	4.3
Idaho	26.50	19.10	23.10	28.20	29.30	*	6.1	6.3	5.7	4.9	4.5	*
Wyoming	3.60	4.20	5.80	3.10	3.50	*	3.6	3.8	3.9	2.5	2.9	*
Colorado	6.80	10.90	11.50	*	*	*	3.2	5.1	5.3	*	*	*
New Mexico	na	na	na	1.60	1.80	*	na	na	na	1.5	1.5	*
Utah	25.70	23.00	20.90	16.30	13.70	*	3.5	3.2	1.9	0.9	0.7	*
Pacific:												
Washington	21.90	29.80	25.10	*	*	*	4.0	4.2	3.1	*	*	*
Oregon	22.60	25.40	21.50	*	*	*	4.0	6.0	6.8	*	*	*
California	37.90	34.20	44.90	26.90	39.30	*	2.2	1.8	1.6	1.6	2.5	*

na = data not available; * = insufficient information. [1] Cash rent as a percent of per acre value of rented pasture. [2] ALVS is Agricultural Land Values Survey. [3] JAS is June Agricultural Survey. [4] Combines 6 States. [5] Insufficient data gathered to estimate rents for Arizona and Nevada. [6] Revisions of previously published estimate.

Source: USDA, ERS, based on Agricultural Land Value Survey and June Agricultural Survey data.

Table 1.4.7—Cattle grazing rates on privately owned nonirrigated land, 1982-96

State	1982	1987	1990	1991	1992	1993	1994	1995	1996
	Dollars per animal-unit month[1]								
Northern Plains:									
North Dakota	8.34	7.41	8.52	8.93	10.04	10.00	9.75	10.30	10.60
South Dakota	11.09	8.61	12.53	12.74	12.44	12.60	13.20	13.90	13.20
Nebraska	13.80	10.29	15.78	14.83	14.83	17.00	17.50	17.60	18.00
Kansas	9.59	8.87	10.58	11.10	10.99	11.30	11.00	10.50	12.00
Southern Plains:									
Oklahoma	6.29	5.68	4.31[2]	7.23	6.58[2]	7.10	6.20	7.00	7.00
Texas	8.06	8.30	7.61[2]	8.60[2]	8.92	8.75	8.75	9.10	8.00
Mountain:									
Montana	8.90	7.94	9.61	10.58	11.86	11.40	11.80	11.90	11.80
Idaho	7.98	6.60	8.42	10.18	9.49	9.25	9.70	10.10	10.20
Wyoming	8.46	6.31	9.64	9.98	9.93	10.50	10.50	11.30	11.00
Colorado	9.04	8.27	10.20	9.30	10.11	9.70	10.20	10.30	11.40
New Mexico	6.26	5.82	6.66	3.02[2]	6.95	7.55	8.08	8.74	8.87
Arizona	*	7.19	*	*	5.53	5.72	5.72	5.75	6.50
Utah	9.29	5.98	7.79	9.64	9.79	8.90	9.00	9.50	9.75
Nevada	5.70	7.31	*	9.45	10.26	8.80	8.80	8.80	8.80
Pacific:									
Washington	6.67	9.55	7.82	7.81	10.69	7.80	8.30	8.50	8.70
Oregon	7.70	5.91	8.28	8.93	9.28	9.75	9.00	10.20	10.00
California	9.23	8.46	9.81[2]	9.61	10.09	10.40	11.00	10.50	10.10
16-State average[3]	9.75	8.09	10.86	9.78	10.46	10.60	11.30	11.20	11.40

[1] Includes cow-calf rates converted to animal-unit month rates.

[2] Coefficient of variation exceeds 15 percent.

[3] All States except Texas.

* Insufficient number of reports for an accurate estimate of grazing rates.

Source: USDA, ERS, based on USDA, 1993b; and on USDA, NASS, *Agricultural Prices.*

formula, grazing fees on public land were lowered 16 percent in January 1996, reflecting lower market prices for livestock and increased production costs. The new fees, which took effect March 1, were set at $1.35 per AUM, 26 cents less than in 1995. (For more on grazing issues, see chapter 1.1, *Land Use*.)

Agricultural Real Estate Taxes

USDA's agricultural real estate tax estimates are used as components in its prices-paid indexes for commodities and services, interest, taxes, and farm wages. Property taxes on farm real estate are a direct cost to landowners, but when farmland is cash-rented, those taxes are passed on to tenants through rents paid, and thus agricultural real estate taxes become a significant cost of production faced by all farm operators. Agricultural real estate taxes are a principal source of funding for State and local governments.

Taxes levied on U.S. agricultural real estate (land and buildings) by State and local governments totaled $4.9 billion in 1994 (the most recent year for which data are available), 2 percent less than a year earlier (table 1.4.8). The U.S. average tax per acre was $5.86, down from $5.98 in 1993. The average tax per $100 of full market value on U.S. agricultural real estate declined from $0.85 in 1993 to $0.75 in 1994 (fig. 1.4.4, table 1.4.8). Agricultural real estate taxes include all ad-valorem taxes (meaning based on value) after allowing for preferential assessments and any old age, homestead, or veterans' exemptions (excluded are levies based on benefits received, such as irrigation and drainage improvements).

Compared with 1993, taxes per acre in 1994 averaged higher in 33 States, lower in 10, and unchanged in 6. Taxes per $100 of full market value in 1994 were higher in 4 States, lower in 39, and unchanged in 6. Taxes varied widely among the States, ranging in 1994 from 40 cents per acre in New Mexico to $56.75 in Rhode Island. Taxes per $100 of full market value ranged from 8 cents in Delaware to $2.00 in Wisconsin. Total and per-acre taxes levied in Michigan declined by 51 percent, reflecting an extensive restructuring of that State's tax system. If, instead, Michigan agricultural real estate taxes had not changed (i.e., zero percent change), then U.S. total and per-acre taxes levied would have shown increases rather than decreases.

Table 1.4.8—Taxes levied on agricultural real estate, by State, 1992-94

State	Total taxes			Average tax per acre			Taxes per $100 of full market value		
	1992	1993	1994	1992	1993	1994	1992	1993	1994
	Million dollars			*Dollars*			*Dollars*		
Alabama	10.9	11.1	11.4	1.32	1.32	1.32	0.16	0.15	0.14
Arizona	49.2	50.7	50.5	5.85	6.02	6.02	1.94	1.97	1.92
Arkansas	38.0	38.6	38.5	2.76	2.83	2.86	0.38	0.37	0.36
California	314.1	338.7	344.4	12.87	13.93	14.21	0.73	0.81	0.83
Colorado	81.2	83.2	89.5	2.83	2.90	3.13	0.77	0.76	0.73
Connecticut	10.0	9.9	9.9	27.46	27.85	28.69	0.68	0.65	0.61
Delaware	1.2	1.2	1.2	2.17	2.24	2.17	0.10	0.09	0.08
Florida	143.8	140.7	130.8	14.75	14.71	13.68	0.72	0.71	0.62
Georgia	53.4	52.4	53.5	5.39	5.29	5.40	0.60	0.55	0.55
Hawaii	42.3	42.9	41.6	24.92	25.33	24.59	0.69	0.74	0.75
Idaho	40.4	39.8	39.7	3.64	3.58	3.58	0.53	0.52	0.46
Illinois	428.6	431.2	465.7	15.18	15.32	16.55	1.01	1.02	1.01
Indiana	131.0	138.6	142.8	8.23	8.71	8.97	0.63	0.64	0.61
Iowa	350.2	358.9	350.6	11.13	11.44	11.21	0.95	0.92	0.85
Kansas	102.7	107.1	111.5	2.22	2.32	2.41	0.46	0.47	0.45
Kentucky	41.6	43.6	44.0	3.04	3.19	3.22	0.31	0.29	0.28
Louisiana	19.4	18.2	17.8	2.61	2.48	2.48	0.29	0.26	0.26
Maine	13.5	13.7	13.9	10.37	10.77	11.31	1.11	1.09	1.05
Maryland	22.7	23.8	24.7	10.64	11.14	11.59	0.47	0.44	0.40
Massachusetts	15.3	14.7	14.9	26.31	26.87	27.68	0.77	0.73	0.69
Michigan[1]	359.5	359.4	176.1	35.65	35.97	17.63	3.23	3.18	1.45
Minnesota	196.1	198.2	206.2	7.45	7.56	7.86	0.85	0.84	0.87
Mississippi	22.7	22.3	22.5	2.33	2.29	2.31	0.32	0.30	0.28
Missouri	75.9	78.4	79.7	2.63	2.73	2.78	0.38	0.38	0.37
Montana	80.5	86.1	71.4	1.66	1.78	1.48	0.66	0.66	0.49
Nebraska	352.8	398.0	426.0	8.06	9.10	9.74	1.42	1.57	1.53
Nevada	4.1	4.1	4.1	0.78	0.76	0.78	0.34	0.36	0.34
New Hampshire	8.3	9.2	9.6	21.18	23.80	24.99	1.04	1.09	1.05
New Jersey	35.0	36.0	36.6	40.83	42.40	43.67	0.86	0.93	0.90
New Mexico	12.5	12.5	12.2	0.41	0.41	0.40	0.17	0.18	0.17
New York	165.4	160.3	156.3	20.98	20.33	20.33	2.00	1.82	1.63
North Carolina	58.5	59.8	60.3	6.90	7.12	7.26	0.55	0.54	0.54
North Dakota	87.0	90.2	92.1	2.33	2.42	2.47	0.65	0.62	0.60
Ohio	155.9	167.0	175.4	10.52	11.42	11.99	0.84	0.90	0.87
Oklahoma	63.6	64.6	65.1	2.04	2.07	2.09	0.41	0.41	0.39
Oregon	86.2	77.8	70.7	5.45	4.91	4.47	0.90	0.75	0.60
Pennsylvania	131.8	132.8	133.7	17.79	18.13	18.49	0.98	1.04	0.97
Rhode Island	2.9	3.0	2.9	54.38	58.51	56.75	1.18	1.20	1.06
South Carolina	19.5	19.8	20.2	4.23	4.33	4.42	0.45	0.50	0.48
South Dakota	133.4	152.0	139.9	3.61	4.11	3.78	0.99	1.11	0.98
Tennessee	52.3	53.2	52.7	4.50	4.65	4.65	0.46	0.44	0.44
Texas	367.5	379.3	391.4	2.93	3.02	3.14	0.63	0.64	0.64
Utah	11.7	12.1	12.6	1.66	1.74	1.83	0.39	0.38	0.36
Vermont	20.8	21.3	21.9	14.98	15.77	16.56	1.38	1.36	1.31
Virginia	59.0	61.7	63.5	7.15	7.57	7.80	0.52	0.58	0.58
Washington	72.3	74.2	77.0	5.63	5.78	6.07	0.71	0.74	0.68
West Virginia	4.6	4.5	5.0	1.37	1.34	1.49	0.19	0.19	0.21
Wisconsin	302.2	308.2	307.6	18.68	19.27	19.46	2.15	2.07	2.00
Wyoming	17.5	18.5	18.6	0.74	0.78	0.79	0.54	0.52	0.47
United States[2]	4,869.2	5,023.3	4,908.6	5.78	5.98	5.86	0.84	0.85	0.75

[1] Change between 1993-94 reflects extensive restructuring of Michigan tax system.

[2] Excludes Alaska.

Source: USDA, ERS, based on Agricultural Real Estate Tax Survey data.

State variation in agricultural real estate tax rates is partly due to (1) the degree to which States rely on real estate taxes as a source of local revenue; (2) the extent to which States provide tax relief, such as use-value assessment, homestead and old-age exemptions, and veterans' preferences; and (3) taxpayer resistance to increasing real estate taxes. All States have laws on preferential (or deferred) land-use assessment of farmland (Aiken, 1990). These laws provide that farmland devoted to farming be assessed on the basis of its use as farmland and not according to its market value. For example, farm or ranch land in a developing urban area would be taxed as farm or ranch land and not at the market value for which the land might sell for, say, residential development. These laws are designed not only to reduce agricultural real estate taxes, but also to encourage the protection of farms and ranches for such aesthetic reasons as open space. Laws vary from State to State with respect to minimum acreage requirements, minimum number of years in farming, percentage of gross annual income the landowner receives from the land, and penalties for converting the land to a nonfarm use.

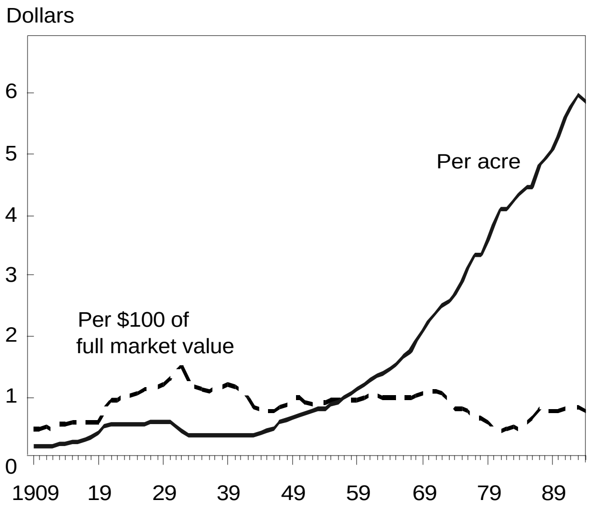
Factors Affecting Farm Real Estate Values

Farm real estate values are affected by many factors, both agricultural and nonagricultural. The net returns from agricultural use of farmland, for which cash rents are often used as a measure, are a principal determinant of farmland values. Farmland values are also influenced by capital investment in farm structures, nonfarm demand for farmland, interest rates, government commodity programs, and a myriad of lesser factors.

Building value currently accounts for about 22 percent of total U.S. farm real estate value, but the percentage varies across the United States. For instance, in Wisconsin, with substantial investment in capital-intensive dairy facilities, buildings account for 42 percent of farm real estate value. In arid regions of the West, buildings account for much less: in Arizona, for instance, building value is 10 percent of total real estate value. Building value as a percentage of farm real estate value also varies across time. Canning (1992) showed farm structures constituting as much as 31 percent (1940) of total U.S. farm real estate value and as little as 14 percent (1979). The interaction of inflation and income tax rates appears to be an important determinant of this relationship.

The potential to convert farmland to nonagricultural uses can increase the price of farmland well above its value in agricultural use. In heavily populated areas, especially, competing demands from nonagricultural uses can far outweigh agricultural productivity as a determinant of farmland value (Robison and Koenig, 1992). Some indication of the influence of urbanization can be gained by examining the rent-to-value ratios in table 1.4.5. In densely populated States along the East Coast, rent-to-value ratios are relatively low, indicating that cash rents (a measure of agricultural productivity) account for only a small proportion of the market value of farm real estate. In more rural States—the Plains, for example—cash rents account for much larger percentages of market value.

Figure 1.4.4--U.S. agricultural real estate taxes



Source: USDA, ERS, Agricultural Real Estate Tax Survey data.

Interest rates, particularly real or inflation-adjusted rates, have been identified as particularly important determinants of U.S. farmland values during the post 1960's period (Gertel, 1990). During much of the mid- to late 1970's, real (inflation-adjusted) interest rates were actually negative, implying a strong incentive to borrow money, with much of the borrowed money used to purchase farmland. Conversely, real interest rates dramatically increased from 1981 to 1985 when nominal interest rates increased rapidly just as expectations of future inflation were decreasing. The resulting increase in the real mortgage interest rate has been attributed as a cause of the slide in farmland values in the early and mid-1980's (Gertel, 1988).

An array of government policies influence the income derived from farmland, and hence its value. Government commodity support programs are the most obvious, but also important are farm credit programs, zoning regulations, habitat protection laws, infrastructure development (such as roads and dams), environmental regulations, and even property and income tax policy. Research has shown that commodity programs have increased farmland values relative to what they would have been in the absence of such programs (Featherstone and Baker, 1988; Herriges, Barickman, and Shogren, 1992). As government assumes a smaller role in the farm economy, analysts expect commodity support programs to be less important in the determination of farmland values. (See chapters 1.1, *Land Use*, and 1.2, *Land Tenure*, for discussion of land use and property rights issues affecting land values.)

The 1996 Farm Act, which phases out commodity support payments over 7 years, has raised concern that such changes will lower farmland values and, hence, the net worth and creditworthiness of farm businesses. Farm-dependent rural communities are concerned that reductions in government commodity support programs will adversely affect the finances of local governments, whose operating revenues are largely dependent on the *ad valorem* property tax. Reductions in farm returns, including government payments, could also have the secondary effect of reducing the incomes of some rural, nonfarm businesses.

Studies conducted by ERS concluded that farmland values could decline by as much as 15 percent if commodity programs abruptly ended (Shoemaker, Perry, and Beach, 1995). Because producers likely have been expecting some reduction in support programs for several years, farmland values in areas heavily dependent on program payments may have already adjusted, as farmers incorporated expectations of changing commodity programs and lower support payments into their assessment of future net returns. With time, producers can adjust capital and other inputs and make other changes to production practices that may mitigate any reduction in program payments. Given that the reduction is being phased in slowly, any remaining impact on farmland values should be small and the effect will probably be overshadowed by recent increases in grain prices.

A myriad of lesser factors contribute to spatial variation in farmland values, including site-specific characteristics of individual parcels. Among these are access to major highways and proximity to commodity and input markets. Nonfarm, but income-generating, uses of farmland are possible on some parcels, including fee-recreation and fee-hunting. Also, farmland value may be enhanced by the attraction of farming as a lifestyle (farm occupation), an aesthetic location, or homesite potential. Inflation, interest rates, lending policies of farm credit agencies and banks, and speculation have also been identified as factors external to farmland markets that affect farmland values.

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Surveys for Collecting Data on Agricultural Land Values, Rents, and Taxes

In 1994, questions on land values and cash rents were added to the June Agricultural Survey (JAS) to replace the Agricultural Land Values Survey (ALVS) which had been used since 1984. The ALVS, as well as the Farmland Market Survey, were discontinued after 1994 in order to reduce respondent burden and data collection costs. The JAS, conducted by the National Agricultural Statistics Service (NASS), is a probability-based survey that divides the area of the United States into “segments” representative of national land uses. A representative sample of all land uses in the 48 contiguous States is obtained by selecting approximately 1 percent of all land in these States for inclusion in the JAS. Twenty percent of the segments are replaced each year. Within the selected segments, enumerators identify “tracts,” which represent a particular farm operator’s acreage within the segment. Farm operators then provide per acre estimates of value and cash rents for the farmland in their tract. In 1995, 14,603 segments were sampled. Within these segments, enumerators identified 119,012 tracts, of which 50,294 were classified as agricultural. Cash rental acres were identified in 17,565 tracts (35 percent of total agricultural tracts).

The JAS—with its area-frame design, probability basis, and personal interview format—is expected to more accurately portray average conditions in each State’s farmland market than did the ALVS. There are several advantages to using JAS. First, JAS uses a much larger sample: approximately 50,000 observations, or about three times as many as the ALVS. Second, the random selection of area-based segments, with 80 percent resurveyed each year, is expected to enhance the statistical reliability of USDA estimates of both farmland values and cash rents. Third, respondents estimate the value or report the cash rent for land they operate within a specific land segment (usually about 1 square mile in area). Respondents to the ALVS, on the other hand, reported values and cash rents for a nonspecific “locality.” And finally, most responses to the ALVS were obtained through telephone contacts, while JAS respondents are visited.

The 1-year overlap of the two surveys in 1994 allows a comparison of cash rent estimates. For most States, the two estimates are similar; for a few States, noticeable differences exist. Several factors associated with the change of survey instrument may have contributed to the differences, but these can be bridged by comparing the cash rent indicators from successive years on each survey.

Data on agricultural real estate taxes are obtained from a national survey of approximately 4,200 taxing jurisdictions. Each provides tax and acreage information for a sample of 10 farm or ranch parcels in its jurisdiction for the current and preceding years. Respondents in jurisdictions with fewer than 10 parcels are requested to provide information on all parcels in the jurisdiction. Taxes per $100 of market value are derived by dividing the average per-acre tax by the average per-acre value of farm real estate. This data series, by State and Nation, dates from 1890 for taxes per acre and from 1909 for total taxes and taxes per $100 of full market value.

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Recent ERS Reports on Land Values, Rents, and Taxes

Agricultural Income and Finance, Situation and Outlook (Annual Lender Issue), AIS-64, Feb. 1997 (Jerome Stam, ed.). This report discusses the financial conditions of commercial agricultural lenders during 1996. Focuses on the four major institutional farm lenders: commercial banks, the Farm Credit System, the Farm Services Agency, and life insurance companies. Financial institutions serving agriculture continued to experience improved conditions in 1996. In recent years, farm-debt-to-farm-income ratios have dropped and farm real estate value increases have led to significantly improved equity positions for many farmers.

"Farm Real Estate Values Continue To Increase," *Agricultural Outlook*, Dec. 1996 (David Westenbarger and Charles Barnard). Discusses changes in farmland values during 1995. U.S. farm real estate values as of January 1, 1996 averaged $890 per acre—a record high—marking the 9th consecutive annual increase since 1987.

Agricultural Land Values, AREI Update, Dec. 1996, No. 15. (John Jones and David Westenbarger) This update reports ERS's annual estimates of farm real estate value for each of 48 States. U.S. farm real estate values averaged $890 per acre as of January 1, 1996—7.0 percent above a year earlier.

Agricultural Cash Rents, AREI Update, June 1997, No. 2 (David Westenbarger, John Jones, and Charles Barnard). This update reports ERS's annual estimates of cash rents for selected States, 1991-95. Cash rents as percentages of market value are also presented. For selected States, estimates are provided for cropland, irrigated cropland, nonirrigated cropland, and pasture. Cash rents for cropland were generally higher in 1995 than in 1994, while those for pasture were generally lower.

"Commodity Payments and Farmland Values," *Agricultural Outlook*, June 1995 (Robin Shoemaker, Janet Perry, and Doug Beach). Includes a general discussion of the influences that agricultural commodity program payments exert upon farmland market values. Describes possible effects that the 1995 Farm Program legislation might have on farmland values.

"New Method For Estimating Land Values," *Agricultural Outlook*, April 1995 (Dave Westenbarger, Doug Beach, and Chris Cadwallader). Discusses advantages to be gained from use of NASS's June Agricultural Survey (JAS) as the survey instrument for obtaining information on farmland values and cash rents. Also describes the statistical basis of JAS sample as it relates to collecting farmland value information.

(Contact to obtain reports: David Westenbarger, (202) 219-0434 [dwest@econ.ag.gov])

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2.1 Water Use and Pricing

Irrigated agriculture remains the dominant use of freshwater in the United States, although irrigation's share of total consumptive use is declining. National irrigated cropland area has expanded by a third since 1969, while field water application rates have declined about one fourth, leaving total irrigation water applied about the same in 1995 as in 1969. Nationally, variable irrigation water costs for ground water and off-farm surface water are roughly equivalent, averaging near $35 per acre. Neither reflects the full costs of water; onfarm well and equipment costs can be substantial for groundwater access, while infrastructure costs are often subsidized for publicly developed, off-farm surface water.

Contents

The United States, as a whole, has adequate water supplies. Annual renewable supplies in surface-water bodies and groundwater aquifers total roughly 1,500 million acre-feet per year (maf/yr). (See "Glossary of Water Use Terms" for definitions.) Of total renewable supplies, only one-quarter is withdrawn for use in homes, farms, and industry, and just 7 percent is consumptively used (Moody, 1993).[1] Renewable surface- and groundwater supplies account for roughly 90 percent of total water use nationwide. The remainder reflects depletion of stored ground water (Foxworthy and Moody, 1986).

An abundance of water in the aggregate belies increasingly limited supplies in many areas, reflecting uneven distribution of the Nation's water resources. In the arid West, consumptive use exceeds half of the renewable water supplies under normal precipitation conditions. In drought years, water use often exceeds renewable flow. While droughts exacerbate supply scarcity, water needs continue to expand in the aggregate and to shift among uses. Urban growth greatly expanded municipal water demands in arid areas of the Southwest and far West. At the same time, demand for high-priority instream (nonconsumptive) water flows for recreation, riparian habitat, and other environmental purposes has tightened competition for available water supplies in all but the wettest years. While future water needs for instream uses are difficult to quantify, the potential demands on existing water supplies are large and geographically diverse (see box, "Instream Water Flows," pp. 80-81).

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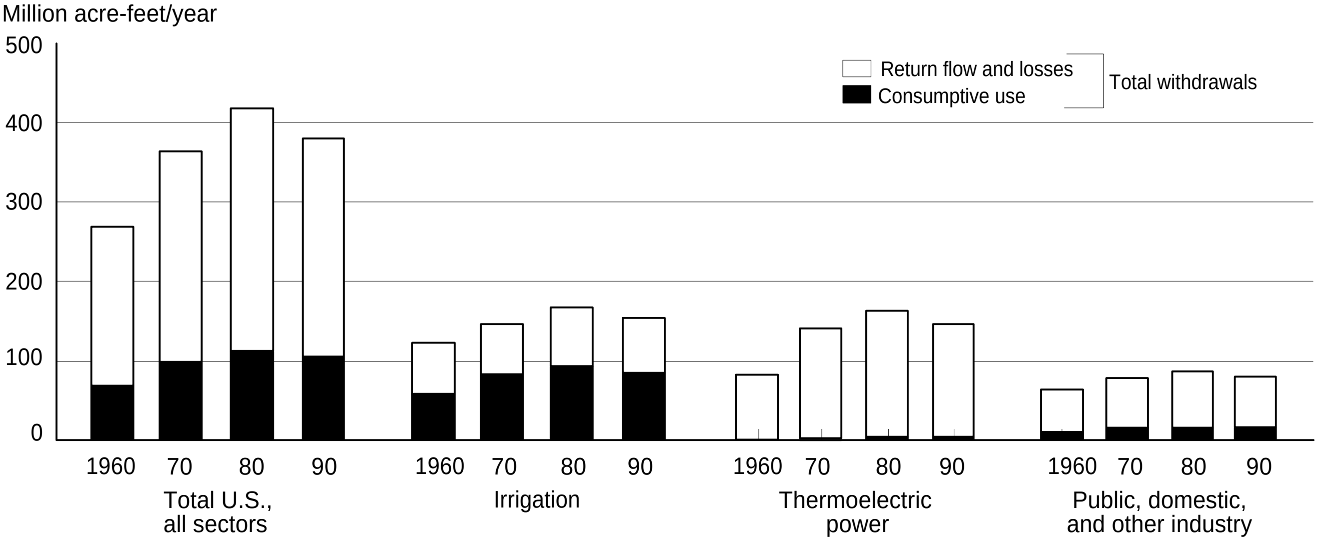
[1] Consumptive uses considered here include those uses occurring after water is withdrawn from a river or aquifer. Other consumptive uses—riparian vegetation use and reservoir evaporation—require no water withdrawals and are not considered here. Instream water use for hydroelectric production, transportation, recreation, or aquatic and riparian habitat is also not included.

Figure 2.1.1--Water withdrawals and consumptive use, 1960-90



Source: USDA, ERS, based on Solley, Pierce, and Perlman, 1993.

Increased water demand in water-deficit areas was historically met by expanding available water supplies. Dam construction, groundwater pumping, and interbasin conveyance provided the water to meet growing urban and agricultural needs. However, future opportunities for large-scale expansion of supplies are limited due to lack of suitable project sites, reduced funding, and increased public concern for environmental consequences. Consequently, meeting future water demands will require some reallocation of existing supplies. And since agriculture is the largest water user, reallocation will likely result in reduced supplies for agriculture.

Irrigated cropland is an important part of the U.S. agricultural sector, contributing about 40 percent of the total value of crops on just 15 percent of total cropland harvested. In 1992, 279,000 farms irrigated 49.4 million acres of crop and pasture land. Irrigated acreage dominated the production of several major crops, including rice with 100 percent irrigated, orchards (76 percent), Irish potatoes (71 percent), and vegetables (65 percent). Irrigated acreages are substantial for several major field crops, including corn for grain with 9.6 million acres, all hay (8.6 million), wheat (4.1 million), and cotton (3.7 million) (USDC, 1994). Changes in agricultural water availability may have significant impacts on irrigated production and rural communities.

Irrigation Withdrawals

Freshwater withdrawals—a measure of the quantity of water diverted from surface- and groundwater sources—totaled 380 million acre-feet (maf) in 1990 (fig. 2.1.1). Major withdrawal categories include irrigation (153 maf), thermoelectric (146 maf), public and rural domestic supplies (52 maf), and other industries (28 maf) (Solley, Pierce, and Perlman, 1993).

Irrigation withdrawals as a share of total freshwater withdrawals declined from 46 percent in 1960 to 40 percent in 1990.[2] Public and rural domestic water withdrawals increased by almost 90 percent over the same period, corresponding with a U.S. population increase of 40 percent and a population shift to arid and warmer climates. Although thermoelectric withdrawals declined through the 1980’s, the 1990 withdrawal was still 77 percent greater than 1960.

Most irrigation water withdrawals occur in the arid Western States where irrigated production is concentrated. Combined irrigation withdrawals in the four largest withdrawal States—California, Idaho, Colorado, and Montana—exceeded 75 maf, or nearly half of total U.S. irrigation withdrawals in 1990 (fig. 2.1.2). The top 20 irrigation States accounted for 97

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[2] Irrigation withdrawal estimates by Solley, Pierce, and Perlman are primarily for agricultural purposes (cropland and pasture), but irrigation of recreational areas (parks and golf courses) is also included. Withdrawal estimates are done every 5 years, but data from 1995 are not yet available.

Table 2.1.1—Irrigation water withdrawals and consumptive use, 20 major irrigation States and total U.S., 1990

State[2]	Withdrawals[1]				Consumptive use[1]	
	Irrigation total	Surface water--Bureau of Reclamation	Surface water--Private	Ground water--All suppliers	Irrigation total	Irrigation's share of State consumptive use
	maf[3]	*Percent of irrigation water withdrawn*[4]			*maf*[3]	*Percent*
California	31.3	20	42	38	21.8	93
Texas	9.5	5	30	66	8.0	79
Idaho	20.9	44	21	35	6.8	99
Colorado	13.0	8	70	22	5.6	94
Kansas	4.7	2	3	95	4.5	92
Nebraska	6.8	13	15	71	4.4	93
Arkansas	5.9	0	18	82	4.4	94
Arizona	5.9	36	25	39	4.0	82
Oregon	7.7	25	67	8	3.4	95
Washington	6.8	70	17	12	2.9	92
Wyoming	8.0	18	79	3	2.9	95
Florida	4.2	0	48	52	2.8	79
Montana	10.1	11	88	1	2.2	93
Utah	4.0	9	77	14	2.2	87
New Mexico	3.4	21	33	46	2.0	86
Nevada	3.2	9	60	31	1.6	86
Mississippi	2.1	0	7	93	1.5	74
Louisiana	0.8	0	36	64	0.7	39
Georgia	0.5	0	40	60	0.5	54
Oklahoma	0.7	6	12	82	0.4	58
All other States	3.9	6	45	49	3.0	25
United States	153.0	20	43	37	85.4	81

[1] Withdrawal and consumptive use estimates are from the U.S. Geological Survey. They include freshwater irrigation on cropland, parks, golf courses, and other recreational lands.

[2] States are ranked based on total irrigation consumptive use.

[3] maf represents 1 million acre-feet.

[4] May not add to 100 due to rounding.

Source: USDA, ERS, based on Solley, Pierce, and Perlman, 1993.

percent of U.S. freshwater irrigation withdrawals (table 2.1.1).[3] Most States rely on a combination of surface- and groundwater supplies for irrigation purposes.

Surface water accounted for 63 percent of total irrigation withdrawals in 1990, with ground water supplying the remaining 37 percent.[4] Approximately 32 percent of surface-water deliveries—or 20 percent of total irrigation withdrawals—was provided by the U.S. Department of Interior, Bureau of Reclamation (BOR). States with the largest total BOR deliveries include Idaho, California, and Washington; BOR's share of total irrigation withdrawals was greatest in Washington, Idaho, Arizona and Oregon. The share of irrigation withdrawals from surface-water sources varies from year to year depending on precipitation, surface runoff, and water stored in reservoirs.

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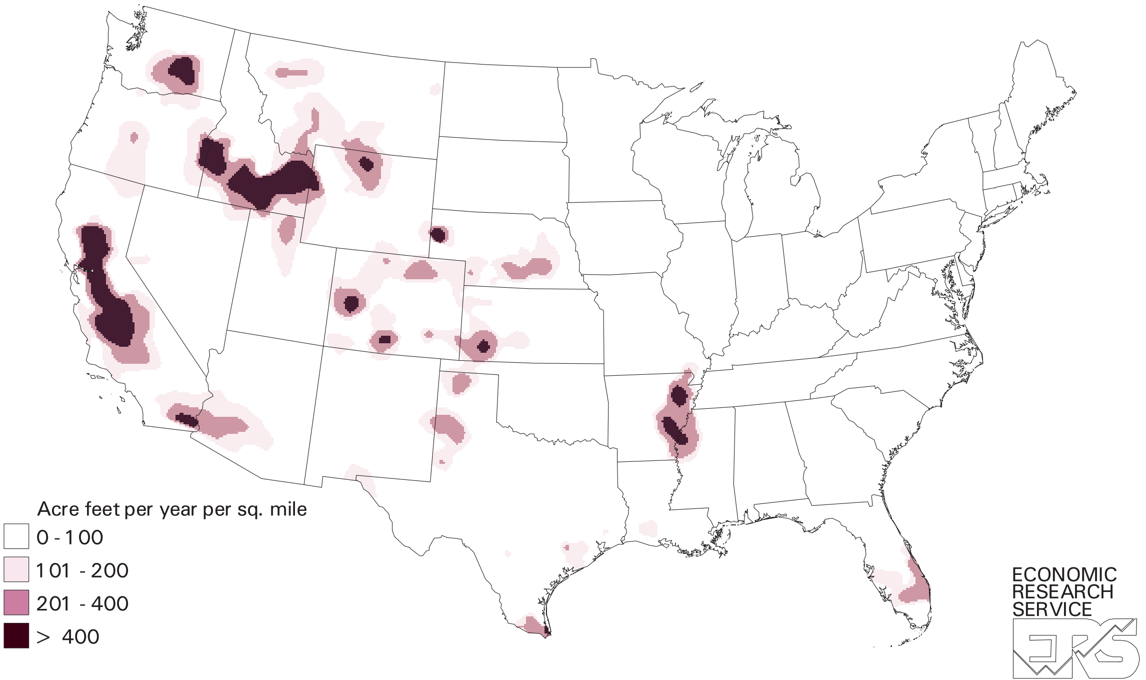
[3] Irrigation States in table 2.1.1 are ranked according to consumptive use, and not irrigation withdrawals.

[4] Surface water availability was below normal over much of the West in 1990. In a normal or above-normal water supply year, the share of water supplied from surface sources is likely to increase.

Figure 2.1.2--Fresh water withdrawals for irrigation, 1990



Source: USDA, ERS, based on Solly, Pierce, and Perlman, 1993.

Ground water is the primary water source for irrigation in about half of the top 20 irrigation States (table 2.1.1). Ground water is pumped from wells drilled into underground, water-bearing strata. Total groundwater withdrawals were largest in the major irrigation States of California, Texas, and Idaho. Ground water as a share of irrigation withdrawals was highest in Kansas, Mississippi, Arkansas, Oklahoma, and Nebraska.

Groundwater overdrafting has been reported in many areas of the Great Plains, Southwest, Pacific Northwest, Mississippi Delta, and Southeast. Overdrafting occurs when withdrawals for irrigation and other uses exceed natural rates of aquifer recharge, which results in lowered water levels and reduced total water reserves. Consequences of overdrafting are slight in any year, but tend to be permanent and cumulative. Major impacts are increases in pumping costs and longrun adjustments in aquifer composition that can lead to land subsidence, saltwater intrusion along coastal areas, and loss of aquifer capacity.

Irrigation Consumptive Use

Consumptive use of freshwater—a measure of water used, not just withdrawn—totaled about 105 maf from all offstream uses in the United States in 1990 (fig. 2.1.1).[5] Irrigation, the dominant consumptive water use, accounted for 85 maf or 81 percent of the U.S. total. Consumptive use as a share of withdrawals was 56 percent for the irrigated sector, compared with 17 percent for public and rural supplies, 16 percent for industries other than thermoelectric, and just 3 percent for thermoelectric. Total irrigation consumptive use depends on crop acreage and evapotranspiration rates, with the latter dependent on climate, crop, yield, and management practices.

Consumptive water use for irrigation increased by about 60 percent between 1960 and 1980, reflecting the rapid expansion in irrigated area. By 1990, irrigation water use had declined from 1980 levels, due largely to reduced water use per irrigated acre. Reduced water consumption per irrigated acre in the 1980's primarily reflects regional cropping pattern shifts, including lower irrigation water needs in more

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[5] Water use estimates are prepared every 5 years, but data for 1995 are not available at this time.

humid eastern States, and a reduction in irrigated cropland in some of the highest water-using areas of the Southwest.

Irrigation consumptive use in the 20 major irrigation States accounted for 96 percent of the national total. California has the greatest irrigation consumptive use, followed by Texas, Idaho, and Colorado. Combined, these four States accounted for nearly half of total irrigation consumptive use in the United States. Of the 20 major irrigation States, 5—Arkansas, Florida, Mississippi, Louisiana, and Georgia—are in humid areas where irrigation supplements usually adequate precipitation.

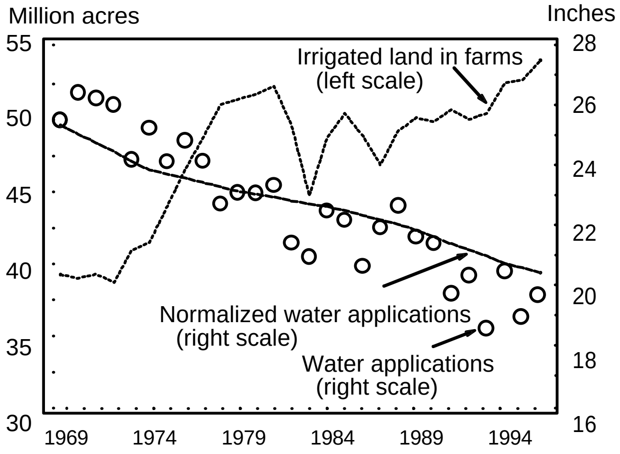
Irrigation's share of total consumptive water use fell by roughly 4 percent over 1960-90. A 4-percent share of the 1990 total water use represents more than 3 maf, or 17 percent of all nonirrigation water uses. This suggests that growth in nonagricultural water needs, particularly in areas with limited opportunities to increase supply, may be met by relatively small reductions in irrigation water use at the national level. However, small transfers from irrigation to other uses in the aggregate may mean substantial adjustments in some regional and local irrigated activity.

Nearly 20 million acres, or about 45 percent of total irrigated acres, were irrigated with surface water in 1994. All surface-water sources in 1990 accounted for 63 percent of total irrigation withdrawals (table 2.1.1). In general, land irrigated from surface-water sources had a higher average withdrawal rate per irrigated acre than groundwater-irrigated lands due to higher conveyance losses, more arid location, and seasonality of rainfall. Greater withdrawals, however, do not necessarily translate into greater consumptive use per acre. The difference between withdrawals and consumptive use highlights the importance of losses, runoff, and return flows. (For more on the relationship among withdrawals, consumptive use, and irrigation application efficiency, see chapter 4.6 on Irrigation Water Management.)

Irrigated Land in Farms

While national area of irrigated farmland is once again near peak levels reached in 1981 (fig. 2.1.3), varying regional trends reflect differences in water resource conditions. Western irrigation reached its peak with the agricultural export boom and high crop prices of the 1970's. The Southwest—the first region to fully utilize available water resources—became the first region to begin abandoning irrigated acreage in the face of growing water demand for urban and environmental uses. Farmers in 6 Southwest States and in the Southern Plains irrigated 3 million acres less in 1995 than in 1981. In contrast, farmers in the Northern Plains and eastern regions continue to expand irrigation capacity, irrigating 3 million acres more in 1995 than in 1981.

Figure 2.1.3--Irrigation trends, 1969-96



For detail on data and assumptions, see tables 2.1.3-2.1.4.

Estimated water applications with weather and crop choice effects removed

Source: USDA, ERS.

The most reliable measure of irrigated farmland continues to be the census of agriculture, taken twice per decade. State summaries from the 1992 Census of Agriculture (table 2.1.2), when contrasted with 1982, highlight the East/West differences in recent trends (USDC, 1994 and 1984). Irrigated area in all but 4 States of the Northern Plains and East increased over 1982, with 8 States experiencing a 50-percent or greater increase in irrigated farmland. In the Pacific Coast and Mountain regions, 9 out of 11 States irrigated less farmland in 1992 than in 1982. The result is an increasing reliance on irrigation in the East, and a redistribution of acres in the West (fig. 2.1.4). Dense concentrations of irrigation are located in California's Central Valley, along the Snake and Columbia Rivers, and over the High Plains Aquifer from Texas to Nebraska. Significant concentrations of irrigation also occur in humid areas—Florida, Georgia, and in the Mississippi Delta, primarily Arkansas and Mississippi.

Changes in irrigated acreage are partially attributable to regional weather patterns. The major western drought of the late 1980's affected surface-water supplies across the region. In 6 southwestern States, the drought combined with competing urban and environmental demands to reduce irrigated area by a

Table 2.1.2—Irrigated area by State and region, 1982 and 1992 Census of Agriculture

State/region	1982	1992	Change
	1,000 acres		*Percent*
Maine	6	10	76
New Hampshire	1	2	34
Vermont	1	2	69
Massachusetts	17	20	15
Rhode Island	2	3	34
Connecticut	7	6	-12
New York	52	47	-11
New Jersey	83	80	-3
Pennsylvania	18	23	27
Delaware	44	62	40
Maryland	39	57	48
Northeast	**271**	**312**	**15**
Michigan	286	368	29
Wisconsin	259	331	28
Minnesota	315	370	17
Lake States	**861**	**1,070**	**24**
Ohio	28	29	6
Indiana	132	241	83
Illinois	166	328	98
Iowa	91	116	27
Missouri	403	709	76
Corn Belt	**820**	**1,423**	**74**
North Dakota	163	187	15
South Dakota	376	371	-1
Nebraska	6,039	6,312	5
Kansas	2,675	2,680	0
Northern Plains	**9,254**	**9,550**	**3**
Virginia	43	62	44
West Virginia	1	3	193
North Carolina	81	113	39
Kentucky	23	28	22
Tennessee	18	37	108
Appalachian	**165**	**242**	**46**
South Carolina	81	76	-7
Georgia	575	725	26
Florida	158	1,783	12
Alabama	66	82	24
Southeast	**2,308**	**2,665**	**15**
Mississippi	431	883	105
Arkansas	2,023	2,702	34
Louisiana	694	898	29
Delta	**3,147**	**4,482**	**42**
Oklahoma	492	512	4
Texas	5,576	4,912	-12
Southern Plains	**6,068**	**5,425**	**-11**
Montana	2,023	1,976	-2
Idaho	3,450	3,260	-6
Wyoming	1,565	1,465	-6
Colorado	3,201	3,170	-1
New Mexico	807	738	-9
Arizona	1,098	956	-13
Utah	1,082	1,143	6
Nevada	830	556	-33
Mountain	**14,056**	**13,264**	**-6**
Washington	1,638	1,641	0
Oregon	1,808	1,622	-10
California	8,461	7,571	-11
Pacific Coast	**11,907**	**10,835**	**-9**
48 States	**48,856**	**49,268**	**1**
Alaska	1	2	135
Hawaii	146	134	-8
U.S total	**49,002**	**49,404**	**0.8**

Source: USDA, ERS, based on USDC, 1994

million acres between 1989 and 1993. About half of this area has subsequently returned to irrigation. Winter precipitation in 1993 and 1995 refilled reservoirs, easing water supply constraints. Additionally, changes in Federal farm programs allowed planting of more program crop acreage. In the East, unusually wet seasons reduced irrigated acres in the Southern Plains, Delta, and Southeast regions in 1992 and across the Northern Plains, Corn Belt, and Lake States regions in 1993.

Based on assumptions of normal weather, over 53 million acres could be irrigated in 1996 (table 2.1.3). This would represent an increase of 1.3 million acres over 1995, with most of this increase projected for corn. The increase in 1996 acreage reflects, in part, changes in Federal commodity programs, which idled irrigable area in the past.

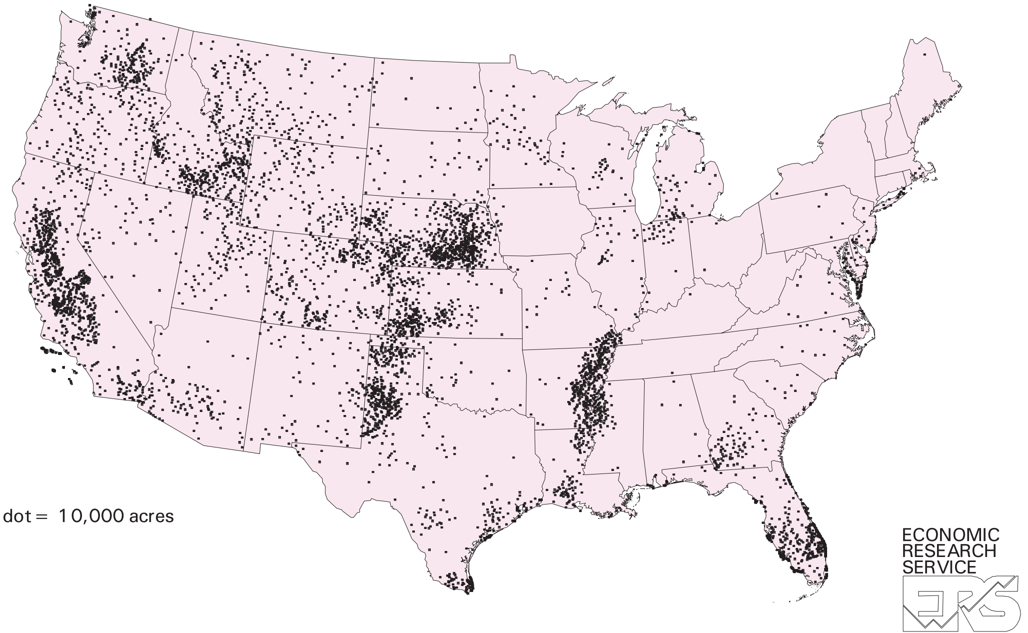
In addition to regional shifts in acreage, there has been a shift in the crop mix on irrigated cropland. Sorghum area irrigated has declined significantly due to improved dryland cultivars, limited water in primary growing areas, and lower returns relative to other irrigated crops. Irrigated areas of barley, oats, silage, and sugarbeets have also declined. Reduced acreage in these crops has been more than offset by increases in irrigated areas of corn, soybeans, alfalfa, fruits, and vegetables. Cotton and rice irrigated areas, while still below record levels of the 1970's, have also increased in recent years.

Irrigation Water Application Rates

Total depth of water applied through the irrigation season has averaged near 20 inches for the past 5 years (table 2.1.4). Since 1969, the national average application rate has declined by about 6 inches, or 25 percent, which is enough to offset the increase in irrigated acreage and maintain total water applied near the level of 25 years earlier. Application rates vary from less than 6 inches for soybeans in Atlantic States to as much as 5 feet for rice in the Southwest. Reductions in application rates have been widespread, with greatest declines in the Northern Plains and Mountain regions. (The higher rates for eastern regions during the 1970's reflects high crop prices and wide adoption of irrigation for water-intensive, specialty crops.)

Of the 6-inch decline in applied water, 2 to 3 inches are attributable to shifting shares of irrigated crop production between States and between crops within States. Recent growth in irrigated area has come in cooler northern States or humid eastern States with lower water application requirements. The remaining

Figure 2.1.4--Irrigated land in farms, 1992



Source: USDA, ERS based on USDC 1992 Census of Agriculture data.

3 to 4 inches of decline in application rates represent efficiency gains from changes in irrigation technologies and water management practices (see chapter 4.6, *Irrigation Water Management*).

Irrigation Water Prices and Costs

Prices paid for irrigation water supplies are of considerable policy interest due to their importance as a cost to irrigated agriculture, and their impact on regional water use. Increasingly, water pricing is viewed as a mechanism to improve the economic efficiency of water use. While the use of pricing to adjust input allocation over time and across sectors has appeal, problems emerge when applied to water.

Irrigation water prices are typically not set in a market, since market development has not been widespread. States generally administer water resources and grant (not auction) rights of use to individuals without charge, except for minor administrative fees. As a result, water expenses are typically based on the access and delivery costs of supplying water and generally do not convey signals about water's relative scarcity.[6]

Water prices could be set administratively, but this approach is not likely to achieve goals of economic efficiency. The localized nature of hydrologic systems and the externalities associated with water use and reuse would require precise adjustments in water prices—spatially and temporally—requiring high program costs. In addition, establishing a slightly higher price may not dramatically change input use in the current institutional environment. To prompt large changes in input use would require very large adjustments in price, all but prohibited by distributional concerns.

The price irrigators pay for water is usually associated with the expense of developing and providing the resource—including access, storage, conveyance, and in some cases, field distribution—and may not reflect the full social cost of its use. Irrigation water costs vary widely (table 2.1.5), reflecting different combinations of water sources, suppliers, distribution

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[6] Irrigators, municipalities, environmental groups, and others seeking to increase water supplies where limits on development or use have been reached must purchase annual water allocations or permanent water rights from existing users. Prices of water purchased better reflect the scarcity of the resource.

Table 2.1.3—Irrigated land in farms, by region and crop, selected years 1969-96

Region	1969[1]	1974[1]	1978[1]	1981[2]	1982[1]	1987[1]	1992[1]	1993[2]	1994[2]	1995[3]	1996[4]
	Thousand acres										
USDA production region:											
Atlantic[5]	1,800	2,000	2,900	3,000	2,700	3,000	3,200	3,300	3,300	3,500	3,400
North Central[6]	500	600	1,400	1,600	1,700	2,000	2,500	2,300	2,600	2,500	2,700
Northern Plains	4,600	6,200	8,800	9,300	9,300	8,700	9,600	9,400	10,100	9,800	10,300
Delta States	1,900	1,800	2,700	3,300	3,100	3,700	4,500	4,500	5,000	4,700	4,900
Southern Plains	7,400	7,100	7,500	7,200	6,100	4,700	5,400	5,800	6,000	6,100	6,100
Mountain States	12,800	12,700	14,800	14,600	14,100	13,300	13,300	13,700	13,500	14,000	14,200
Pacific Coast	10,000	10,600	12,000	12,400	11,900	10,800	10,800	10,700	11,100	11,400	11,500
United States[7]	39,100	41,200	50,300	51,600	49,000	46,400	49,400	49,800	51,800	52,000	53,300
Crop:											
Corn for grain	3,300	5,600	8,700	8,500	8,500	8,000	9,700	9,600	10,600	9,800	10,900
Sorghum for grain	3,500	2,500	2,000	2,100	2,200	1,300	1,600	1,200	1,200	1,100	1,100
Barley	1,600	1,400	2,000	1,800	1,900	1,300	1,100	1,100	1,100	1,100	1,100
Wheat	2,000	3,300	3,000	4,800	4,600	3,700	4,100	4,100	4,100	4,300	4,500
Rice	2,200	2,600	3,000	3,800	3,200	2,400	3,100	2,900	3,400	3,200	3,300
Soybeans	700	500	1,300	1,800	2,300	2,600	2,500	2,600	2,900	2,800	2,700
Cotton	3,100	3,700	4,700	5,100	3,400	3,500	3,700	4,000	4,200	4,700	4,600
Alfalfa hay	5,000	5,200	5,900	5,700	5,500	5,500	5,700	6,000	6,100	6,400	6,400
Other hay	2,900	2,800	3,000	2,900	3,000	3,100	2,900	3,100	2,900	3,300	3,300
Vegetables	1,500	1,600	1,900	1,800	1,900	2,000	2,200	2,200	2,400	2,300	2,300
Land in orchards	2,400	2,600	3,000	3,300	3,300	3,400	3,600	3,700	3,800	3,700	3,700
Other land in farms	10,800	9,400	11,800	10,100	9,200	9,500	9,100	9,300	9,300	9,200	9,300

[1] Census of Agriculture.
[2] Revised estimates constructed from several unpublished USDA sources and the Census of Agriculture.
[3] Preliminary estimates.
[4] Forecast assumes normal weather and no ARP's.
[5] Northeast, Appalachian, and Southeast farm production regions.
[6] Lake States and Corn Belt production regions.
[7] Includes Alaska and Hawaii.
Source: USDA, ERS, based on USDC, Census of Agriculture, various years; and USDA, ERS data.

systems, and other factors.[7] Cost determinants are generalized below for ground- and surface-water sources.

Groundwater Costs

Ground water was the sole water source for 22.5 million acres and supplied some of the water for an additional 6.3 million acres in 1994. Ground water from an estimated 330,000 irrigation wells served approximately 105,000 farms nationwide (USDC, 1996). California had the most wells used for irrigation in 1994 with 63,000, followed by Texas, 55,000; Nebraska, 54,000; and Arkansas, 28,000. Ground water is usually supplied from onfarm wells, with each producer having one or more wells to supply the needs of a single farm. On average, a groundwater irrigated farm will have more than 3 wells, with about 6 percent of the farms reporting 10 or more wells.

Costs associated with groundwater pumping reflect both the variable cost of extraction and the fixed cost of access. Variable extraction costs primarily reflect the energy needed to power a pump.[8] Energy costs

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[7] Other factors include farm (or field) proximity to water source, topography, underlying aquifer conditions, energy source, and structure of the water delivery organization.

[8] A limited number of artesian wells, in which natural aquifer pressure forces water to the ground's surface, are located primarily in Florida and Washington.

Table 2.1.4—Depth of irrigation water applied per season, by region and crop, selected years 1969-96

Item	1969[1]	1974[1]	1984[2]	1988[2]	1991[3]	1992[3]	1993[3]	1994[2]	1995[3]	1996[4]
					Inches[5]					
Region:										
Atlantic[6]	8.5	11.5	16.5	15.5	11.5	14.5	16.5	12.5	14.0	15.0
North Central[7]	7.5	8.0	9.5	10.5	8.0	8.0	5.0	7.5	7.0	7.5
Northern Plains	16.0	17.0	13.5	14.5	13.0	11.5	8.0	12.0	11.0	11.0
Delta States	15.5	17.5	17.5	18.0	12.0	15.0	15.0	13.5	14.5	14.0
Southern Plains	18.0	18.5	17.0	17.0	15.0	15.5	17.0	18.0	17.0	17.0
Mountain States	30.5	28.5	24.5	24.5	23.5	24.0	22.6	24.5	22.5	23.0
Pacific Coast	33.0	34.0	34.0	34.5	31.5	32.0	29.0	32.5	28.0	30.5
United States[8]	25.5	25.0	22.5	22.5	20.0	20.5	19.0	20.5	19.0	19.5
Crop:										
Corn for grain	18.5	19.5	16.0	16.0	14.0	13.0	11.0	13.5	12.5	12.5
Sorghum	19.0	19.0	14.5	14.0	13.5	12.5	11.5	13.5	12.0	12.5
Barley	30.0	26.5	18.5	18.0	17.5	18.5	17.5	19.0	17.5	18.0
Wheat	23.0	24.0	16.5	16.0	14.0	15.5	14.0	17.0	15.0	15.0
Rice	28.0	28.5	34.0	32.5	24.5	27.0	27.0	27.5	27.0	27.0
Soybeans	12.0	11.0	9.5	10.0	9.0	8.0	7.0	8.5	8.0	8.0
Cotton	23.0	25.5	25.0	24.5	21.0	23.0	21.5	21.0	20.5	21.0
Alfalfa hay	32.5	30.5	28.0	29.0	27.0	27.0	24.5	26.5	25.0	25.5
Other hays	22.0	21.0	21.0	19.5	19.5	20.0	19.5	20.5	20.0	20.0
Vegetables	25.0	25.5	27.0	26.5	24.5	24.5	23.5	24.0	23.0	24.0
Land in orchards	29.0	30.0	31.0	31.5	24.5	27.0	23.0	27.0	20.0	25.5

[1] Census of Agriculture, with imputations for individual crops.

[2] Estimates constructed by State, by crop from U.S. Dept. Commerce's Farm and Ranch Irrigation Surveys (FRIS) and ERS estimates of irrigated area.

[3] Aggregated from FRIS State/crop application rates adjusted to reflect annual changes in precipitation. Sensitivity to precipitation is estimated as a function of average precipitation and soil hydrologic group.

[4] Forecast using precipitation records through September 1995.

[5] Depths rounded to the nearest 0.5 inch.

[6] Northeast, Appalachian, and Southeast production regions.

[7] Lake States and Corn Belt farm production regions.

[8] Includes Alaska and Hawaii.

Source: USDA, ERS, based on USDC, Census of Agriculture, selected years; USDC, Farm and Ranch Irrigation Surveys.

vary widely depending on the depth to water, pumping system efficiency, the cost of energy, pressurization needs, and quantity of water applied. Total U.S. energy expenditures for irrigation water pumping were estimated at more than $1.2 billion in 1994 (USDC, 1996). Average energy expenditures were $34 per acre with a State range from $11 to $74 per acre (table 2.1.5). Capital costs of accessing ground water can be substantial, depending on local drilling costs, well depth, aquifer conditions, discharge capacity, power source, and pump type. Capital costs for a typical well and pumping plant are usually $20,000 to $120,000.

A limited amount of ground water is supplied to farms from off-farm sources. In this case, an irrigation district or mutual water-supply company will develop wells to serve irrigators during times of the year when surface-water supplies are unavailable or in short supply. While the quantities of water supplied are small—estimated at only 2 percent of irrigation withdrawals—the water is often critical for improved water management and drought protection. Availability of off-farm groundwater reserves provides irrigators a wider variety of crop alternatives without incurring the capital costs of individual well development. Pumping and access costs are probably similar to onfarm-supplied ground water, but producers pay a higher price because of overhead and water delivery losses.

Table 2.1.5—Supply sources and variable costs of irrigation water, 1994[1]

Water	Acres irrigated	Share of acres irrigated[2]	Average cost[2]	Cost range[2]	Comments
	Million	*Percent*	*$/acre*	*$/acre*	
Ground water			34[3]	11-74[4]	Pumping cost varies with energy prices and depth to water.
Only source[5]	22.5	49			
Combined sources	6.3	14			
Onfarm surface water			n/a	0-15[6]	Costs are very low in most cases. Some water is pumped from surface sources at higher costs, since energy is required.
Only source	3.7	8			
Combined sources	2.2	5			
Off-farm surface water[7]			36[8]	13-78[9]	Most acres relying on off-farm sources are located in the West.
Only source	8.9	18			
Combined sources	5.0	11			
Total			n/a	n/a	The sum of acres is greater than the irrigated total in the Farm and Ranch Irrigation Survey due to double counting of combined water sources.
Only source	35.1	76			
Combined sources	13.5	29			

n/a indicates no data available.

[1] These values include only energy costs for pumping or purchased water costs. Management costs and labor costs associated with irrigation decisions, system maintenance, and water distribution are not included. [2] Available data are from the 1994 Farm and Ranch Irrigation Survey. [3] Reported national average energy expense for the onfarm pumping of irrigation water. [4] Range in State energy expenses for onfarm pumping of irrigation water. [5] Only source means that farms used no other irrigation water source. [6] Cost estimates based on engineering formulas with an efficient electric system. [7] Includes a minor amount of ground water supplied from off-farm suppliers. [8] Reported average cost for off-farm supplies. [9] Range is the average cost reported from off-farm suppliers for States irrigating 50,000 or more acres from off-farm sources. If all States are included, the range expands to $1 - $78 per acre.

Source: USDA, ERS, based on USDC, Farm and Ranch Irrigation Surveys.

Surface-Water Costs

Surface water from rivers, streams, and lakes supplied almost 20 million irrigated acres in 1994 (table 2.1.5). Onfarm surface water supplied about 6 million acres, including 3.7 million acres as the sole source. Off-farm water supplies provided all the water for about 9 million acres, and part of the supply for an additional 5 million acres. Water supplied by off-farm water suppliers is largely from surface-water sources (over 95 percent).

Onfarm surface-water sources provide all or part of the water needs for over 35,000 farms nationwide. Lands irrigated with onfarm surface water are concentrated in Montana, California, Oregon, Wyoming, and Colorado. Costs of onfarm surface water are likely the lowest on average, although little supporting data are available. In most cases, water is conveyed relatively short distances to the field by means of gravity, with costs limited to ditch establishment, maintenance, and repair. Where gravity conveyance is not possible due to topography or levees, water must be pumped. However, pumping costs are generally lower than groundwater pumping costs since the vertical lift is not as high.

Off-farm water suppliers provided water to about 85,000 farms nationwide. Seventy percent of the acres partially or totally supplied from off-farm sources are located in just six States—California, Idaho, Colorado, Montana, Washington, and Wyoming. These States account for more than two-thirds of the acres depending on off-farm water as the only water source.

Several types of organizations have been established to convey and deliver irrigation water from off-farm sources to irrigators.[9] Almost all are nonprofit

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[9] See section 2.1, USDA, ERS, 1994 (AREI) for more information on types of irrigation organizations.

entities with a goal of dependable water service at low cost. In 1994, irrigators reported an average cost of water from off-farm sources of almost $36 per acre irrigated, or an estimated $16 per acre-foot (table 2.1.5). Pricing is often based on acreage served rather than water delivered, since administrative costs are lower with land-based charges. Under a land-based payment system, producers generally pay a fixed cost per acre and receive a specified water allotment. With this pricing system, producers have little financial incentive to conserve since charges are assessed regardless of the amount of the water allotment used.

Water Costs on Federal Projects

Since passage of the Reclamation Act of 1902, the Federal Government has had an important role in the development and distribution of agricultural water supplies in the West. Primary responsibility for construction and management of Federal water supply projects has resided with the U.S. Department of the Interior, Bureau of Reclamation (BOR). Today, the BOR serves as a water "wholesaler" for about 25 percent of the West’s irrigated acres—collecting, storing, and conveying water to local irrigation districts and incorporated mutual water companies that, in turn, serve irrigators. Water delivery quantities and prices are usually specified under long-term (25-50 year) contracts between BOR and irrigation delivery organizations. New demands on water for urban growth and environmental restoration have focused attention on issues such as the recovery of irrigation subsidies and economic efficiency through water pricing.

The 1902 legislation emphasized Western settlement rather than a full market return for Federal water projects, and most water projects were subsidized. The subsidy stems primarily from Congressional actions authorizing the Reclamation program to (1) allow long-term repayment of construction loans to irrigators with no interest, and (2) shift irrigation-related costs that are above producers’ “ability to pay” to other project beneficiaries. These subsidies have reduced the cost of irrigation water to both the delivery organization and irrigators. The degree to which subsidies have influenced water allocations and economic efficiency, both within agriculture and across sectors, varies across projects. Factors include magnitude of the subsidy, availability of water from alternative sources, profitability of cropping alternatives, and water demands from other sectors.

The Reclamation program has constructed 133 projects that provide irrigation water, spending $21.8 billion from 1902 through 1994. Of the total construction expenditures, $16.9 billion is considered reimbursable to the Federal Treasury. Reimbursable construction costs are those associated with hydroelectric power production and water-supply development for irrigation, municipal, and industrial use. Non-reimbursable construction costs are those allocated to flood control, recreation, dam safety, fish and wildlife purposes, and other uses that are national in scope. Irrigation has been allocated $7.1 billion of the reimbursable construction costs, with no interest costs considered. Of the $7.1 billion allocated to irrigation, $3.7 billion of the costs (53 percent) were determined to exceed irrigation’s “ability to pay” and have been either shifted to other sectors ($3.4 billion) or relieved by congressional action ($0.3 billion) (GAO, 1996).

Considerable debate has focused on the issue of recovering some portion of the irrigation subsidy associated with past project construction. Critics contend that the current program seems inconsistent with Federal spending and equity goals because irrigators (1) continue to repay loans without interest and (2) shift costs to other sectors based on “ability-to-pay” provisions.[10] Additionally, some subsidies continue in the form of reduced electric power rates for irrigators in Federal projects and interest-free construction loans for the few projects still under construction. Proponents argue that subsidies associated with irrigation water delivery must be placed in an historic context that considers the goals of the Reclamation program established by Congress. They contend that the historic construction subsidy program reflected the intent of Congress and has effectively met program objectives. They also point to equity concerns in trying to recover subsidies from individuals who may not have directly benefited. In many cases, the value of the water subsidy has been capitalized into the value of the land; the original owner of the land received the subsidy, not subsequent owners who payed a higher price for the land because it had access to lower-cost water. Potential impacts on rural communities are also a major concern. While the discussion continues, the basic structure of the cost-repayment and cost-allocation system remains in effect after several congressional debates.

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[10] Historically, the ability-to-pay calculations were made prior to construction based on projected profitability of a small-farm operation. The BOR is now requiring that all new, renewed, and amended contracts recompute ability-to-pay every 5 years.

Rising water demands for urban and environmental purposes have prompted discussions on how to more accurately reflect the opportunity costs of water in prices paid by irrigators. There are several options for States (and the BOR in some cases) to modify irrigation water price or quantity allocations to more accurately reflect scarcity value of water and to improve benefits derived from this important resource. Water-pricing reform, voluntary water transfers or markets, and water-quantity restrictions could all be used to achieve the same goals. One major limitation to both water-pricing reform and water-quantity restrictions is the need for intensive administrative control and oversight. Voluntary water markets require less administrative control and are allowed by most Western States; however, transactions costs are high in some locations, and institutional rigidities may limit water movement. The BOR can encourage the establishment of water markets by: (1) developing standard language on water marketing in all BOR contracts with water delivery organizations; (2) considering removal of restrictions on changes in location and type of water use, since most Western States already require this as a precondition to transfer; (3) clarifying who receives the increased income from the water sale or lease; and (4) reducing uncertainty regarding the effect of transfers on current contracts, contract water quantities, and procedures for assessing environmental benefits and costs (Mecham and Simon, 1995).

Recent legislation involving the Central Valley Project (CVP) in California—the BOR's largest project—establishes an important legislative precedent for the pricing, allocation, and transfer of Federal water supplies. Provisions of the law increase water prices for renewed contracts, implement tiered water-pricing schedules (higher per-unit rates for higher usage), and reallocate some water for environmental purposes. In addition, the legislation removed important barriers to water market transfers, thus allowing water to move both within and off the project areas to satisfy higher valued demands. CVP reforms may guide future BOR efforts in promoting water conservation and increasing economic returns from water use on other federally financed projects.

A recently completed study by the National Research Council (1996) concludes that irrigated agriculture is likely to remain an important sector, both in terms of the value of agricultural production and demand on land and water resources. However, changes in the irrigation sector are anticipated in response to increasing water demands for urban and environmental uses, and changing institutions governing farm programs and water allocations. Water dedicated to agricultural production will likely decline, with at least some portion shifted to satisfy environmental goals.

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Glossary of Water Use Terms

Acre-foot—A volume of water covering an acre of land to a depth of 1 foot, or 325,851 gallons.

Consumptive use—Amount of water lost to the immediate water environment through evaporation, plant transpiration, incorporation in products or crops, or consumption by humans and livestock.

Ground water—Generally all subsurface water as opposed to surface water. Specifically, water from the saturated subsurface zone (zone where all spaces between soil or rock particles are filled with water).

Industrial withdrawals/use (other than thermoelectric)—Includes the water withdrawn/consumptively used in facilities that manufacture products (including use for processing, washing, and cooling) and in mining (including use for dewatering and milling).

Irrigation withdrawals/use—Includes the water withdrawn/consumptively used in artificially applying water to farm and horticultural crops. Some data sources include water to irrigate recreational areas such as parks and golf courses.

Loss—Water that is lost to the supply, at the point of measurement, from a nonproductive use, including evaporation from surface-water bodies and nonrecoverable deep percolation.

Overdrafting—Withdrawing ground water at a rate greater than aquifer recharge, resulting in lowering of groundwater levels. Also referred to as aquifer mining.

Public and rural domestic withdrawals/use—Includes the water withdrawn/consumptively used by public and private water suppliers and by self-supplied domestic water users.

Recharge—The percolation of water from the surface into a groundwater aquifer. The water source can be precipitation, surface water, or irrigation.

Return flow—Water that reaches a surface-water source after release from the point of use, and thus becomes available for use again.

Surface water—An open body of water such as a stream, river, or lake.

Thermoelectric withdrawals/use—Includes the water withdrawn/consumptively used in the generation of electric power with fossil-fuel, nuclear, or geothermal energy.

Irrigation water application—The depth of water applied to the field. Irrigation application quantities differ from irrigation withdrawals by the quantity of conveyance losses.

Withdrawal—Amount of water diverted from a surface-water source or extracted from a groundwater source.

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Instream Water Flows

Increased demand for instream water flows have intensified competition for limited water supplies in many areas. Water historically withdrawn for consumptive use in irrigation and municipal sectors, or impounded for navigation and hydropower generation, is finding a new "use" as instream flows for recreational and environmental purposes. Instream flow requirements are increasingly guaranteed through legislatively mandated transfers, and in some cases, direct market purchases.

Recreation. Demand for water-based recreation has generally increased over time with expanding populations, leisure time, and disposable income. While water demanded for recreation is difficult to quantify due to the multi-use nature of recreational waters, the increase in participation provides an indicator of the increased demand for water-based recreation activities. The number of adults participating in boating activities nationally—including sailing, motor boating, water skiing, and canoeing—has expanded from 49.5 to 60.1 million (21 percent) since 1982 (Forest Service and others, 1995). Swimming in natural water bodies has increased from 56.5 to 78.1 million persons (38 percent) over the same period. Fishing activity has declined 3 percent, from 60.1 to 58.3 million persons.

Wildlife habitat. Wildlife, including but not limited to endangered species, often competes with out-of-stream uses for water resources. Many wildlife communities and their habitats—aquatic, riparian, wetland, and estuarine—depend on water. Efforts to protect wildlife and habitat may involve restrictions on water withdrawals, timing of deliveries, lake storage levels, and drainage flows. Instream flow restrictions to protect wildlife habitat has important implications for irrigated production and farm income. The responsibility of private water developments located on public lands to provide water for downstream fish and wildlife habitat is being "reexamined" through Section 389 of the 1996 Farm Act, which requires a Water Rights Task Force. The task force will study the issue of water rights for environmental protection on national forest land, the protection of minimum instream flows, and the protection of water rights that involve facilities on Forest Service lands.

Endangered species. Aquatic plant and animal species, and other predatory species that depend on healthy aquatic systems, may be highly sensitive to changes in instream water conditions. There are currently 663 species nationwide listed as "threatened" or "endangered" under the Federal Endangered Species Act (ESA). Current species listings specify various water flow-related reasons for species decline, potentially related to irrigation. These include water diversion/drawdown (141 species), water-level fluctuation (82 species), water-level stabilization (26 species), water temperature alteration (61 species), reservoirs (103 species), groundwater drawdown (71 species), and salinity alteration (14 species) (computed from data supplied by Biodata Inc., Golden, CO, 1995).

The restoration of aquatic and riverine ecosystems to protect and recover endangered species has emerged as one of the most critical agricultural water-supply issues of the 1990's. Many of the current conflicts involve allocation of surface-water flows in western river systems. This reflects various factors particular to the West—the unique biota of many western river systems; the scarcity of renewable water supplies in an arid environment; and the nature of water demands based on the concentration of irrigated production and rapid urban growth. However, conflicts involving wildlife and agriculture are not limited to surface water, and are no longer limited to the arid Western States.

Examples of instream flow competition. In the Pacific Northwest, a major Federal/State effort is underway to restore declining native salmon stocks of the Columbia-Snake River Basin, including three stocks listed under the ESA. Hydropower generation, irrigation diversions, land-use activities (logging, mining, and grazing), and fish harvesting have all contributed to the decline through extensive loss and degradation of salmon habitat. Increasing instream flow velocities to assist migrating salmon—through reservoir drawdown along the lower Snake River (Washington/Oregon) and reduced irrigation diversions in the upper Snake River (Idaho/Oregon)—represents a major element of recovery strategies under consideration (Aillery and others, 1996).

In California's San Francisco Bay/San Joaquin-Sacramento River Delta (Bay/Delta) area, efforts are underway to manage flows to restore endangered fish species and federally protected migratory waterfowl. The Bay/Delta region is important, both as a pumping/transfer point for agricultural and urban water supplies for much of central and southern California and as a natural site of ecological significance. Increased freshwater outflows from the Bay/Delta, linked to salinity standards, are being used to improve estuarine habitat. The higher water outflows translate into reduced water supplies for agriculture. Additionally, adjustments in river management to improve species protection are limiting the timing of withdrawals for agricultural purposes. Progress on solutions is being made through Federal, State and local cooperation (McClurg, 1996).

--cont. on next page

Instream Water Flows (cont.)

The Edwards Aquifer region of south-central Texas illustrates the interaction between ground water and species protection. Extensive groundwater pumping for agricultural and urban uses contributes to annual declines in the aquifer water level, which reduces flows from aquifer-fed springs that support habitat for endangered aquatic species. The situation is compounded by the nature of the aquifer, which has high recharge from precipitation, and is therefore susceptible to the vagaries of weather and drought. Potential restrictions on groundwater use in the region to ensure minimum spring flows would impact irrigated agriculture (Baldwin and others, 1993 and Collinge and others, 1993).

In South Florida, extensive water-control infrastructure and management has severely altered the natural hydrologic cycle, contributing to the declining productivity of the natural ecosystem (Finkl, 1995). Wetland conversion for agricultural and urban uses has substantially reduced available wetlands for wildlife habitat and other environmental uses. Of the remaining wetlands, large areas are seriously degraded due to disruptions in the quantity, timing, and distribution of flows to meet water-supply and flood-control purposes. In addition, land-use activities have contributed to impaired water quality in some areas. A major effort is underway at the Federal and State level to restore natural hydrologic functions, to the extent practicable, while meeting water-supply and flood-control objectives for agriculture and an expanding urban sector (SFWMD, 1995).

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Recent ERS Research on Water Issues

Irrigation Water Use, 1994, AREI Update, 1996, No. 8 (Noel Gollehon and Marcel Aillery). This update presents State-level information on water sources (onfarm wells, onfarm surface, and off-farm surface) and irrigated acres by crop based on the 1994 Farm and Ranch Irrigation Survey.

Water Supplies, AREI Update, 1996, No. 3 (Noel Gollehon and Marcel Aillery). This look at the 1996 spring water supply forecasts and conditions highlights the drought area in the Southwest and Southern Plains, near- to above-normal irrigation supplies in the West, and adequate subsoil moisture conditions in the East.

Salmon Recovery in the Pacific Northwest: Agricultural and Other Economic Effects, AER-727, Feb. 1996 (Marcel Aillery, Paul Bertels, Joseph Cooper, Michael Moore, Steve Vogel, and Marca Weinberg). The agricultural effects of two proposed Snake River management measures—reservoir drawdown on the lower Snake and reductions in irrigation water supplies in the upper Snake—considered to recover three salmon runs are analyzed. For the Northwest region, adjustments in crop production could lower producer profit by $4-$35 million annually (less than 3 percent of the 1987 baseline), depending on specific alternatives.

Economic Analysis of Selected Water Policy Options for the Pacific Northwest, AER-720, June 1995 (Glenn Schaible, Noel Gollehon, Mark Kramer, Marcel Aillery, and Michael Moore). Irrigated agriculture in the Pacific Northwest could use significantly less water with minimal impact on agricultural economic returns. Net water savings for field crops of up to 18 percent of current use levels could be realized with less than a 2-percent decline in economic returns. Combining different approaches spreads the conservation burden among farmers, water suppliers, and production regions.

"Multicrop Production Decisions in Western Irrigated Agriculture: The Role of Water Price," ***American Journal of Agricultural Economics***, 76:859-874, Nov. 1994 (Michael Moore, Noel Gollehon, and Marc Carey). Econometric estimates of water demand and irrigated crop supply functions for four regions of the West provide the statistical base for this analysis. The analysis examined irrigator response to shortrun water price change, measured as increases in groundwater pumping cost. Findings suggest that irrigators respond primarily at the extensive margin—changing the acres devoted to specific crops—rather than at the intensive margin—changing the quantity of water applied during the irrigation season.

"Alternative Models of Input Allocation in Multicrop Systems: Irrigation Water in the Central Plains," ***Agricultural Economics***, 11:143-158, Dec. 1994 (Michael Moore, Noel Gollehon, and Marc Carey). This analysis compared different farm-level models of irrigation decisionmaking on farms with multiple crops in the Central Plains region. Water was modeled three ways: as a variable input, an input used without regard for price, and a fixed-allocatable input. The model considering water a fixed-allocatable input dominated the other models in both model specification tests and prediction accuracy measures.

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2.2 Water Quality

Agricultural production often emits pollutants that affect the quality of the Nation's water resources and impose costs on water users. The extent and magnitude of agricultural pollution is difficult to assess because of its nonpoint nature. However, agriculture is the leading source of impairment in the Nation's rivers and lakes, and a major source of impairment to estuaries.

Contents

Producing food and fiber involves many activities and practices that can affect the quality of water resources under and near the field. For example, tilling the soil and leaving it without plant cover for extended periods of time results in accelerated soil erosion. The use of chemical inputs increases the probability that some of these materials will wash off or leach through the field to enter water resources. Irrigation can move salt and other dissolved minerals to surface water. Livestock operations produce large amounts of waste which, if not properly disposed of, can threaten human health as well as contribute to excess nutrient problems in streams, rivers, and lakes.

Quality of the Nation's Water

The Clean Water Act (passed in 1972 as the Federal Water Pollution Control Act) defines water quality in terms of designated beneficial uses with numeric and narrative criteria that support each use. Designated beneficial uses are the desirable uses that water resources should support. Examples are drinking water supply, primary contact recreations, and aquatic life support. Numeric water quality criteria establish the minimum physical, chemical, and biological parameters required for water to support a beneficial use. Physical and chemical criteria may set maximum concentrations of pollutants, acceptable ranges of physical parameters, and minimum concentrations of desirable parameters, such as dissolved oxygen. Biological criteria describe the expected attainable community attributes and establish values based on measures such as species richness, presence or absence of indicator taxa, and distribution of classes of organisms (EPA, 1994). Narrative water quality criteria define conditions and attainable goals that must be maintained to support a designated use. Narrative biological criteria describe aquatic community characteristics expected to occur within a water body.

Surface-Water Quality

The Nation's surface-water quality has improved since 1972, primarily through reductions in pollution from point sources. However, many water quality problems remain. Water Quality Inventories, published by the U.S. Environmental Protection Agency (EPA), show no major improvement in the quality of the Nation's rivers, lakes, ponds, and estuaries since 1990 (EPA, 1995). Agriculture is cited by States as a leading source of water quality impairment. A little over one-third of river miles, lake acres (excluding the Great Lakes), and estuarine waters assessed by the States were found to not fully support their designated uses in 1994 (table 2.2.1).

The Great Lakes continue to suffer serious pollution, even though some progress has been made in reducing the worst cases of nutrient enrichment

Table 2.2.1—Status of the Nation's surface-water quality, 1988-94

Item	Rivers				Lakes[1]				Estuaries			
	1988	1990	1992	1994	1988	1990	1992	1994	1988	1990	1992	1994
					Percent of total water							
Water systems assessed	29	36	18	17	41	47	46	42	72	75	74	78
					Percent of assessed waters							
Meeting designated uses:												
Supporting	70	69	62	64	74	60	56	63	89	67	68	63
Partially supporting	20	21	25	22	17	19	35	28	8	25	23	27
Not supporting	10	10	13	14	10	21	9	9	3	8	9	9
Clean Water Act goal of fishable:												
Meeting	86	80	66	69	95	70	69	69	97	77	78	70
Not meeting	11	19	34	31	5	30	31	31	3	23	22	30
Not attainable	3	1	-	-	-	0	-	-	0	-	0	0
Clean Water Act goal of swimmable:												
Meeting	85	75	71	77	96	82	77	81	92	88	83	85
Not meeting	11	15	20	23	4	18	22	19	1	12	17	15
Not attainable	4	10	9	-	-	-	-	-	7	-	0	-

- = less than 1 percent of assessed waters.

[1] Excluding Great Lakes.

Source: USDA, ERS, based on Environmental Protection Agency National Water Quality Inventories, 1988, 1990, 1992, 1994.

(particularly in Lake Erie). Only 3 percent of the assessed shoreline miles (with 96 percent assessed) fully support designated uses (EPA, 1995). Sixty-three percent of the assessed shoreline does not support designated uses at all. Most of the Great Lakes shoreline is polluted with toxic organic chemicals, primarily PCB's and DDT that are often found in fish samples. Atmospheric deposition of toxics, including pesticides, and contaminated sediments are the leading sources of impairment.

The Chesapeake Bay, the largest estuary in the world, has seen water quality degrade over time because of agricultural development, population growth, and sewage treatment plant emissions. While an aggressive program has reduced phosphorus, nitrogen concentrations remain high, leaving the bay overenriched. Shellfish harvests have declined dramatically in recent years, and poor water quality is believed to be an important contributing factor.

Contaminated seafood and fishkills are also indicators of surface water quality. States issue fish consumption advisories to protect the public from ingesting harmful quantities of toxic pollutants. All States but Alaska, South Dakota, and Wyoming issued fish consumption advisories in 1994, for a total of 1,531. This was up from 1,279 fish consumption advisories in 46 States in 1993 (EPA, 1994). Mercury, PCB's, chlordane, dioxin, and DDT caused more than 93 percent of the fish consumption advisories in 1994. These contaminants have been linked with human birth defects, cancer, neurological disorders, and kidney ailments. In addition, bacterial and viral contamination closed over 6,000 square miles of shellfish beds in 15 States during 1992-94. Most of the problems are from improperly treated sewage and urban runoff, but animal waste also contributes.

The number of fishkills provides some idea of pollutant impacts on aquatic life. These are most often sporadic events, rather than a chronic problem. Thirty-two States, tribes, and other jurisdictions reported 1,454 fishkill incidents during 1992-93 (EPA, 1995). Pesticides and manure/silage were identified by States as major contributors to fishkill incidents.

Groundwater Quality

Some States report on the general quality of their groundwater resources in Section 305(b) reports. Of 38 States that reported overall groundwater quality in 1992, 29 judged their goundwater quality to be good or excellent (EPA, 1994). Generally, States report that degradation of groundwater resources is a local occurrence. Agriculture was cited as a source in 44 of the 49 States that reported major sources of groundwater contamination.

An indication of agriculture's impact on groundwater quality comes from the EPA's National Survey of Pesticides in Drinking Water Wells, conducted in 1988-90. The survey provided the first national estimates of the frequency and concentrations of pesticides and nitrate in community water system wells and rural domestic drinking water wells. (Results of this survey are reported in following sections.) In summary, the proportion of wells found to contain any particular pesticide or pesticide degradate was low. However, many wells were affected by the presence of nitrate at levels exceeding EPA health guidelines.

Agricultural Pollutants

Agricultural production produces a wide variety of pollutants. These include sediment, nutrients, pesticides, salts, and pathogens. While farmers do not intend for these materials to move from the field to water resources, they often do. For example, as much as 15 percent of the nitrogen fertilizer and up to 3 percent of pesticides applied to cropland in the Mississippi River Basin makes its way into the Gulf of Mexico (Goolsby and Battaglin, 1993). States reported that agriculture is the leading remaining source of impairment in the Nation's rivers and lakes, and a major source of impairment in estuaries (EPA, 1995). An estimated 71 percent of U.S. cropland (nearly 300 million acres) is located in watersheds where the concentration of at least one of four common surface-water contaminants (nitrate, phosphorus, fecal coliform bacteria, and suspended sediment) exceeded generally accepted criteria in 1989 (Smith, Schwarz, and Alexander, 1994).

Sediment

Disturbing the soil through tillage and cultivation and leaving it without vegetative cover increases the rate of soil erosion. Dislocated soil particles can be carried in runoff water and eventually reach surface water resources, including streams, rivers, lakes, reservoirs, and wetlands. Sediment causes various damage to water resources and to water users.

Table 2.2.2—Trends in concentrations of agricultural water pollutants in surface waters, 1980-90

Water resources region	Nitrate	Phosphorus	Suspended sediment
	Average percentage change per year		
North Atlantic	*	-1.4	-0.4
South Atlantic-Gulf	*	0.1	0.2
Great Lakes	*	-3.3	0.5
Ohio-Tennessee	*	-1.0	-1.3
Upper Mississippi	-0.4	-1.2	-1.3
Lower Mississippi	-1.6	-3.8	-1.2
Souris-Red-Rainy	*	-0.8	1.2
Missouri	*	-1.7	-0.2
Arkansas-White-Red	*	-3.1	-0.7
Texas-Gulf-Rio Grande	*	-0.9	-0.6
Colorado	*	-2.4	-0.8
Great Basin	*	-2.7	-0.2
Pacific Northwest	*	-1.7	-0.1
California	*	-1.4	-0.6

* Between -0.1 and 0.1.
Source: USDA, ERS, based on Smith, Alexander, and Lanfear, 1993.

Accelerated reservoir siltation reduces the useful life of reservoirs. Sediment can clog roadside ditches and irrigation canals, block navigation channels, and increase dredging costs. By raising stream beds and burying streamside wetlands, sediment can increase the probability and severity of floods. Suspended sediment can increase the cost of water treatment for municipal and industrial water uses. Sediment can also destroy or degrade aquatic wildlife habitat, reducing diversity and damaging commercial and recreational fisheries.

Siltation is one of the leading pollution problems in U.S. rivers and streams and among the top four problems in lakes and estuaries (EPA, 1995). Sediment damages from erosion have been estimated to be between $2 billion and $8 billion per year (Ribaudo, 1989). These include damages or costs to navigation, reservoirs, recreational fishing, water treatment, water conveyance systems, and industrial and municipal water use.

Soil conservation efforts over the past 10 years, particularly the Conservation Reserve Program and Conservation Compliance, are starting to pay off (see chapters 6.2 and 6.3). The National Resources Inventory reports that the average rate of sheet and rill erosion on cropland declined by about one-third between 1982 and 1992. In most regions of the country, the U.S. Geological Survey (USGS) found that suspended sediment concentrations trended slightly downward over the 1980's, particularly in the Ohio-Tennessee, and Upper and Lower Mississippi regions (table 2.2.2) (Smith, Alexander, and Lanfear, 1993). Areas characterized by corn and soybean production and mixed crops had the greatest downward trends.

Nutrients

Nutrients can enter water resources three ways. *Runoff* transports pollutants over the soil surface by rainwater or irrigation water that does not soak into the soil. Nutrients move from fields to surface water while dissolved in runoff water or adsorbed to eroded soil particles. *Run-in* transports chemicals directly to groundwater through sinkholes or porous or fractured bedrock. *Leaching* is the movement of pollutants through the soil by percolating rain or irrigation water. Soil organic matter content, clay content, and permeability all affect the potential for nutrients in soils to leach through the root zone.

Important nutrients from a water quality standpoint are nitrogen and phosphorus. Nitrogen, primarily found in the soil as nitrate, is easily soluble and is transported in surface runoff, in tile drainage, or with leachate. Phosphorus, primarily in the form of phosphate, is only moderately soluble and, relative to nitrate, is not very mobile in soils and ground water. However, erosion can transport considerable amounts of suspended phosphorus to surface waters.

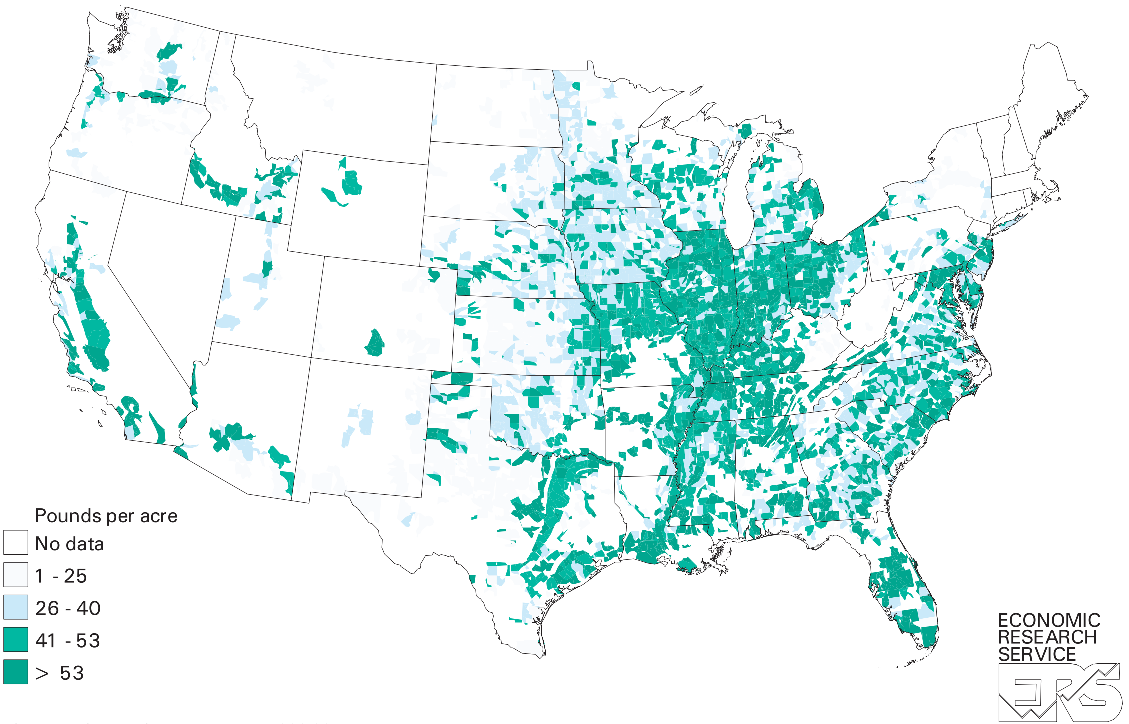
Nutrients from agriculture can accelerate algal production in receiving surface water, resulting in a variety of water-quality problems, including clogged pipelines, fishkills, and reduced recreation opportunities. Nitrate is the only nutrient for which the EPA has established a maximum contaminant level (MCL, a legal maximum long-term exposure) in drinking water (10 mg/L). Nitrate can be converted to nitrite in the gastrointestinal tract. In infants under 6 months of age, this nitrite could cause methemoglobinemia, otherwise known as "blue-baby syndrome," which prevents the transport of sufficient oxygen in the bloodstream. The presence of nitrate in concentrations above 10 mg/L in sources of public drinking water systems requires additional treatment, with associated treatment costs.

EPA reports that nutrient pollution is the leading cause of water quality impairment in lakes and estuaries, and is the third leading cause in rivers (1995). Agriculture is the primary source of nutrients in impaired surface waters.

From its 1988-90 national survey of drinking water wells, the EPA found nitrate in more than half of the 94,600 community water system (CWS) wells and almost 60 percent of the 10.5 million rural domestic wells, making nitrate the most frequently detected chemical in well water. However, only 1.2 percent of the CWS's and 2.4 percent of the rural domestic wells were estimated to contain levels above the MCL. About 3 million people (including 43,500 infants) using water from CWS's and about 1.5 million people (including 22,500 infants) using rural wells are exposed to nitrate at levels above the MCL (EPA, 1992). Higher findings for rural domestic wells are expected since they are closer to farmland and are generally shallower than wells used by CWS's, making them more susceptible to contamination. More recently, the USGS found that the MCL was exceeded in about 1 percent of CWS's, but 9 percent of rural domestic wells (Mueller and others, 1995). The difference with EPA's findings is probably due to different sampling strategies. The USGS found that about 21 percent of wells under agricultural land exceeded the MCL in selected watersheds, with particularly high proportions exceeding the MCL in the Northern Plains (35 percent) and the Pacific (27 percent) regions.

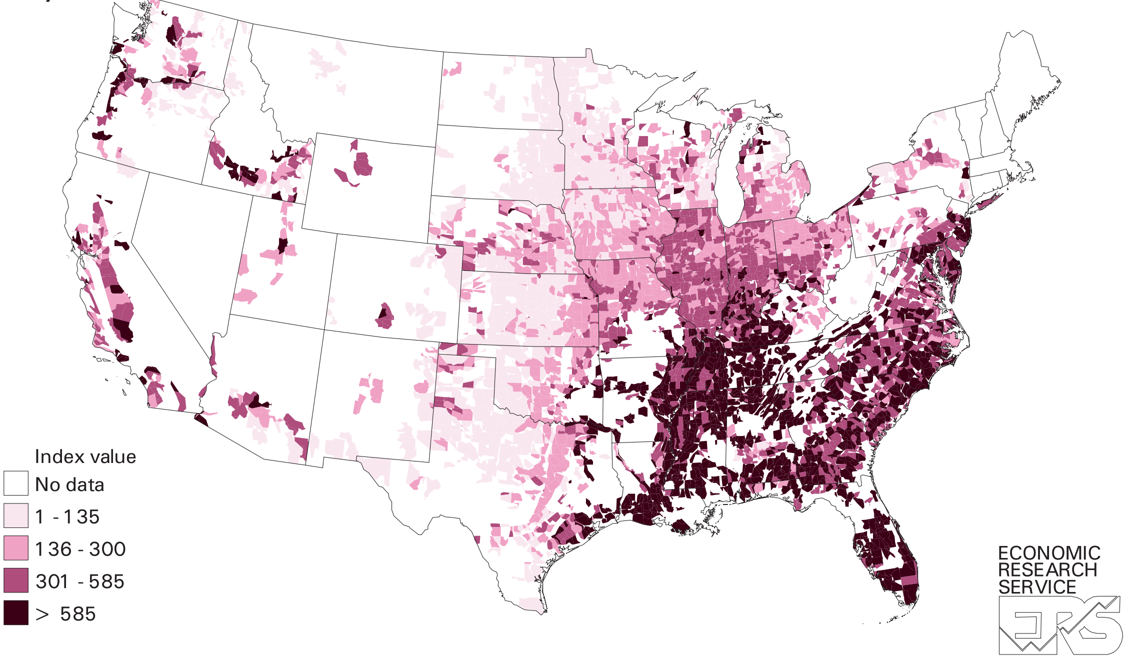
Residual nitrogen is that portion of nitrogen available from natural and manmade sources that is not taken up by crops. Residual nitrogen on cropland (nitrogen from both commercial and manure sources in excess of plant needs) is an indicator of potential nitrate availability for runoff to surface water or leaching to ground water. Regions with relatively high residual nitrogen include the Corn Belt, parts of the Southeast, and the intensively irrigated areas of the West (fig. 2.2.1). However, residual nitrogen by itself does not necessarily result in water quality problems. For example, warm, moist soil conditions in the Southeast tend to volatilize residual nitrogen to the atmosphere, and vegetative buffers capture excess nitrogen before it reaches water systems (Mueller and others, 1995). Therefore, nitrate levels in surface and ground water in the Southeast tend to be low, even though the vulnerability index and residual applications may be high. Regions with the greatest potential for nitrate contamination of groundwater include parts of the Lower Mississippi River, Southeast, and intensively irrigated areas of the West, reflecting areas of heavy

Figure 2.2.1--Residual soil nitrogen including nitrogen from manure, early 1990's



Source: USDA, ERS, estimated from 1990-93 cropping practices and other survey data.

Figure 2.2.2--Groundwater vulnerability index for nitrogen including nitrogen from manure, early 1990's



Source: USDA, ERS, estimated from NRCS National Resources Inventory and 1990-93 Cropping Practices Survey and other data.

use and/or areas with soils prone to leaching (fig. 2.2.2). A similar index is not available for surface water. However, areas with high residual nitrogen and low groundwater vulnerability are more likely to have a high surface-water vulnerability.

Agricultural activities are not the only cause of nutrient pollution. Other sources of nitrogen and phosphorus include point sources such as wastewater treatment plants, industrial plants, and septic tanks. Atmospheric deposition is another nonpoint source of nitrogen. Indeed, more than half the nitrogen emitted into the atmosphere from fossil fuel-burning plants, vehicles, and other sources is deposited on U.S. watersheds (Puckett, 1994). The relative shares of point and nonpoint sources vary by region, with commercial agricultural fertilizers the dominant source in some areas of the West, and in the central and southeastern United States (Puckett, 1994). Nitrogen discharges from point sources, based on National Pollution Discharge Elimination System permits, are concentrated in the Northeast, Lake States, and Appalachian regions, areas with major population centers and large concentrations of industry (fig. 2.2.3). Areas that may have to deal with both point and nonpoint sources include the eastern Corn Belt, the agricultural areas of California, parts of the Southeast, and the Mid-Atlantic region (including Chesapeake Bay).

USGS analysis of nutrients in surface waters over the 1980's shows different trends for nitrate and phosphorus in surface water (table 2.2.2) (Smith, Alexander, and Lanfear, 1993). Nitrate, in general, showed no statistically significant trend, which differs from the rise noted during 1974-81. This follows the pattern of agricultural nitrogen use, which rose sharply during the 1970's, peaked in 1981, and then stabilized. Phosphorus in water during the 1980's continued a decline noted in the 1970's, likely due to improved wastewater treatment, decreased phosphorus content of detergents, reduced phosphorus fertilizer use, and reduced soil erosion. Indeed, the rate of phosphorus decline in water in cropland areas was more than twice that in urban areas.

Pesticides

A wide variety of pesticides, with different levels of toxicity, solubility, and persistence, are applied to agricultural crops to control pests, fungus, and disease (see chapter 3.2, *Pesticides*). Pesticides are extremely important to production, but their use and/or misuse may lead to water quality problems. Pesticides move to water resources much as nutrients do. In addition, some pesticides can be carried into the air attached to dust or as an aerosol, and deposited into water bodies with rainfall.

Pesticide residues reaching surface-water systems may harm freshwater and marine organisms, damaging recreational and commercial fisheries. Pesticides in drinking water supplies pose risks to human health. Some commonly used pesticides have been identified as probable or possible human carcinogens. The presence of regulated pesticides above specified levels in water supplies requires additional treatment, placing added costs on water utilities and their customers. Enforceable drinking water standards have been established for 15 currently used pesticides, and more are pending (see box, "Maximum Contaminant Levels").

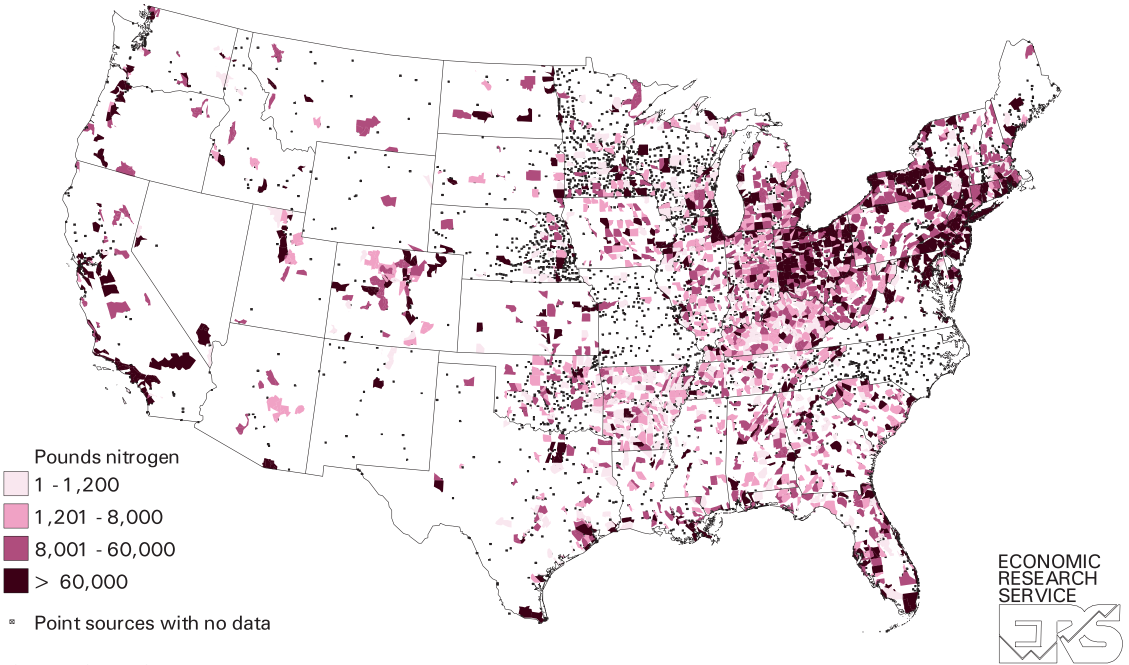
Well over 500 million pounds (active ingredient) of pesticides are applied annually on farmland (see chapter 3.2, *Pesticides*), and certain chemicals can travel far from where they are applied (Smith, Alexander, and Lanfear, 1993; Goolsby and others, 1993). Their presence in food and water has been highlighted and made an issue by environmental and consumer safety groups.

Maximum Contaminant Levels (MCL's)

Public Water Systems are required to make sure that the water they supply does not exceed the MCL for each chemical. These are enforceable standards, set by EPA, that are considered feasible and safe. MCL's have been set for 15 agricultural chemicals.

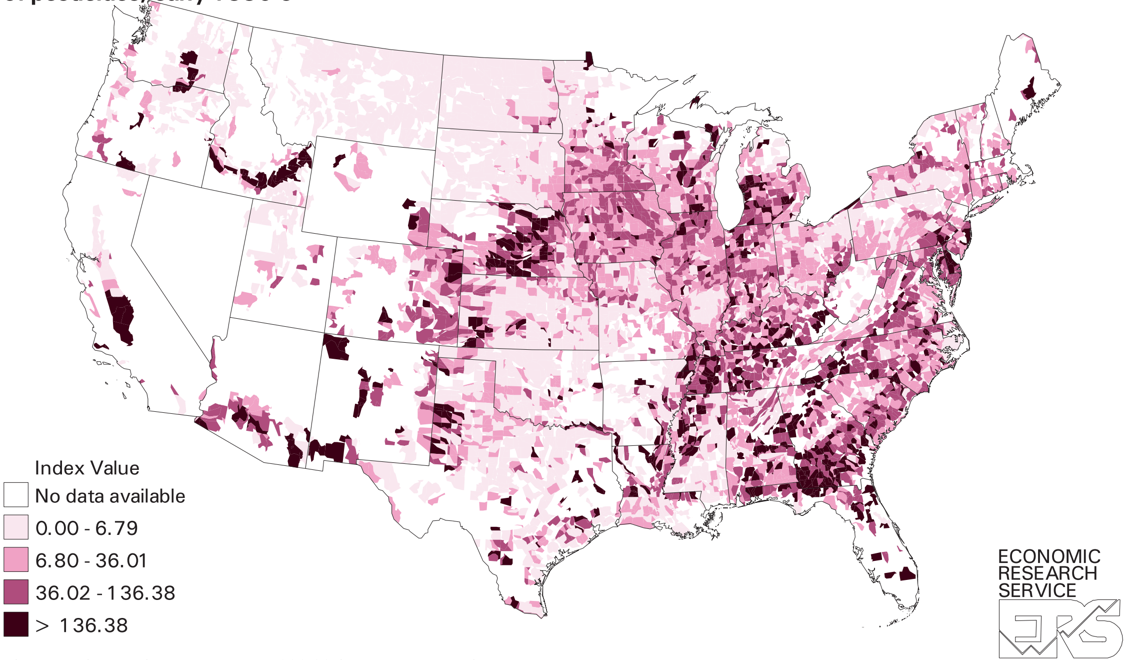
Chemical	MCL (mg/l)	Type chemical
Nitrate	10.0	fertilizer
Alachlor	.002	herbicide
Atrazine	.003	herbicide
Carbofuran	.04	insecticide
2,4-D	.07	herbicide
Dalapon	.2	herbicide
Dinoseb	.007	herbicide
Diquat	.02	herbicide
Endothall	.1	other
Glyphosate	.7	herbicide
Lindane	.0002	insecticide
Methoxychlor	.04	insecticide
Oxamyl	.2	insecticide
Picloram	.5	herbicide
Simazine	.004	herbicide

Figure 2.2.3--Nitrogen from point sources (excluding confined animal operations), 1993



Source: USDA, ERS, based on EPA permit compliance system data.

Figure 2.2.4--Groundwater vulnerability index for pesticides weighted by persistence and toxicity of pesticides, early 1990's



Source: USDA, ERS, estimated from 1990-93 Cropping Practices Survey and other data.

Areas with low pesticide use usually have low detection frequencies (Barbash and Resek, 1995). Conversely, areas where a pesticide is detected frequently are often those of high use. However, low frequencies of pesticide detection are often encountered in areas of high use, indicating that other factors influence pesticide movement.

Most studies of pesticides in surface water focus on the midcontinent region where large amounts of pesticides are used. Goolsby and others (1993) found that herbicides are detected at low levels throughout the year in the rivers of the Midwest, including the Mississippi River. The amounts transported by streams and rivers in the Midwest are generally less than 3 percent of the amount applied, but can still result in concentrations above the MCL. Atrazine (and its metabolites), alachlor, cyanazine, and metolachlor, used principally for weed control in corn and soybeans, were the principal contaminants detected, and are also the most widely used pesticides in the region. Such chemicals, once in drinking water supplies, are not controlled by conventional treatment technologies (Miltner and others, 1989). About 21 million people in the Midwest rely on drinking water from surface sources, about 42 percent of the population.

High concentrations of atrazine in some water supplies in the Midwest have prompted concerns that public water utilities will have to install expensive water treatment systems in order to meet Safe Drinking Water Act requirements. In 1990, about 29 percent of public utilities dumped powdered activated carbon into their systems to spot-treat for organic chemicals, primarily pesticides (American Water Works Association, 1992). If all the treatment plants withdrawing from surface sources upgrade their treatment systems to remove pesticides, annual treatment costs would increase by $400 million per year (Ribaudo and Bouzaher, 1994). Because of these concerns, EPA has placed the triazine herbicides (atrazine, cyanazine, and simazine) under special review due to potential health and ecological concerns. DuPont has already announced that it will phase out its cyanazine production.

Some pesticides leach into underlying aquifers. EPA's survey of drinking water wells found that 10 percent of the CWS's and 4 percent of rural domestic wells contained at least one pesticide (1990). Pesticides or their transformation products have been detected in the ground waters of 43 States (Barbash and Resek, 1995). However, the EPA estimated that less than 1 percent of the CWS's and rural domestic wells had concentrations above MCL's or Lifetime Health Advisory Levels (the maximum concentration of a water contaminant that may be consumed safely over an average lifetime). Problems were found more frequently in shallow wells in agricultural areas. A sampling of wells in corn- and soybean-growing areas in the Midwest found 28 percent of wells had detectable levels of selected pesticides and metabolites, but none exceeded the MCL (Kolpin, Burkart, and Thurman, 1993). Atrazine was the most frequently detected compound.

Groundwater vulnerability to pesticides varies geographically, depending on soil characteristics, pesticide application rates, and the persistence and toxicity of the pesticides used (fig. 2.2.4) (see chapter 3.2, *Pesticides*, for more discussion of persistence and toxicity). Areas with sandy, highly leachable soils, such as central Nebraska and the blueberry barrens of Maine, have high vulnerability ratings. Highly vulnerable areas characterized by heavy applications of generally toxic materials on fruit and vegetable crops include the San Joaquin Valley in California, Florida, and southern Arizona. In contrast, the Corn Belt, despite the widespread use of chemicals, particularly herbicides, has a lower rating than other areas because the predominant soils are not prone to leaching.

Animal Waste

Animal operations can generate large amounts of waste which, if improperly handled or disposed of, can affect the quality of surface- and groundwater resources. Improperly constructed storage pits or lagoons at confined facilities can break or leak, releasing large amounts of concentrated waste directly into surface water. Dissolved material can leach into groundwater if lagoons or pits are improperly lined. Pastured animals allowed to graze near or to water in streams can contaminate water. Improper application of animal waste on fields, such as spreading on frozen ground, can result in large amounts being flushed into water bodies after rain or a thaw.

An issue of increasing importance to water quality is the management of manure from confined animal operations. This stems from increasing concentration in the animal industry, a number of incidents where manure has contaminated local water bodies (see box "Animal Waste Storage Failures"), and a greater awareness of the potential for contamination of drinking water supplies by waste-borne parasites. Larger operations, particularly for hogs and dairy cows, now characterize the industry. As animal production units grow increasingly large and

Animal Waste Storage Failures

The growing concerns over concentrated animal operations were highlighted when a dike around a large hog-waste lagoon in North Carolina failed, releasing an estimated 25 million gallons of hog waste (twice the volume of the oil spilled by the Exxon Valdez) into nearby fields, streams, and the New River. The 8-acre earthen lagoon was built to allow microbes to digest the waste, and is a common form of management for confined operations. The spill killed virtually all aquatic life in the 17-mile stretch between Richlands and Jacksonville, NC.

There are approximately 6,000 confined animal operations with at least 1,000 animal units in the United States. (One animal unit equals 1 beef animal, 0.7 dairy cow, 2.5 hogs, 18 turkeys, or 100 chickens.) Under the Clean Water Act, these facilities cannot discharge to waters except in the event of a 25-year/24-hour storm. This requirement necessitates the construction of onsite storage facilities for holding manure and runoff. In addition to these large operations, facilities with more than 300 animal units that discharge directly to waters are required to take the same measures. Regions with large numbers of animal operations containing more than 1,000 animal units include the Northern Plains (for beef), Pacific (dairy), Corn Belt (swine), Appalachian (swine), and Southeast (broilers).

Most States are responsible for carrying out Clean Water Act regulations. A survey of livestock waste control programs in 10 Midwest and Western States indicated that few States actively inspect facilities for problems, including the integrity of storage structures (Iowa Dept. Nat. Res., 1990). National estimates of broken or leaking storage facilities do not exist. However, a North Carolina State University study estimated that wastes were leaking from half of North Carolina’s lagoons built before 1993 (Satchell, 1996), so the problem may be widespread.

specialized, they tend to lack sufficient cropland on which manure can be spread. Without adequate cropland, larger and more sophisticated manure handling and storage systems are required. Improper management, equipment failure, or unusual rainstorms can cause serious water quality problems.

Animal waste contains a number of pollutants. Waste can contain significant amounts of nitrogen and phosphorus. These nutrients pose the same concerns about eutrophication and methemoglobinemia as inorganic sources. In addition, fish and other aquatic organisms may die from ammonia produced as manure decays, or they may suffocate due to insufficient oxygen levels caused by the oxygen-demanding decomposition of organic matter in the manure.

Nitrogen from animal waste is an important source of total nitrogen loads in some parts of the country. Many areas have high ratios of nitrogen from manure on confined animal operations to the operations’ land available for spreading (see chapter 4.5, *Nutrient Management*). The highest ratios of nitrogen to land are found in parts of the Southeast, Delta, and Southwest. Studies in 16 watersheds found that manure was the largest nitrogen source in 6, primarily in the Southeast and Mid-Atlantic States (Puckett, 1994).

Animal waste also contains pathogens that pose a threat to human health. Up to 150 diseases from the microorganisms in livestock waste can be contracted through direct contact with contaminated water, consumption of contaminated drinking water, or consumption of contaminated shellfish. Some illnesses that can be contracted from animal waste include cholera, tuberculosis, typhoid fever, salmonella, and polio. Parasites of concern include cryptosporidium and giardia.

Outbreaks of cryptosporidia, a parasite found in the feces of some animals and that causes gastrointestinal illness, are causing growing concern over the safety of water supplies in areas with large numbers of cattle. This organism has been implicated in gastroenteritis outbreaks in Milwaukee, Wisconsin (400,000 cases and 100 deaths in 1993) and in Carrollton, Georgia (13,000 cases in 1987). The cost of the Milwaukee outbreak is estimated to exceed $54 million (*Health and Environment Digest*, 1994). While the source of the organism in these outbreaks was never determined, its incidence in many dairy herds has brought some attention to this sector, especially given the proximity of dairies to population centers.

Salinity

Irrigation return flows can carry dissolved salts, as well as nutrients and pesticides, into surface- or groundwater. Dissolved salts and other minerals can have significant impacts on surface- and groundwater quality. Increased concentrations of naturally occurring toxic minerals, such as selenium and boron, can harm aquatic wildlife and degrade recreation opportunities. Increased levels of dissolved solids in public drinking water supplies can increase water treatment costs, force the development of alternative water supplies, and reduce the lifespans of water-using household appliances. Increased salinity levels in irrigation water can reduce crop yields or damage soils so that some crops can no longer be grown.

Dissolved salts and other minerals are an important cause of pollution in the Southern Plains, arid Southwest, and southern California. Total damages from salinity in the Colorado River range from $310 million to $831 million annually, based on the 1976-85 average levels of river salinity. These include damages to agriculture ($113-$122 million), households ($156-$638 million), utilities ($32 million), and industry ($6-$15 million) (Lohman, Milliken, and Dorn, 1988).

The USGS reports mixed trends of salinity in surface water (Smith, Alexander, and Lanfear, 1993). Measures of dissolved solids (mostly ions of calcium, magnesium, sodium, potassium, bicarbonate, sulfate, and chloride) indicate that water quality improved at more stations than it worsened. However, while salinity trends in water for domestic and industrial purposes generally improved during the 1980's, salinity worsened for irrigation purposes. Among USGS cataloguing units (watersheds) having significant irrigation surface-water withdrawals, the percentage of stations having annual average dissolved solids concentrations greater than 500 mg/L increased during 1980-89 from 30 to 33 percent.

Reducing Loadings from Agriculture

Farmers can take many steps to reduce loadings of agricultural pollutants to water resources. Both structural and management practices are available to farmers. In a study of 16 of USDA's 242 Water Quality Program projects, 134 different practices were installed, nearly half of which were labeled "new and innovative" (USDA, NRCS, 1996). Water quality practices work by managing water and chemical inputs more efficiently, or by controlling runoff. Practices include pest management, nutrient management, irrigation water management, animal waste management, tillage management, and runoff control (for more on practices, see chapters 4.1-4.6).

USDA has had several programs that provide farmers the means to adopt water quality practices, including the Agricultural Conservation Program, Water Quality Incentive Projects, and the Water Quality Program. Most current programs focus on providing education, technical, and financial assistance to farmers to get them to adopt alternative management systems that protect water quality. Education raises farmer awareness not only of the potential financial and environmental benefits of alternative practices, but also of the link between the practices they implement and local water quality. Technical and financial assistance provide the means for a farmer to actually try a new practice and to acquire the skill to apply it effectively. Failure of voluntary programs to achieve needed changes in farming practices may increasingly result in regulations, already occurring in a number of States (see chapter 6.2, *Water Quality Programs*, for more on Federal and State programs).

Groundwater Vulnerability Indexes

The groundwater vulnerability index for nitrates (GWVIN) was developed by Kellogg and others (1992). It is a function of soil leaching potential, nitrate leaching potential, precipitation, and nitrogen fertilizer use. Excess nitrogen per acre is the difference between the amount of nitrogen from commercial fertilizer and animal manure applied, including credit for nitrogen fixed by previous leguminous crops, and the amount taken up by the crop.

The groundwater vulnerability index for pesticides (GWVIP), also developed by Kellogg and others (1992), is a function of soil leaching potential, pesticide leaching potential, precipitation, and chemical use. It is an extension of the national-level Soil-Pesticide Interaction Screening Procedure (SPISP) developed by the Natural Resources Conservation Service (Goss and Wauchope, 1990). GWVIP does not depend on the amount of chemical applied, but the type of chemical, its leaching potential, and the leaching potential of the soil to which the chemical is applied. The GWVIP can be weighted by persistence and toxicity to further account for potential harm to the environment. Persistence is defined as the soil half-life. Toxicity is defined as the acute oral toxicity to rats. Chronic toxicity or toxicity to fish would have been preferred, but these data are not available for most pesticides. For further discussion of weighting for persistence and toxicity, see chapter 3.2, *Pesticides*.

Improvements in water quality from farmers' efforts to reduce pollutant loadings often take years to detect and document. The links between improved management and observed changes in water quality are complex. As many as 10 consecutive years of water quality data are needed before long-term changes can be distinguished from short-term fluctuations (Smith, Alexander, and Lanfear, 1993). Phosphorus accumulated in bottom sediments will affect water quality long after conservation practices have dramatically reduced phosphorus loadings in runoff. Similarly, fish, insects, and other biological indicators of a healthy stream may not reach acceptable levels until many years after water quality improves and riparian habitat is restored. Aquifers may take decades to show improvements in quality after chemical management is improved. In most project areas, agriculture is not the only source of pollution.

In addition, many projects do not establish or maintain adequate water quality monitoring for detecting changes in water quality. National water quality monitoring systems already in place are inadequate for detecting changes in small watersheds where water quality programs have generally been targeted. For these reasons, improvements in water quality may in fact be taking place undetected.

Costs and Benefits of Pollution Control

The assessment of policies to reduce pollution from agricultural production requires a complete knowledge of benefits and costs to water users of changes in water quality. Benefits and costs are measured in terms of changes in economic welfare, represented by consumer and producer surpluses. Estimating the economic effects of changes in water quality is complicated by the lack of organized markets for environmental quality. There are no observed prices with which to measure economic value. A number of methods exist for deriving these measures. One method for estimating consumer surplus is to study an individual's behavior in averting the consequences of poor environmental quality, such as expenditures made to prevent household damages from salinity. A second approach is to exploit the relationship between private goods and environmental quality (when it exists) to draw inferences about the demand for environmental quality. A third approach is to ask individuals to reveal directly their willingness to pay for changes in environmental quality.

When water quality is a factor in the production of a market good, the benefits of changes in quality can be inferred from changes in variables associated with the production of the market good. There are two avenues through which benefits can be obtained. The first is through changes in the price of the marketable good to consumers. The second is through changes in incomes received by owners of factor inputs. The choice of approaches for estimating consumer and produce welfare effects depends largely on the availability of data and the nature of demand for water quality.

Economists have conducted numerous studies of the value of water quality over the years. Most of these studies have focused on specific sites or "local" water quality issues (Crutchfield, Feather, and Hellerstein, 1995). Relatively few studies have looked at the costs of water pollution and the benefits of pollution reduction on a nationwide scale, and none have included costs to all classes of water users (table 2.2.3). However, the results of these studies indicate that the annual benefits from improving water quality could total tens of billions of dollars. Water quality benefits from erosion control on cropland alone could total over $4 billion per year (Hrubovcak, LeBlanc, and Eakin, 1995).

Although increasing, public funds spent on nonpoint source pollution are small compared with the expenditures on point sources. Between $80 and $100 billion of public funding was spent on water pollution control during the 1980's (Ervin, 1995), mainly to control pollutants from municipal sources. In contrast, only $1 to $2 billion has been spent on agricultural water quality initiatives over the last two decades (Ervin, 1995). This spending is much less than the potential benefits from improved water quality. However, an increasing amount of financial and other resources is being directed to agricultural nonpoint source pollution. USDA spent $194 million on water quality-related research, education, technical assistance, financial assistance, and data activities in 1995. Such expenditures have doubled since 1989, despite an overall decrease in USDA expenditures for conservation. Farmers themselves have spent an unknown amount on water quality practices, although in many cases changes were made to enhance profitability. In addition, EPA made over $65 million in regional grant awards to States for agricultural nonpoint source programs in 1994-95, an increase of 50 percent over the previous 2-year period. These funds are frequently contracted to cooperating agencies such as local conservation districts to support project implementation. (For more information on water quality programs, see chapter 6.2.)

Table 2.2.3—National estimates of the damages from water pollution or the benefits from water pollution control

Study/year	Estimate of:	Description
Freeman (1982)	National benefits of water pollution control	Total damages to recreational water uses from all forms of pollution: $1.8-$8.7 billion, "best guess" of $4.6 billion (1978 dollars per year).
Russell and Vaughan (1982)	National recreational fishing benefits from controlling water pollution	Total benefits of $300-$966 million, depending on level of pollution control instituted.
Clark et al. (1985)	National water quality damages from soil erosion on cropland	Damages to all uses: $3.2-$13 billion, "best guess" of $6.1 billion (1980 dollars). Cropland’s share of erosion-related damages: $2.2 billion.
Ribaudo (1986)	Regional and national water quality benefits of reducing soil erosion	Erosion reductions from 1983 soil conservation programs implied $340 million in offsite benefits. Benefits per ton of erosion reduced were from $0.28 to $1.50.
Nielsen and Lee (1987)	National costs of groundwater contamination	Monitoring costs for presence of agricultural chemicals put at $890 million-$2.2 billion for private wells, and $14 million for public wells.
Ribaudo (1989)	Regional and national water quality benefits from the Conservation Reserve Program	Reducing erosion via retirement of 40-45 million acres of highly erodible cropland would generate $3.5-$4.5 billion in surface-water quality benefits over the life of the program.
Carson and Mitchell (1993)	National benefits of surface-water pollution control	Annual household willingness to pay for maximum water quality improvement of $205-$279 per household per year, or about $29 billion nationally.
Feather and Hellerstein (1997)	National recreation benefits of soil erosion reductions	A total of $286 million in benefits from erosion reductions on agricultural lands since 1982, based on data from a recreation survey.

Source: USDA, ERS, based on Crutchfield, Feather, and Hellerstein, 1995; and Feather and Hellerstein, 1996.

While regulations were used to reduce point sources, efforts to reduce nonpoint sources have primarily relied on voluntary measures. Analysis has shown that many of the management practices that reduce agricultural nonpoint source pollution are not costly to implement, and may even increase net returns (U.S. Congress, OTA, 1995). A highly targeted approach that emphasizes low-cost land management changes—and that is backed by sound science, technical and financial support, and regulations—would provide the best means of achieving most water quality goals.

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Recent ERS Reports on Water Quality Issues

Accounting for the Environment in Agriculture, TB-1847, October 1995 (James Hrubovcak, Michael LeBlanc, and B. Kelly Eakin). Detailed information derived from the national income and product accounts provides the basis for economic interpretations of changes in the Nation's income and wealth. The effects of soil erosion on agricultural productivity and income, the economic effect of decreased water quality, and depletion of water stock are presented as examples of the potential scope of accounting adjustments needed in the agricultural sector.

USDA's Water Quality Program Enters its 6th Year, AREI Update, 1995, No. 11 (Marc Ribaudo). Sixty-five water quality projects were started in 1995, and 6 projects were completed at the end of 1994. Over 400 water quality projects have been started since 1990.

Voluntary Incentives for Reducing Agricultural Nonpoint Source Water Pollution, AIB-716, May 1995 (Peter Feather and Joe Cooper). Data from the Area Studies are used to evaluate the success of existing incentive programs to control agricultural nonpoint source pollution. Because profitability drives production decisions, these programs tend to be most successful when they promote inexpensive changes in existing practices.

The Benefits of Protecting Rural Water Quality: An Empirical Analysis, AER-701, January 1995 (Stephen R. Crutchfield, Peter M. Feather, and Daniel R. Hellerstein). The use of nonmarket valuation methods to estimate the benefits of protecting or improving rural water quality from agricultural sources of pollution is explored. Two case studies show how these valuation methods can be used to include water-quality benefits estimates in economic analyses of specific policies to prevent or reduce water pollution.

Atrazine: Environmental Characteristics and Economics of Management, AER-699, September 1994 (Marc Ribaudo and Aziz Bouzaher). Atrazine is an important herbicide in the production of corn and other crops in the United States. Recent findings indicate that elevated amounts of atrazine are running off fields and entering surface-water resources. The costs and benefits of an atrazine ban, a ban on pre-plant and pre-emergent applications, and a targeted ban to achieve a surface-water standard are examined.

Cotton Production and Water Quality: Economic and Environmental Effects of Pollution Prevention, AER-664, December 1992 (Stephen Crutchfield, Marc Ribaudo, LeRoy Hansen, and Ricardo Quiroga). The most widespread potential water-quality problems from cotton production are nitrate leaching and losses of pesticides to surface waters. Alternative policies for reducing these types of pollution are evaluated.

Estimating Water Quality Benefits: Theoretical and Methodological Issues, TB-1808, September 1992 (Marc Ribaudo and Daniel Hellerstein). Knowledge of the benefits and costs to water users is required for a complete assessment of policies to create incentives for water quality-improving changes in agricultural production. A number of benefit estimation methods are required to handle the varying nature of water quality effects.

Water Quality Benefits from the Conservation Reserve Program, AER-606, February 1989 (Marc Ribaudo). The Conservation Reserve Program was estimated to generate between $3.5 and $4 billion in water quality benefits if it achieves its original enrollment goal of 40-45 million acres. Potential benefits include lower water treatment costs, lower sediment removal costs, less flood damage, less damage to equipment that uses water, and increased recreational fishing.

(Contact to obtain reports: Marc Ribaudo, (202) 501-8387 [mribaudo@econ.ag.gov])

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3.1 Nutrients

Nutrients need to be applied to most fields to maintain high crop yield. Most nutrients applied are from commercial fertilizer. Commercial fertilizer use in the United States has declined from a peak in 1981 because of fewer planted acres and stable or falling application rates. Fertilizer prices paid by farmers were relatively stable from 1989 to 1993, but increased dramatically in 1994 and 1995.

Contents

Crops take up nutrients—primarily nitrogen (N); phosphate ($P_2 0_5$), the oxide form of phosphorus (P); and potash ($K_2 0$), the oxide form of potassium (K)—from the soil as they grow (see Glossary for more on the roles of nutrients in food and fiber production). Plants require other nutrients than nitrogen, phosphate, and potash, but in smaller amounts. Magnesium, calcium, and sulphur are also essential nutrients for plant growth and development. Sulphur, for example, is important to plants for protein formation. Nutrients that plants need in only small or trace amounts (called micronutrients) include boron, chlorine, copper, iron, manganese, molybdenum, cobalt, sodium, and zinc. Commercial fertilizers are applied by farmers to ensure sufficient nutrients for high yields.

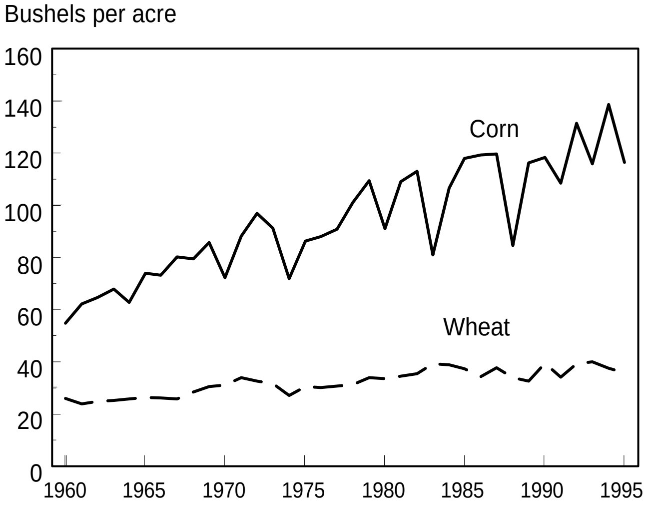
Lime is also applied to some soils as a soil conditioner, rather than as a nutrient. Lime reduces soil acidity (pH) so that crops can better utilize available nutrients and micronutrients.

From the settlement of the United States until the 19th century, increased food production came almost entirely from expanding the cropland base and mining the nutrients in the soil. However, the expanding demand for agricultural commodities required soil nutrient replacement to maintain or expand crop yields. First, manure and other farm refuse were applied to the soils. Later, applications of manure were supplemented with fish, seaweed, peatmoss, leaves, straw, leached ashes, bonemeal, and Peruvian guano, materials that contained a higher percentage of nitrogen, phosphate, and potash than did manure (Wines, 1985). As manufacturing developed, production of chemical fertilizers like superphosphates and, later, urea and anhydrous ammonia (see Glossary) replaced most fertilizers produced from recycled wastes. Commercial fertilizers provided low-cost nutrients to help realize the yield potential of new crop varieties and hybrids (Ibach and Williams, 1971). Since 1960, yields per unit of land area for major crops have increased dramatically. For example, average corn yield has increased from 55 bushels per acre in 1960 to 139 bushels in 1994 and average wheat yield from 26 to 38 bushels per acre (fig. 3.1.1). If nutrients were not applied, today's crops would rapidly deplete the soil's store of nutrients and yields would plummet.

Nutrient Sources

Commercial fertilizer is by far the major source of applied plant nutrients in the United States, followed by animal manure. Treated or composted municipal and industrial wastes are applied as sources of plant nutrients in some areas, but little data are available and overall use is likely limited, although increasing. Specific aspects of these three sources of nutrients are described in the following sections.

Figure 3.1.1--Average corn and wheat yields per harvested acre, 1960-95



Source: USDA, ERS, based on Agricultural Statistics, 1994 and earlier issues; and ERS, Agricultural Outlook, 1995.

Commercial Fertilizer

The U.S. commercial fertilizer industry is essentially composed of three separate industries (nitrogen, phosphate, and potash). Each has different material and process requirements but both are horizontally and vertically integrated (Andrilenas and Vroomen, 1990).

Anhydrous ammonia is the source of nearly all nitrogen fertilizer. It may be applied directly to the soil or converted into other nitrogen fertilizer such as ammonium nitrate, urea, nitrogen solutions, synthetic ammonium sulfate, and ammonium phosphate. Anhydrous ammonia is synthesized through a chemical process that combines atmospheric nitrogen with hydrogen. Nitrogen can be obtained from the air, but the hydrogen is derived from natural gas.

U.S. capacity to produce anhydrous ammonia and other nitrogen fertilizers increased since 1950 in response to rising demand. Capacity increased from 7.8 million tons in 1964 to 20 million tons in 1981, but has declined to about 17 million tons due to plant closures and lack of new plant construction (International Fertilizer Development Center, 1995). Plants built before 1960 were scattered around the country in areas of high market demand. However, plants built since then are located near natural gas regions of the Delta (Mississippi, Arkansas, and Louisiana) and the Southern Plains (Texas and Oklahoma).

The United States is a net importer of nitrogen. In 1995, the United States exported more than 3 million nutrient tons of nitrogen and imported over 5 million nutrient tons; however, imports are understated because anhydrous ammonia imports from the former Soviet Union are not reported by the Department of Commerce due to a disclosure claim. The major fertilizer import is anhydrous ammonia while the major export is diammonium phosphate, which contains nitrogen.

Nearly all phosphate fertilizer is produced by treating phosphate rock with sulfuric acid to produce phosphoric acid, which is further processed into various phosphatic fertilizer materials such as superphosphates and diammonium phosphates. The United States has become the world's largest phosphate fertilizer exporter. Approximately 3.3 tons of phosphate rock and about 2.8 tons of sulfuric acid are required to produce a ton of phosphate fertilizer. U.S. annual phosphoric acid capacity is over 14 million tons. Phosphate rock is obtained from mines mainly in Florida and North Carolina, with annual capacity estimated at 65 million tons.

Potash can be used as a fertilizer with less processing or refining than nitrogen or phosphate. Most potash deposits in the United States are located near Carlsbad, New Mexico. However, these deposits supply less than 10 percent of U.S. demand. Vast potash deposits in Saskatchewan and New Brunswick, Canada are cheaper to mine than the dwindling U.S. reserves because of the large size, uniformity, and high quality of the Canadian deposits, and the modern mining techniques used. The United States currently imports over 5 million tons of potash and over 95 percent of these imports come from Canada. U.S. and Canadian annual potash capacity is about 1.6 and 13.9 million tons, respectively.

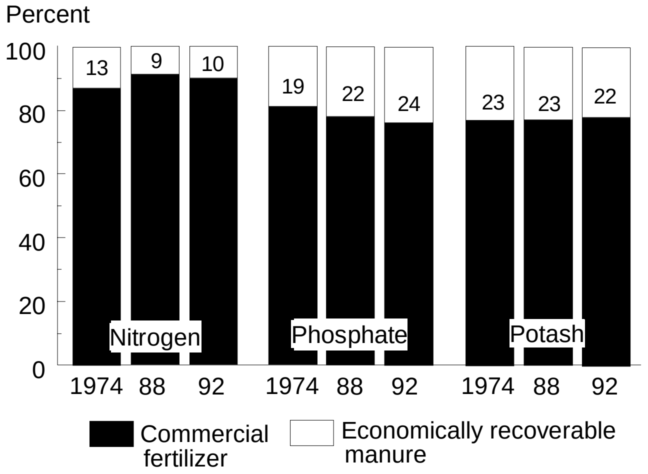
Calcium, magnesium, and sulfur are often added to soils to correct plant conditions such as empty peanut shells due to the failure of fruit to develop, failure of new emerging corn leaves to unfold, yellowing between veins of older leaves, and pale yellow or light green leaves. Applying lime to bring soil pH into proper range for optimum plant growth usually supplies sufficient calcium. Primary sources of calcium are the liming materials and gypsum, which are considered soil amendments rather than fertilizers. The most common source of magnesium is dolomite limestone, which contains up to 12 percent magnesium (Fertilizer Institute, 1982). The main forms of sulfur in soil are inorganic sulfates and sulfur in organic matter. Atmospheric sulfur dioxide had been a major source of sulfur for crops, but as atmospheric emissions of sulfur dioxide are reduced by environmental controls the sulfur needs of crops must be supplied by fertilizer sources. Sulfuric acid, a byproduct in phosphate fertilizer manufacturing, provides an adequate amount of sulfur for many crop needs.

Availability of micronutrients to plants is related to soil pH. Availability of boron, copper, iron, manganese, and zinc generally decrease as soil pH increases from 5 to 7; availability of molybdenum increases. Micronutrients are involved in cell division, photosynthesis, fruit formation, carbohydrate and water metabolism, chlorophyll formation, protein synthesis, and seed development in plants. Micronutrient needs during different stages of plant growth must be better understood by both research scientist and farmer so that appropriate amounts are made available.

Animal Manure

Animal waste is primarily manure, but on some large poultry operations, dead chickens are also a disposal problem and a source of nutrients if properly composted. In recent years, animal wastes have provided 9-24 percent of total nutrients available for crop production (fig. 3.1.2). Actual application of animal wastes as nutrients is less than this (table 3.1.3). Because of transportation costs, use of animal waste as fertilizer is economically feasible only if onfarm or nearby sources exist, and thus occurs on relatively few acres.

Figure 3.1.2--Availability of nutrients for application, 1974, 1988, and 1992



Source: USDA, ERS, based on U.S. EPA, 1979; USDA, unpublished data, 1977; and USDA, 1992.

In 1992, there were 435 million acres of cropland, of which 124 million or 28 percent were operated by farmers having confined animal units. These 511,000 farms had 60.7 million animal units of beef, dairy, swine, turkey, and poultry (Letson and Gollehon, 1996), producing an estimated 1.23, 1.32, and 1.44 million tons of economically recoverable nitrogen (N), phosphate (P_20_5), and potash (K_20). Letson and Gollehon (1996) also determined that large specialized animal production farms produce most animals but have little cropland. Facilities with fewer animals produce a minor share of the animals but have a large share of the cropland associated with confined livestock farms. Concentration of increasing numbers of animals on fewer farms has been a long-term trend (see fig.1.2.7 in chapter 1.2, *Land Tenure*). The significance of the shares of animals and acres is emphasized by the fact that around 90 percent of manure does not leave the farm where it is produced (Bosch and Napit, 1992). High-density areas like dairy farms in southern California, beef feedlots in the Southern Plains, large hog operations in the Corn Belt, and the broiler belt across the Delta, Southeast, and Appalachian States provide large quantities of manure that is likely underused as fertilizer. However, some areas have both high manure nutrient densities and high fertilizer spending per acre, suggesting redundant nutrient applications that may be an avoidable farming expense and that could impair water resources (Letson and Gollehon, 1996).

Environmental degradation, particularly of water, can occur from excessive use or improper handling or application of nutrients (Achorn and Broder, 1991; Bosch, Fuglie, and Keim, 1994; Kanwar, Baker, and Baker, 1988; and Kellogg, Maizel, and Goss, 1992: see also chapter 2.2, *Water Quality*). Large livestock operations are already under regulation as point sources of pollution, requiring installation of certain facilities and practices. In many critical areas, USDA is helping smaller livestock operations efficiently manage animal and commercial nutrients to reduce their loss to the environment (for more information, see chapter 4.5, *Nutrient Management*, and chapter 6.2, *Water Quality Programs*).

Municipal and Industrial Wastes

Municipal wastes include municipal solid wastes (MSW) and sewage sludge (SS). America's cities generated 200 million tons of MSW in 1990 (Millner and others, 1993). MSW includes paper and paperboard, glass, metals, plastics, rubber, leather, textile, wood, food wastes, yard trimmings, miscellaneous inorganic wastes, and other residential, institutional, and industrial wastes. The three major methods for MSW disposal in 1990 were land filling (61 percent), recoveries for recycling (17 percent), and incineration (12 percent). SS is collected at municipal wastewater plants. The three major methods of SS disposal in 1988 were land application (36 percent), surface water disposal (10) percent, and incineration (3 percent) (the rest of SS disposal is either not regulated or unknown). Agricultural land application was about 27 percent. A small portion (about 1.2 percent) of SS was used for composting in 1988. The number of municipal wastewater plants producing SS compost increased from 90 in 1983 to 318 in 1994 (Golstein and others, 1994). The outlets for SS compost are public works applications; wholesale marketing to soil blenders, landscapers, and nurseries; and give-away to the public.

The potential for agricultural use of municipal wastes is large, but a number of issues need resolution (see box, “Potential for Agricultural Use of Municipal Wastes,” p. 111).

Commercial Fertilizer Use and Product Change, 1960-95

Commercial fertilizer use depends on a variety of factors including soil, climate, feasible technology, weather, crop mix, crop rotations, technological change, government programs, and commodity and fertilizer prices (Denbaly and Vroomen, 1993). Total fertilizer use has fluctuated with planted acreage because application rates and percentage of acres treated have been less variable than planted acreage.

U.S. nitrogen, phosphate, and potash use for all purposes rose from 7.5 million nutrient tons in 1960 to a record 23.7 million tons in 1981 (table 3.1.1). Total nutrient use has dropped from this level, along with total crop acreage, to 21.3 million nutrient tons.

Nitrogen, phosphate, and potash all contributed to the dramatic increase in fertilizer use during the 1960’s and 1970’s (table 3.1.1, fig. 3.1.3), although nitrogen use increased most rapidly. In 1960, nitrogen use was about 37 percent of total commercial nutrient use; by 1981, nitrogen use had increased 335 percent and represented over 50 percent of total commercial nutrient use. Nitrogen use equaled 11.7 million tons in 1995, or 55.2 percent of total commercial nutrient use. This relative gain in nitrogen use is the result of

Table 3.1.1—U.S. commercial fertilizer use, 1960-95[1]

Year ending June 30[2]	Total fertilizer materials3	Primary nutrient use			
		Nitrogen (N)	Phosphate (P_2O_5)	Potash (K_2O)	Total[4]
		Million tons			
1960	24.9	2.7	2.6	2.2	7.5
1961	25.6	3.0	2.6	2.2	7.8
1962	26.6	3.4	2.8	2.3	8.4
1963	28.8	3.9	3.1	2.5	9.5
1964	30.7	4.4	3.4	2.7	10.5
1965	31.8	4.6	3.5	2.8	10.9
1966	34.5	5.3	3.9	3.2	12.4
1967	37.1	6.0	4.3	3.6	14.0
1968	38.7	6.8	4.4	3.8	15.0
1969	38.9	6.9	4.7	3.9	15.5
1970	39.6	7.5	4.6	4.0	16.1
1971	41.1	8.1	4.8	4.2	17.2
1972	41.2	8.0	4.9	4.3	17.2
1973	43.3	8.3	5.1	4.6	18.0
1974	47.1	9.2	5.1	5.1	19.3
1975	42.5	8.6	4.5	4.4	17.6
1976	49.2	10.4	5.2	5.2	20.8
1977	51.6	10.6	5.6	5.8	22.1
1978	47.5	10.0	5.1	5.5	20.6
1979	51.5	10.7	5.6	6.2	22.6
1980	52.8	11.4	5.4	6.2	23.1
1981	54.0	11.9	5.4	6.3	23.7
1982	48.7	11.0	4.8	5.6	21.4
1983	41.8	9.1	4.1	4.8	18.1
1984	50.1	11.1	4.9	5.8	21.8
1985	49.1	11.5	4.7	5.6	21.7
1986	44.1	10.4	4.2	5.1	19.7
1987	43.0	10.2	4.0	4.8	19.1
1988	44.5	10.5	4.1	5.0	19.6
1989	44.9	10.6	4.1	4.8	19.6
1990	47.7	11.1	4.3	5.2	20.6
1991	47.3	11.3	4.2	5.0	20.5
1992	48.8	11.5	4.2	5.0	20.7
1993	49.2	11.4	4.4	5.1	20.9
1994	52.3	12.6	4.5	5.3	22.4
1995	50.7	11.7	4.4	5.1	21.3

[1] Includes Puerto Rico. Detailed State data shown in USDA, 1995. Fertilizer statistics used in this report include commercial fertilizers and natural processed and dried organic materials. Purchased natural processed and dried organic materials historically have represented about 1 percent of total nutrient use.

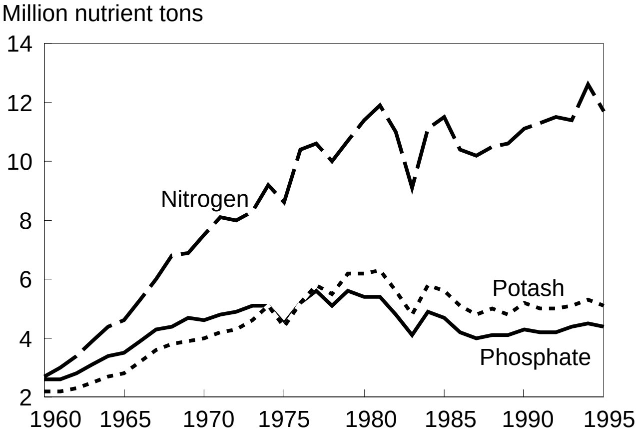
[2] Fertilizer use estimates for 1960-84 are based on USDA data; those for 1985-94 are Tennessee Valley Authority (TVA) estimates; those for 1995 are the Association of American Plant Food Control Officials estimates.

[3] Includes secondary and micronutrients. Most of the difference between primary nutrient tons and total fertilizer materials is filler material.

[4] Totals may not add due to rounding.

Source: USDA, ERS, based on Tennessee Valley Authority, *Commercial Fertilizers*, 1994 and earlier issues; USDA, *Commercial Fertilizers*, 1985 and earlier issues; Association of American Plant Food Control Officials, *Commercial Fertilizers, 1995.*

Figure 3.1.3--U.S. commercial fertilizer use, 1960-95



Source: Compiled by ERS from Tennessee Valley Authority, 1994 and earlier issues; Association of American Plant Food Control Officials, 1995.

increased farmer demand stemming primarily from favorable crop yield responses, especially corn, to nitrogenous fertilizers.

Phosphate's share of total commercial nutrient use declined from 34.5 percent in 1960 to 20.8 percent by 1995 (table 3.1.1). Potash use, historically below that of both nitrogen and phosphate, exceeded phosphate use for the first time in 1977 and will likely hold this position. In 1995, potash accounted for 24.0 percent of total fertilizer use.

Fertilizer products have changed over time. In 1960, mixed fertilizers (containing two or more nutrients) constituted almost 63 percent of total fertilizer consumption (Vroomen and Taylor, 1992). This share declined to 37 percent in 1995. The share of direct application materials (containing primarily one nutrient) increased from 37 percent to 63 percent during this period. The use of major direct-application nitrogen materials increased through the early 1980's (Fertilizer Institute, 1982). High-analysis products such as anhydrous ammonia, nitrogen solutions, and urea benefited from economies in transportation, distribution, and storage, and from the ease and accuracy of applying nitrogen solutions.

Directly applied phosphate fertilizer products have declined since the early 1970's because of the increased use of diammonium phosphate (DAP). The trend throughout the 1960's and 1970's was toward increased use of triple superphosphates (products that contained a higher percentage of phosphate) relative to normal superphosphates because of transportation, distribution, and storage economies. Since 1979, consumption of both normal and triple superphosphate has declined. The use of DAP, a mixed fertilizer containing 18 percent nitrogen and 46 percent phosphate, has dramatically increased since the 1960's (Tennessee Valley Authority, 1994).

The use of potassium chloride, the major directly applied potash fertilizer containing about 60 percent potash, has also greatly increased since the 1960's. Total use of potassium chloride reached 5.4 million tons in 1995, up from 389,000 tons in 1960.

Fertilizer Use by Region and Crop

The Corn Belt (Ohio, Indiana, Illinois, Iowa, and Missouri) uses more commercial fertilizer than any other region (table 3.1.2). Corn, the most fertilizer-using crop, historically has used around 45 percent of all fertilizer. However, from 1985 to 1993 nitrogen use in the Corn Belt decreased from 3.4 to 3.0 million tons, but then increased to 3.5 million tons in 1994 following the 1993 flood. Nitrogen use in the Corn Belt equaled 3.2 million tons in 1995. Phosphate use decreased from 1.5 million tons in 1985 to 1.3 million tons in 1995 and potash use decreased from 2.3 to 2.0 million tons. Fertilizer use is highly dependent on soil type and condition, crop mix, planting methods, and planted acres (Meisinger, 1984: Nelson and Huber, 1987: Mengel, 1986: Pierce and others, 1991: Rhoads, 1991: and Scharf and Alley, 1988). Fewer crop acres have been planted in the Corn Belt since 1981 because of government programs such as the Acreage Reduction Program (ARP) and the Conservation Reserve Program (CRP). Thus, total fertilizer use in the Corn Belt has declined even though application rates per fertilized acre and the proportion of acres treated have increased since the early 1980's. In the areas flooded in 1993, additional nutrients were applied in 1994 in excess of normal application rates to replenish flood-damaged soils. The Northern Plains region (North Dakota, South Dakota, Nebraska, and Kansas) is the second highest user of nitrogen and phosphate; nitrogen use increased from 1.8 million tons in 1985 to 2.1 million tons in 1995 (table 3.1.2).

Fertilizer use among crops differs significantly (Vroomen and Taylor, 1992; USDA, 1995). U.S. farmers use more commercial fertilizer on corn than on any other crop. Nearly all acres in corn, fall potatoes, and rice, and over three-fourths of cotton and wheat acres received some form of commercial fertilizer (table 3.1.3). The most frequently applied nutrient was nitrogen. In contrast, only 27-36 percent

Table 3.1.2—Regional commercial fertilizer use for year ending June 30, 1985-95[1]

Region	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
						1,000 tons					
Nitrogen:											
Northeast	312	278	290	278	313	306	299	328	350	376	349
Lake States	1,211	1,059	1,063	1,053	1,011	1,134	1,128	1,119	1,073	1,186	1,108
Corn Belt	3,443	3,116	2,889	2,991	3,041	3,215	3,280	3,279	3,003	3,562	3,228
Northern Plains	1,837	1,739	1,698	1,737	1,680	1,751	1,978	1,954	2,090	2,319	2,133
Appalachian	687	621	603	592	613	667	662	718	705	720	694
Southeast	720	659	665	614	643	670	627	655	682	701	640
Delta States	548	557	511	523	560	643	609	674	615	663	630
Southern Plains	1,110	965	1,022	1,204	1,217	1,117	1,223	1,192	1,235	1,377	1,208
Mountain	626	557	573	583	626	642	628	666	744	775	765
Pacific	987	860	882	924	916	921	838	849	886	953	953
U.S. total[2]	11,480	10,412	10,196	10,498	10,619	11,065	11,273	11,432	11,382	12,633	11,709
Phosphate:											
Northeast	229	196	203	193	188	197	188	208	211	232	203
Lake States	612	509	493	505	477	508	479	468	474	465	461
Corn Belt	1,478	1,380	1,255	1,303	1,254	1,334	1,262	1,269	1,312	1,317	1,257
Northern Plains	521	498	468	486	522	550	583	577	646	649	617
Appalachian	422	378	378	370	361	381	384	409	410	412	399
Southeast	331	288	300	280	297	308	281	295	314	297	313
Delta States	180	164	132	153	154	177	154	180	172	192	197
Southern Plains	364	298	305	324	342	315	334	288	340	363	341
Mountain	232	213	218	228	253	279	255	270	296	298	300
Pacific	288	250	250	281	270	289	274	248	257	291	326
U.S. total[2]	4,652	4,173	4,003	4,123	4,119	4,339	4,195	4,212	4,431	4,517	4,412
Potash:											
Northeast	288	263	253	249	232	261	262	267	262	299	280
Lake States	1,048	871	912	852	852	941	832	809	779	781	760
Corn Belt	2,264	2,165	2,020	2,126	1,974	2,132	2,044	1,987	2,034	2,133	1,996
Northern Plains	126	115	100	121	129	133	134	123	134	123	124
Appalachian	585	532	508	506	506	538	539	584	575	576	574
Southeast	607	542	524	531	558	559	517	556	581	535	563
Delta States	243	225	184	217	212	240	229	280	288	302	336
Southern Plains	169	142	133	140	149	143	150	146	168	191	168
Mountain	54	49	44	46	53	65	80	55	80	68	79
Pacific	157	137	146	171	155	179	200	220	230	252	231
U.S. total[2]	5,541	5,040	4,824	4,960	4,820	5,192	4,988	5,026	5,131	5,259	5,112

[1] Totals may not add due to rounding. Northeast = ME, NH, VT, MA, RI, CT, NY, NJ, PA, DE, and MD; Lake States = MI, WI, and MN; Corn Belt = OH, IN, IL, IA, and MO; Northern Plains = ND, SD, NE, and KS; Appalachian = VA, WV, NC, KY, and TN; Southeast = SC, GA, FL, and AL; Delta States = MS, AR, and LA; Southern Plains = OK, and TX; Mountain = MT, ID, WY, CO, NM, AZ, UT, and NV; and Pacific = WA, OR, CA, AK, and HA.

[2] Excludes Puerto Rico. Detailed State data shown in USDA, 1995.

Source: USDA, ERS, based on Tennessee Valley Authority, *Commercial Fertilizers*, 1994 and earlier issues; The Association of American Plant Food Control Officials, *Commercial Fertilizers, 1995*.

of the acres in soybeans, a nitrogen-fixing crop, received commercial fertilizer applications in 1995. Nitrogen application rates have been highest for fall potatoes, averaging 221 lbs. per acre in 1995, followed by corn (table 3.1.4). Fall potatoes also have the highest rate of both phosphate and potash applications, two to three times the rates for other major field crops. Nitrogen application rates on corn dropped from 132 lbs. per acre in 1986 to 129 lbs. per acre in 1995. In contrast, the average application rates increased for fall potatoes. The percentage of various crops receiving fertilizer, and fertilizer application rates, vary among the major growing States (USDA, 1995).

Table 3.1.3—Percent of acres receiving various nutrients, selected field crops in major producing States[1]

Crop, year	Manure	Commercial				Sulfur	Lime	Micro-nutrients
		Fertilizer	Nitrogen	Phosphate	Potash			
				Percent				
Corn for grain (10 States):								
1986	NA	96	95	84	76	NA	NA	NA
1987	16	96	96	83	75	3	2	5
1988	18	97	97	87	78	10	6	11
1989	15	97	97	84	75	8	5	11
1990	17	97	97	85	77	9	6	11
1991	19	97	97	82	73	10	4	11
1992	16	97	97	82	72	11	4	12
1993	18	97	97	82	71	10	4	11
1994	16	97	97	83	72	10	5	11
1995	14	98	97	81	72	NA	NA	NA
Cotton (6 States):								
1986	NA	80	80	50	39	NA	NA	NA
1987	3	76	76	47	33	7	1	9
1988	4	80	80	54	32	15	2	18
1989	2	79	79	54	32	21	2	15
1990	4	80	79	49	31	23	2	17
1991	3	81	81	52	34	20	2	18
1992	3	80	80	48	37	22	1	18
1993	4	85	85	54	36	23	3	18
1994	3	87	86	54	37	20	4	20
1995	3	87	87	56	40	NA	NA	NA
Fall potatoes (11 States):								
1989	4	99	98	94	83	48	7	52
1990	5	99	98	98	89	48	7	50
1991	4	99	99	98	88	52	4	56
1992	3	100	100	99	88	57	6	57
1993	4	100	100	98	91	58	6	58
1994	2	100	100	98	91	58	6	59
1995	2	100	99	98	89	NA	NA	NA
Rice (2 States):								
1988	1	99	99	46	36	7	NA	17
1989	*	99	99	46	33	5	NA	13
1990	*	98	97	36	37	13	1	14
1991	2	99	99	30	32	NA	2	11
1992	3	98	98	34	37	10	NA	9
Soybeans, Northern (7 States):								
1990	7	27	14	20	25	1	4	2
1991	6	26	14	19	22	1	4	2
1992	7	27	13	19	23	1	4	2
1993	7	26	12	18	24	1	4	2
1994	8	27	13	19	25	2	4	3
1995	5	27	16	19	23	NA	NA	NA
Soybeans, Southern (7 States):								
1990	2	41	26	38	39	4	6	5
1991	3	37	21	33	35	1	6	3
1992	2	39	22	36	37	2	8	1
1993	2	38	22	34	36	1	6	2
1994 (AR only)	2	37	17	32	34	1	4	2
1995	2	36	21	31	33	NA	NA	NA
All wheat (15 States):								
1986	NA	79	79	48	19	NA	NA	NA
1987	3	80	80	50	15	7	1	1
1988	2	83		83	53	18	6	1
1989	3	81	81	53	18	7	1	2
1990	2	79	79	52	19	7	1	2
1991	4	80	80	54	20	7	1	1
1992	3	84	83	56	18	8	1	2
1993	3	87	86	60	17	9	1	2
1994	3	87	87	59	17	10	1	2
1995	2	87	87	63	18	NA	NA	NA

Table 3.1.4—Average application rates of nutrients on selected field crops in major producing States[1]

Crop, year	Commercial nitrogen	Commercial phosphate	Commercial potash	Sulfur	Lime
			Pounds/acre		*Tons/acre*
Corn for grain (10 States):					
1986	132	61	80	NA	NA
1987	132	61	85	NA	NA
1988	137	63	85	11	1.9
1989	131	59	81	9	1.4
1990	132	60	84	11	1.6
1991	128	60	81	11	1.7
1992	127	57	79	11	1.9
1993	123	56	79	15	1.7
1994	129	57	80	12	1.7
1995	129	56	81	NA	NA
Cotton (6 States):					
1986	77	44	50	NA	NA
1987	82	44	45	NA	NA
1988	78	42	39	10	1.5
1989	84	43	40	23	1.3
1990	86	44	47	10	1.0
1991	91	47	48	12	1.0
1992	88	48	57	13	1.4
1993	89	47	58	13	1.0
1994	110	43	55	13	1.1
1995	95	43	51	NA	NA
Fall potatoes (11 States):					
1989	192	157	155	61	1.0
1990	198	163	143	57	0.9
1991	195	158	143	59	0.9
1992	200	159	147	61	0.9
1993	206	167	156	68	1.0
1994	264	192	184	82	0.9
1995	221	171	170	NA	NA
Rice (2 States):					
1988	127	47	50	19	NA
1989	125	45	45	17	NA
1990	114	45	49	11	1.0
1991	127	46	47	15	NA
1992	134	44	50	18	NA
Soybeans, Northern (7 States):					
1990	22	47	87	9	1.6
1991	24	49	80	12	2.0
1992	20	46	76	10	2.0
1993	18	47	83	15	1.5
1994	24	46	83	13	1.8
1995	27	55	91	NA	NA
Soybeans, Southern (7 States):					
1990	28	47	70	20	1.1
1991	28	45	70	12	1.2
1992	27	49	74	9	1.0
1993	24	44	70	22	0.9
1994 (AR only)	34	48	66	NA	1.3
1995	37	51	68	NA	NA
All wheat (15 States):					
1986	60	36	44	NA	NA
1987	62	35	43	NA	NA
1988	64	37	52	12	2.2
1989	62	37	46	12	1.9
1990	59	36	44	9	1.8
1991	62	36	43	11	1.4
1992	63	34	39	13	1.4
1993	64	34	35	14	1.7
1994	67	35	38	11	1.7
1995	65	33	38	NA	NA

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[1] Data not available for manure or micronutrients. Major producing States generally account for 70-90 percent of each crop's acreage. For States included, see "Cropping Practices Survey" in the appendix. NA = Not available. Source: USDA, ERS, based on Cropping Practices Survey data.

Table 3.1.5—Manure and commercial fertilizer use by tillage type on corn for grain, 10 major States, 1990-95[1]

Crop, year	Acres receiving				Average application rates		
	Manure	Commercial nitrogen	Commercial phosphate	Commercial potash	Commercial nitrogen	Commercial phosphate	Commercial potash
	Percent				*Pounds/acre*		
Conventional with plow							
1990	32	94	87	83	109	57	81
1991	35	94	85	79	106	56	77
1992	37	93	84	79	106	51	73
1993	39	95	89	84	95	54	76
1994	39	92	85	80	97	49	70
1995	38	93	83	71	96	50	66
Conventional without plow							
1990	14	97	85	78	138	61	84
1991	16	97	83	75	132	63	83
1992	15	97	84	74	129	58	81
1993	18	97	84	74	127	59	85
1994	16	97	84	74	133	60	84
1995	15	98	81	81	132	59	84
Mulch till							
1990	16	96	81	72	134	64	87
1991	18	97	78	68	130	59	78
1992	12	96	80	69	133	58	81
1993	15	96	81	68	122	57	75
1994	13	98	83	70	129	58	79
1995	14	97	83	70	134	57	75
No till							
1990	7	98	82	65	132	62	90
1991	10	98	81	67	129	59	84
1992	10	98	78	68	127	57	77
1993	10	98	83	73	122	50	71
1994	9	98	79	67	132	56	80
1995	8	98	79	65	134	56	76
Ridge till							
1990	20	100	96	49	145	32	52
1991	7	100	70	36	155	47	52
1992	6	99	96	33	143	41	50
1993	10	97	78	27	149	29	36
1994	2	99	78	38	142	37	57
1995	0	100	72	36	161	29	49

[1] States include IL, IN, IA, MI, MN, MO, NE, OH, SD, and WI.
Source: USDA, ERS, based on Cropping Practices Survey data.

The percentage of and quantity of crop acres receiving lime, sulfur, and micronutrients vary by crop (tables 3.1.3 and 3.1.4). For example, only about 1 percent of wheat acres received lime in 1994, while about 4 percent of northern soybeans and 6 percent of fall potatoes used lime. Lime application rates average between 1 and 2 tons per acre for all crops. Almost 60 percent of potato acres received an average of 82 pounds of sulfur in 1994. Other crops received between 11 and 18 pounds per acre with acres receiving sulfur ranging from 1 to 20 percent. Over 50 percent of potato acres received micronutrients.

Fertilizer use also varies by tillage system (tables 3.1.5-3.1.7). The Cropping Practices Survey data indicate lower nitrogen application rates on land using conventional tillage with plow for corn. These low applications appear to be supplemented with manure. For example, the average nitrogen application rate on

Table 3.1.6—Manure and commercial fertilizer use by tillage type on soybeans, 7 Northern States, 1990-95[1]

Crop, year	Acres receiving				Average application rates		
	Manure	Commercial nitrogen	Commercial phosphate	Commercial potash	Commercial nitrogen	Commercial phosphate	Commercial potash
	Percent				*Pounds/acre*		
Conventional with plow							
1990	8	13	18	25	15	39	87
1991	10	14	18	20	31	53	86
1992	10	14	20	22	13	37	67
1993	9	12	17	22	13	43	82
1994	9	13	18	22	19	38	78
1995	3	16	14	14	11	53	80
Conventional without plow							
1990	7	16	23	28	24	50	83
1991	5	16	21	25	22	48	80
1992	5	13	22	26	18	46	75
1993	7	15	23	29	18	45	81
1994	9	13	20	25	26	44	78
1995	6	16	21	26	31	60	86
Mulch till							
1990	5	11	14	17	19	47	81
1991	6	13	15	17	23	46	76
1992	9	11	14	17	26	49	78
1993	7	9	12	16	15	44	84
1994	9	9	15	18	28	52	89
1995	7	13	14	16	27	57	92
No till							
1990	4	18	27	42	38	53	109
1991	4	11	18	24	28	56	89
1992	9	15	21	30	20	50	85
1993	5	13	22	31	20	52	87
1994	7	15	24	32	20	48	88
1995	3	18	23	29	26	51	97
Ridge till							
1990	20	12	21	30	19	48	109
1991	3	30	36	27	11	39	42
1992	8	26	21	18	26	16	5
1993	0	29	17	21	17	34	54
1994	0	36	31	27	10	20	43
1995	12	21	21	21	16	44	34

[1] Northern States include IL, IN, IA, MN, MO, NE, and OH.

Source: USDA, ERS, based on Cropping Practices Survey data.

corn acreage using conventional tillage with plow was 96 pounds per acre in 1995 compared with, say, 161 pounds for ridge-till land (table 3.1.5). However, 38 percent of conventional-till land using the moldboard plow received manure applications, compared with none for ridge-till.

Factors Affecting Fertilizer Use

Crop Acreage

As indicated, with application rates fairly constant, the total amount of fertilizer used has varied with crop acreage. Acreage of principal crops has varied over the years, ranging from 300 million acres in 1970 to 372 million acres in 1981. Since then, acreage has

Table 3.1.7—Manure and commercial fertilizer use by tillage type on winter wheat, major States, 1991-95[1]

Crop, year	Acres receiving				Average application rates		
	Manure	Commercial nitrogen	Commercial phosphate	Commercial potash	Commercial nitrogen	Commercial phosphate	Commercial potash
	Percent				*Pounds/acre*		
Conventional with plow							
1991	1	97	55	15	65	33	38
1992	2	94	53	13	74	34	37
1993	2	92	48	17	69	41	38
1994	1	95	63	10	63	34	61
1995	4	93	70	10	63	33	52
Conventional without plow							
1991	4	85	49	23	67	40	54
1992	3	87	49	22	67	38	49
1993	2	86	49	17	64	36	46
1994	2	87	49	13	66	37	49
1995	2	87	53	15	69	36	45
Mulch till							
1991	3	73	42	18	55	41	52
1992	1	71	36	16	51	33	39
1993	2	82	32	10	52	36	32
1994	4	67	25	9	55	31	43
1995	4	75	35	7	54	33	54
No till							
1991	6	84	70	48	71	48	75
1992	4	96	83	54	75	49	65
1993	3	95	82	59	80	49	67
1994	2	98	83	58	83	50	65
1995	2	93	76	52	79	56	69
Ridge till							
1991	nr	nr	nr	nr	nr	nr	nr
1992	nr	nr	nr	nr	nr	nr	nr
1993	nr	nr	nr	nr	nr	nr	nr
1994	nr	nr	nr	nr	nr	nr	nr
1995	nr	nr	nr	nr	nr	nr	nr

nr = none reported.

[1] States include AR, CO, ID, IL, IN, KS, MO, MT, NE, OH, OK, OR, SD, TX, and WA in 1991 and 1992. AR and IN not surveyed in 1993-95.

Source: USDA, ERS, based on Cropping Practices Survey data.

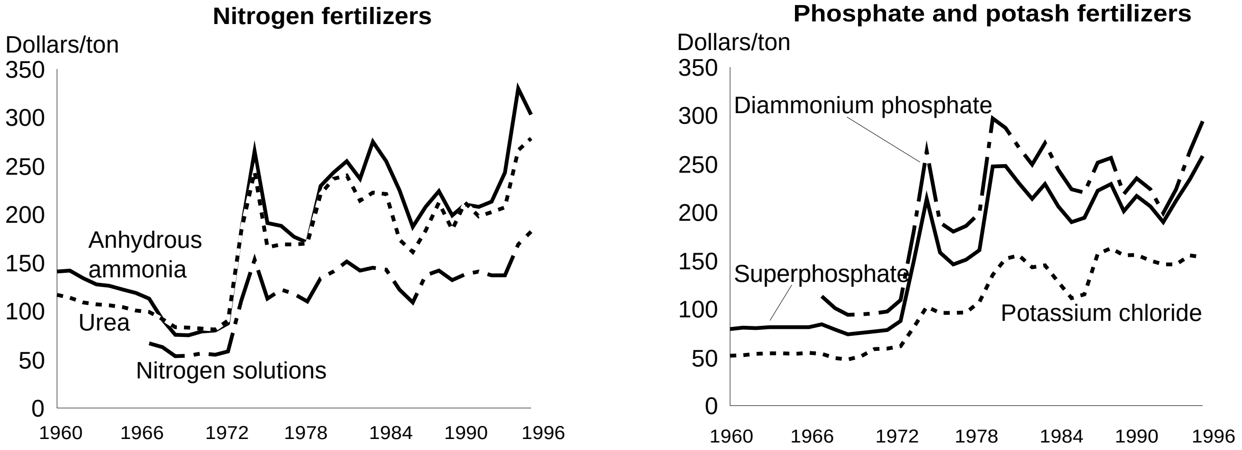
varied between 315 million and 340 million acres. In 1994, acreage of principal crops planted equaled 324 million acres.

Acreage and crop mix planted is dependent on many factors, including government programs, weather, expected commodity prices, input costs, and export market. Acres planted to corn and wheat greatly affect fertilizer use and prices. Corn is the most fertilizer-using crop, accounting for over 45 percent of all use, while wheat is second at 16 percent. Planted corn acreage has ranged from 60 to 85 million acres over the past 30 years and planted wheat acreage has ranged from 53 to 88 million acres. In 1994, approximately 79 and 70 million acres were planted to corn and wheat. To the extent that CRP and ARP acreage comes back into production as a result of contract expiration and higher crop prices, nutrient use could expand.

Fertilizer Prices

Fertilizer use in the United States has historically been inversely related but relatively unresponsive to changes in fertilizer prices, particularly in the short run. Analyses have found elasticities (the percentage change in fertilizer use per percentage change in fertilizer price) to run upwards from -0.19 in the short run and from -0.31 in the long run (after farmers have

Figure 3.1.4--Average farm prices of selected fertilizers, 1960-96



Source: USDA, ERS, based on USDA, NASS 1996 and earlier issues. See also table 3.1.8.

had adequate time to adjust operations) (Griliches, 1958; Denbaly and Vroomen, 1993). In some major Corn Belt States, the elasticities may be even less. One analysis of Indiana and Illinois data—using a model that allowed short- and long-run substitution among agricultural inputs (hired labor, feeds, seeds, fertilizer, pesticides, fuels, and capital) and that included a weather index—found elasticities of about -0.07 for corn both in the short and in the long run (Fernandez-Cornejo, 1993).

Individual fertilizer product prices vary from year to year and substitution among products within nutrient groups does occur. Annual price changes among products can result in different combinations of products used by farmers from year to year.

Fertilizer purchases have historically represented about 6 percent of total farm production costs. Total expenditures on fertilizer by U.S. farmers in 1994 are estimated at $9.1 billion, up 9 percent over 1993. The increase in expenditures is a combination of increased fertilizer prices, increased planted corn acres, and increased application rates over 1993. With current fertilizer prices, 1996 expenditures were likely to have exceeded those of 1994 and 1995.

Throughout the 1960's, prices paid by farmers for most fertilizer products declined as growth in industry capacity exceeded growth in demand (table 3.1.8, fig. 3.1.4). Economic Stabilization Program regulations froze all prices in 1971 to control inflation, including fertilizer prices at the producer level (USDA, 1971-81). Prices were controlled in domestic markets but exported materials were not subject to price regulation. Demand for U.S. fertilizer in strong-currency countries increased as the dollar weakened resulting in a two-price system for U.S. fertilizer, with export prices much higher than domestic prices. With the end of government control in 1973, domestic fertilizer prices increased over 60 percent and equaled world prices.

Decontrol and the oil embargo brought sharp increases in fertilizer prices. By the spring of 1975, farm prices of most fertilizer materials had doubled from 1973. High prices reduced the quantity demanded, causing fertilizer manufacturers' inventories to increase in 1976. Consequently, farm fertilizer prices fell. Prices began to rise again in 1979 following another oil embargo and as a result of strong domestic and export demand and rapidly rising production, transportation, and retailing costs. Rising energy prices in particular were instrumental in increasing production costs, especially for nitrogen products. Prices of most fertilizer products increased in 1980 and 1981 and held steady in 1982.

Fertilizer prices have changed less than other agricultural inputs during the last 10 years. For example, nominal prices farmers paid for fertilizers increased 18 percent from 1984 to 1995 while wage rates went up 51 percent, farm machinery increased 40 percent, agricultural chemicals other than fertilizers increased 28 percent, and seeds went up 16 percent.

Farm fertilizer prices fell during 1983 and again in 1985/86 as a record level of crop acreage was diverted, first by the payment-in-kind program (PIK)

Table 3.1.8—Average U.S. farm prices of selected fertilizers, 1960-96

Year[1]	Anhydrous ammonia (82% nitrogen)	Nitrogen solutions (30% nitrogen)	Urea (45-46% nitrogen)	Ammonium nitrate (33% nitrogen)	Ammonium sulfate (21% nitrogen)	Super-phosphate (20% phosphate)	Super-phosphate (44-46% phosphate)	Diammonium phosphate (18 percent nitrogen, 46 percent phosphate)	Potassium chloride (60% potassium)
					Dollars per ton				
1960	141	NA	117	82	58	38	79	NA	51
1961	142	NA	114	83	58	38	81	NA	52
1962	134	NA	109	82	57	38	80	NA	53
1963	128	NA	107	81	52	41	81	NA	54
1964	126	NA	106	80	53	40	81	NA	54
1965	122	NA	104	79	53	41	81	NA	54
1966	119	NA	101	77	53	41	81	NA	55
1967	113	67	99	74	54	42	84	113	54
1968	91	63	92	68	54	43	78	101	49
1969	76	54	84	62	53	44	74	94	48
1970	75	54	83	60	52	45	75	94	51
1971	79	56	82	63	52	48	77	96	58
1972	80	55	81	65	52	50	78	97	59
1973	88	58	90	71	55	54	88	109	62
1974	183	111	183	139	110	91	150	181	81
1975	265	153	244	186	148	118	214	263	102
1976	191	113	166	135	98	95	158	189	96
1977	188	122	169	141	101	99	146	180	96
1978	177	118	169	140	109	104	151	186	96
1979	171	110	170	138	118	109	161	199	107
1980	229	134	221	165	138	128	247	297	135
1981	243	141	237	185	150	134	248	287	152
1982	255	151	240	195	165	NA	230	267	155
1983	237	142	214	185	149	NA	214	249	143
1984	275	145	222	198	150	NA	229	271	145
1985	255	143	221	192	156	NA	206	244	128
1986	225	122	174	171	149	NA	190	224	111
1987	187	109	161	157	144	NA	194	220	115
1988	208	137	183	166	140	NA	222	251	157
1989	224	142	212	189	154	NA	229	256	163
1990	199	132	184	180	154	NA	201	219	155
1991	210	138	212	184	151	NA	217	235	156
1992	208	141	198	178	151	NA	206	224	150
1993	213	137	202	186	157	NA	190	199	146
1994	243	137	207	196	170	NA	212	224	146
1995	330	169	266	223	182	NA	234	263	155
1996	303	182	278	233	184	NA	258	294	153

NA = Not available.

[1] April prices for 1960-76, 1986-96; all other prices are for March.

Source: USDA, ERS, based on USDA, NASS, *Agricultural Prices*, 1961-96.

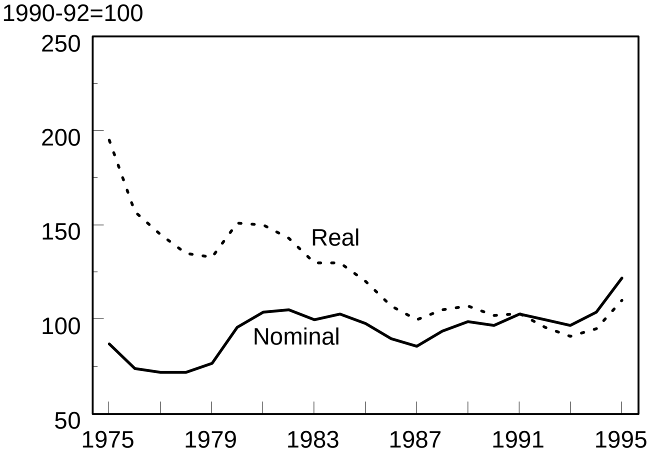
and later by the ARP and CRP programs and excess supplies (Vroomen and Taylor, 1992). Prices rose steadily from 1986 to 1989. Prices of most fertilizer materials have fallen from 1989 levels, but remained relatively stable through 1992 (Taylor, 1994). Prices paid by farmers for fertilizer in 1994-96 increased over 1993 prices due to increased planted acres and other market conditions.

The prices U.S. farmers currently pay for many fertilizer materials have risen significantly since 1993. For example, the price of anhydrous ammonia increased 64 percent from October 1993 to April 1995 to a record high of $330 per ton. Diammonium phosphate's price increased 37 percent over this time period. Other fertilizer products also increased, but not as much. Real fertilizer prices (fertilizer price index adjusted by the implicit price deflator of the United States) have declined from an index of 195 in 1975 to 110 in 1995 using 1990-92 as a base (fig. 3.1.5). In constant dollars, farmers paid 44 percent less for fertilizer in 1995 than they did in 1975.

The increase in fertilizer prices since 1993 is a result of tight world supplies and increased demand. For example, anhydrous ammonia use increased 26 percent from 1993 to 1994, and total nitrogen use increased over 11 percent due to an increase in corn acres (corn uses about 45 percent of all fertilizer). Increases in planted acres of soybeans, cotton, and rice also contributed to an increased demand for fertilizer. Nitrogen application rates on corn increased from 123 to 129 pounds per acre in 1994-95 following the 1993 flood; phosphate and potash application rates also increased. In addition, weather conditions were ideal for the direct application of anhydrous ammonia. There was also an increase in nonagricultural demand for nitrogen in products such as adhesives, plastics, resins, and rubber. During 1995, U.S. fertilizer exports increased over 1994 because of China's increased demand for diammonium phosphate and other fertilizer products.

On the supply side, several factors placed upward pressure on fertilizer prices during 1994 and 1995, including higher priced imports from the former Soviet Union, unscheduled repairs that caused plant closings, low inventories, and an explosion that temporarily closed a large nitrogen production plant. The United States is a net importer of ammonia. Since 1990, U.S. ammonia demand has exceeded U.S. supplies while nitrogen plants have been producing in excess of 100 percent capacity. These factors have occurred during a period in which both agricultural and industrial demands have been growing and ammonium phosphate exports have risen.

Figure 3.1.5--Index of prices paid by farmers for fertilizer



Source: USDA, ERS, based on USDA, NASS 1995 and earlier issues.

Commodity Programs

Commodity programs can directly influence fertilizer use through planted acreage or application rates. The U.S. Government supported crop prices for over half a century by lending farmers money at varying loan rates, using crops as collateral and guaranteeing minimum crop prices (target prices set by law). When market prices of commodity program crops were lower than target prices, participating farmers could receive from the Government deficiency payments for crops planted to base acreage. Deficiency payments were the difference between the target price and the higher of the loan rate or average market price. Participation in commodity programs provided farmers with a more stable farm economy over time; however, participation also required some land to be idled (CRP and ARP programs). Data from the 1991 and 1992 Cropping Practices Survey were analyzed to determine if economic incentives from participation in commodity programs caused program participants to apply fertilizers at greater rates than nonparticipants (Ribaudo and Shoemaker, 1995). Fertilizer and agricultural chemical use between corn grower program participants and nonparticipants were analyzed. The results of that study suggest that economic conditions created by commodity programs increased fertilizer application rates on corn. Future fertilizer use is uncertain. If farm and trade policy continues to provide farmers with more acreage flexibility and freer market

Potential for Agricultural Use of Municipal Wastes

Many urban areas in the United States have an urgent need for a long-term environmentally safe method for recycling and disposal of municipal wastes. Currently the number of landfills is limited and new landfills that meet EPA standards for protecting the environment are costly. Municipal wastes contain nutrients and organic matter and other soil conditioners that can be used for agriculture which could mitigate urban waste disposal problems and their economic costs. The fertilizer-equivalent value to U.S. farmers of municipal solid wastes (MSW) is about $378 million and sewage sludge (SS) is about $72 million. Nutrients from the wastes could reduce dependence on commercial fertilizer from limited supplies of mineral and energy resources. Wastes are being used in the horticultural industry; greater use in agriculture would contribute to the long-term sustainability of agricultural production.

One promising way to use municipal wastes is through composting, a microbiological process that partially decomposes organic wastes through the growth and activity of bacteria, actinomycete, and fungi that are indigenous to the organic wastes. The process reduces the weight and volume of the waste while abating odors, destroying pathogens, and converting nutrients to more plant available forms.

Issues

Technical, economic, and public perception issues hinder agricultural use of municipal wastes. Research is underway to provide better information. Technical issues to be resolved include: (1) uncertainty about the quality of municipal wastes because of heterogeneity and range in chemical and physical characteristics of wastes; (2) concern about the fate and effects of trace elements, synthetic organics and pathogens in wastes on soils, plants, animals and humans; (3) uncertainty about application methods and levels of waste applied to agricultural or horticultural production systems to minimize damage to the environment, such as the accumulation of non-nutrient heavy metals in soils; and (4) inadequate information on blending, mixing, or co-composting different wastes to produce final products with desirable characteristics for agricultural or horticultural use.

Economic issues include: (1) uncertainty about the fertilizer equivalent and soil-conditioning value of municipal wastes; (2) economic application to land; (3) the extent to which municipalities may need to subsidize waste transportation expenses to make its use economically feasible in agricultural production. Public perception issues include the need to show that agricultural use of municipal wastes is environmentally safe and does not pose a human health risk.

Sources: USDA, ERS, based on ARS, 1993; Goldstein and others, 1994; and EPA, 1993.

conditions, fertilizer use could increase as more acres come into production. At the same time, possible declines in commodity prices could reduce the demand for fertilizer.

Increased Nutrient Management

Over 1,400 counties contain areas where groundwater is susceptible to contamination from agricultural pesticides or fertilizers (National Research Council, 1989). States including California, Florida, Iowa, Nebraska, New York, and Wisconsin have developed strategies for dealing with agriculturally induced groundwater contamination. Contamination is prevalent in areas with sandy soils, which are highly porous. In some of these areas, restrictions have been placed on fall applications of nitrogen-based fertilizers. Applications are restricted either under certain weather conditions or during certain time periods. In ammonium form, nitrogen is fairly immobile in soil. Under most conditions, however, ammonium is converted biologically to nitrate, which readily moves with the soil water. Nitrate that is applied in the fall when no crop is planted or when plant uptake is minimal has greater potential of moving with the soil water from the soil to groundwater, streams, and impoundments. Otherwise, it denitrifies and passes to the atmosphere as gas. Effective timing of split fertilizer application during the crop-growing season and the use of nitrification inhibitors can reduce nitrate leaching and denitrification and improve crop nutrient uptake. Efforts to improve nitrogen efficiency will require better synchronization between soil nitrogen availability and crop nitrogen requirements.

A wide variety of nitrogen fertilizer formulations are available to producers to accommodate various times, rates, and methods of application. Additional nitrogen management may be required to minimize contamination of groundwater. Management systems that hold promise include the use of satellite imagery or Global Positioning Systems and grid farming, which allow nitrogen management by soil variation rather than by field. For more discussion of nutrient management, see chapter 4.5.

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Recent ERS Reports on Nutrient Issues

1995 Nutrient Use and Practices on Major Field Crops, AREI Update, May 1996, No. 2 (Harold Taylor). Total nutrient use was 5 percent lower in 1995 than in 1994 with nitrogen use down 7 percent and phosphate and potash use down about 2 percent each. The major factor was decreased corn acreage, which uses 40-45 percent of all fertilizer.

Agricultural Input Trade, AREI Update, 1995, No 10. (Stan Daberkow, Mohinder Gill, Harold Taylor, Marlow Vesterby). The United States is a major exporter of phosphate and nitrogen fertilizer products and a major importer of potash. The value of fertilizer exports has varied from $3.0 billion in 1991 to $1.8 billion in 1993. Data are reported by region and country.

Pesticide and Fertilizer Use and Trends in U.S. Agriculture, AER-717, May 1995 (Biing-Hwan Lin, Merritt Padgitt, Len Bull, Herman Delvo, David Shank, and Harold Taylor). Pesticides and fertilizer contribute to increased productivity in agriculture, but their use is also associated with potential human health, wildlife, and environmental risks. Nitrogen, phosphate, and potash all shared in the dramatic increase in fertilizer use, but the relative use of nitrogen increased much more rapidly from 37 percent of total nutrient use in 1960 to more than 50 percent since 1981.

Chemical Use Practices, RTD Update, July 1994, No. 2 (Harold Taylor, Biing-Hwan Lin, and Herman Delvo). Chemical application timing and methods varied considerably among the major field crops. Fertilizer was more frequently applied before planting to corn, soybeans, and winter wheat, at planting to durum and spring wheat, and after planting to cotton and fall potatoes. Herbicides were most frequently applied after planting to most crops except upland cotton. Area and State-level data are for corn; upland cotton; fall potatoes; soybeans; and winter, spring, and durum wheat.

Fertilizer Use and Price Statistics, SB-893, Sept. 1994 (Harold Taylor). The rapid growth in fertilizer consumption throughout the 1960's and 1970's peaked at 23.7 million nutrient tons in 1981. Use remained relatively stable, ranging from 19.1 to 21.8 million tons during 1984-93. Fertilizer prices vary by product and year, but the fertilizer price index was less during the late 1980's and early 1990's than in 1982. Area and State data are for corn, cotton, soybeans, and wheat from 1964-1993, and total U.S. consumption data are from 1960 to 1993.

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Glossary

Ammonium nitrate: A prilled or granulated product containing not less than 33 percent nitrogen, one half of which is in the ammonium form and one half in the nitrate form.

Ammonium sulfate: Soluble in water and contains 21 percent nitrogen and 24 percent sulphur. It is usually made by treating bauxite with sulfuric acid. It is applied to western soils to make them less alkaline.

Anhydrous ammonia: A colorless, pungent gas containing 82.25 percent nitrogen and 17.75 percent hydrogen, which can be liquefied and transported at normal temperatures in high-pressure cylinder tanks, and injected under pressure into the soil or mixed with irrigation water.

Available nutrients: That part of fertilizer supplied to the plant that can be taken up by the plant.

Blended fertilizer: A mechanical mixture of two or more fertilizer materials.

Diammonium phosphate (DAP): A product made from wet process phosphoric acid and ammonia containing 18 percent nitrogen and 46 percent phosphate.

Economically recoverable manure: The excreta of animals (dung and urine) mixed with straw or other materials that can be economically recovered and used as a fertilizer.

Guano: Partially decomposed excrements of birds, bats, seals, or other animals.

Inorganic fertilizers: Fertilizer materials in which carbon is not an essential component of its basic chemical structure.

Lime: A soil conditioner consisting essentially of calcium carbonate, calcium oxide, calcium hydroxide, magnesium carbonate, magnesium oxide, or a combination of these capable of neutralizing soil acidity.

Micronutrients: Boron, chlorine, cobalt, copper, iron, manganese, molybdenum, sodium, and zinc are needed only in small amounts. They contribute to cell division, photosynthesis, fruit formation, carbohydrate and water metabolism, chlorophyll formation, protein synthesis, and seed development.

Mixed fertilizers: Two or more fertilizer materials mixed or granulated together into individual pellets.

Muriate of potash (potassium chloride): A potash salt of hydrochloric acid (muriatic acid) containing 60-62 percent soluble potash.

Natural organic fertilizers: Materials derived from either plant or animal products containing one or more elements (other than carbon, hydrogen, and oxygen) essential for plant growth.

Nitrogen solutions: Solutions of nitrogen fertilizer chemicals in water. Urea ammonium nitrate (UAN) solutions are made from a mixture of urea and ammonium nitrate and contain 28-32 percent nitrogen.

Primary Nutrients:

> **Nitrogen (N)** is an essential element in the production of food protein by the plants and in the conversion of carbon dioxide in the air and water into carbohydrates through photosynthesis. It also is essential for vigorous plant growth and for obtaining high crop yields. Principal forms of nitrogen fertilizer are anhydrous ammonia, urea, ammonium nitrate, and nitrogen solutions.
>
> **Phosphate (P_20_5), the oxide form of phosphorus (P)** is vital to plant growth playing a key role in photosynthesis, respiration, energy storage and transfer, cell division, cell enlargement, genetic coding, and many other plant processes. An adequate level of phosphate provides rapid, extensive growth of young plant roots. Principal forms of phosphate fertilizer are normal and superphosphate, and diammonium phosphate.
>
> **Potash (K_20), the oxide form of potassium (K)** activates many enzyme systems in the plant and helps the plant use water more efficiently with less loss. It is essential for varied process-photosynthesis rates, product formation, winter hardness, and disease resistance. It stops stalks from lodging, preventing a decrease in crop yields. Principal forms of potash fertilizer are potassium chloride, potassium sulfate, and potassium nitrate.

Secondary Nutrients: Calcium, magnesium, and sulfur are essential to plant growth in lesser quantity than nitrogen, phosphate, and potash but in greater quantity than micronutrients.

Sewage sludge: Solids removed from sewage by screening, sedimentation, chemical precipitation, or bacterial digestion.

Sodium nitrate: Sodium salt of nitric acid containing not less than 16 percent nitrate nitrogen and 26 percent sodium.

Superphosphate: Products obtained when rock phosphate is treated with either sulfuric acid or phosphoric acid or a mixture of these acids. Normal superphosphate contains up to 22 percent phosphoric acid. Enriched superphosphate contains more than 22 percent but less than 40 percent phosphoric acid. Concentrated or triple superphosphate contains more than 40 percent phosphoric acid.

Urea: A white crystalline or granular solid synthesized from ammonia and carbon dioxide under high temperature and pressure and containing not less than 45 percent nitrogen.

Sources: *Farm Chemical Handbook 93*, Meister Publishing Company, 1993; Fertilizer Institute, 1982.

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3.2 Pesticides

Pesticides have been the fastest growing agricultural production input in the post-World War II era, and have contributed to the relatively high productivity levels of U.S. agriculture. Agricultural production and storage account for about 75 percent of total U.S. pesticide use. Herbicides and insecticides account for most pesticide use, but the recent increase in pounds of pesticide used is mostly for fungicides and other pesticide products applied to high-valued crops. In recent years, agricultural pesticide expenses have increased about 5.5 percent each year, keeping pace with farm production expenses in general. Pesticides have remained about 4 percent of total production expenses during the 1990's and about one-third of the manufactured inputs (fuels, fertilizers, and pesticides).

Contents

Approximately $7.5 billion per year is spent in the United States on agricultural pesticides (USDA, ERS, Aug. 1996). Herbicides account for about two-thirds of the agricultural expenditures for pesticides while insecticides account for about one-fifth (Aspelin, 1994). (See "Glossary" for definitions of terms.)

Pesticide use has engendered concerns about health risks from residues on food and in drinking water and about the exposure of farmworkers when mixing and applying pesticides or working in treated fields. Pesticide use has also raised concerns about impacts on wildlife and sensitive ecosystems.

Pesticide use has conventionally been measured in pounds of active ingredients applied and acres treated. These measurements are useful for assessing the adoption and intensity of pesticide use, making relative comparisons of use between commodities or production regions, and analyzing the cost of pesticides as a production input. These measurements, however, do not account for changes in the pesticide attributes over time or safety features associated with their use and application. New products and the related changes in intensity of treatment, rather than treatment of additional acres, now account for most pesticide use changes. Product formulation has changed in order to lessen environmental and human health effects, to reduce the development of pesticide-resistant pests, and to provide more cost-effective pest control. Efforts to account for changing risk and productivity in aggregate measures of pesticide use are underway. This chapter reports traditional measures of pesticide use—acres treated and pounds applied—as well as new indicators that attempt to account for some pesticide attributes—toxicity and persistence—that may affect human and environmental health.

Table 3.2.1—Overall pesticide use on selected U.S. crops by pesticide type, 1964-1995[1]

Commodities	1964	1966	1971	1976	1982	1990	1991	1992	1993	1994	1995
	1,000 pounds of active ingredients										
Herbicides	48,158	79,384	175,668	341,390	430,345	344,638	335,177	350,534	323,510	350,449	323,791
Insecticides	123,304	119,240	127,709	131,730	82,651	57,392	52,828	60,047	58,096	67,896	69,599
Fungicides	22,167	23,237	29,308	26,632	25,219	27,762	29,439	34,922	36,583	43,059	44,804
Other pesticide	21,379	18,747	31,710	30,741	34,232	67,900	79,451	90,019	97,810	129,639	127,445
Total on selected crops	215,008	240,608	364,395	530,493	572,448	497,693	496,895	535,522	515,999	591,044	565,639
	1,000 cropland acres										
Area represented	174,552	175,040	190,638	233,221	255,866	228,508	226,021	231,531	226,586	232,804	227,855
Total cropland used for crops	335,000	332,000	340,000	340,800	383,000	341,000	337,000	338,000	330,000	338,500	338,000
	Pounds of active ingredient per planted acre										
Herbicides	0.276	0.454	0.921	1.464	1.682	1.508	1.483	1.514	1.428	1.505	1.421
Insecticides	0.706	0.681	0.670	0.565	0.323	0.251	0.234	0.259	0.256	0.292	0.305
Fungicides	0.127	0.133	0.154	0.114	0.099	0.121	0.130	0.151	0.161	0.185	0.197
Other pesticides	0.122	0.107	0.166	0.127	0.134	0.297	0.352	0.389	0.432	0.557	0.559
Total on selected crops	1.232	1.375	1.911	2.275	2.237	2.178	2.198	2.313	2.277	2.539	2.482
Percent of crop area represented[2]	52	53	56	68	67	67	67	69	69	69	67

[1] Estimates include corn, soybeans, wheat, cotton, potatoes, other vegetables, citrus fruit, apples, and other fruit.

[2] Share of total for the selected crops to total cropland used for crops.

Source: USDA, ERS, AER-717 (prior to 1993); unpublished USDA survey data (following 1993).

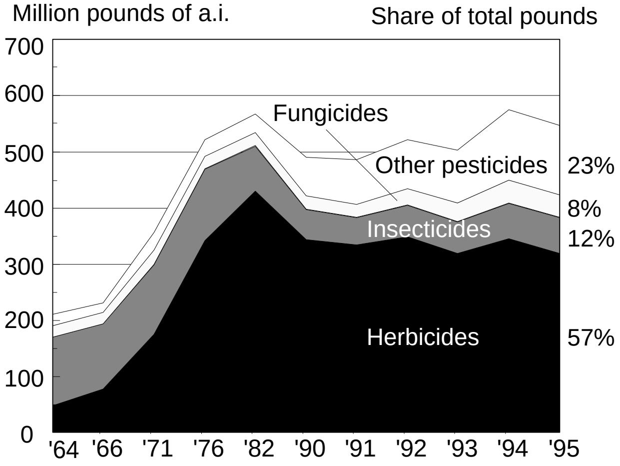
Pesticide Use on Major Crops

Synthetic pesticides were initially developed for commercial agricultural use in the late 1940's and 1950's and were widely adopted by the mid-1970's. USDA's benchmark surveys of pesticide use by farmers show that the quantities applied to major field crops, fruits, and vegetables first peaked in 1982 (fig. 3.2.1 and table 3.2.1). The crops included in the surveys—corn, cotton, soybeans, wheat, fall potatoes, other vegetables, citrus, apples, and other fruit—account for about 67 percent of the current cropland used for crops. Pesticide use on these crops grew from 215 million pounds in 1964 to 572 million pounds in 1982. This increase can be attributed to three factors: increased planted acreage, greater proportion of acres treated with pesticides, and higher application rates per treated acre. (More detail on proportions of acres treated, application rates, and pest management practices can be found in chapter 4.4, *Pest Management*.)

Pesticide use declined between the 1982 and 1990 benchmark surveys as commodity prices fell and large amounts of land were taken out of production by Federal programs.

Since 1990, total quantities of pesticides have generally increased, but continue to fluctuate with changes in planted acreage, infestation levels, adoption of new products, and other factors. An estimated 565 million pounds of pesticides were applied to major field crops and most fruits and

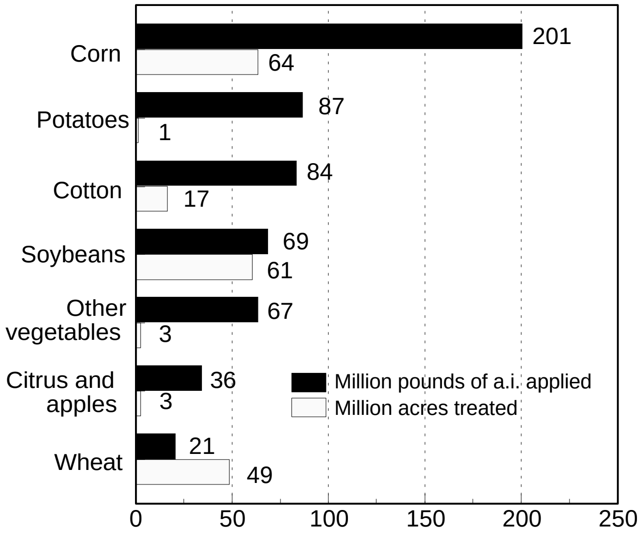
Figure 3.2.1--Total pesticide use on major crops, 1964-95



Includes corn, cotton, soybeans, wheat, potatoes, other vegetables, citrus, and apples, and other fruit (about 67 percent of U.S. cropland).

Source: USDA, ERS estimates.

Figure 3.2.2--Amount of pesticide applied and acres treated, 1995



Source: USDA, ERS estimates

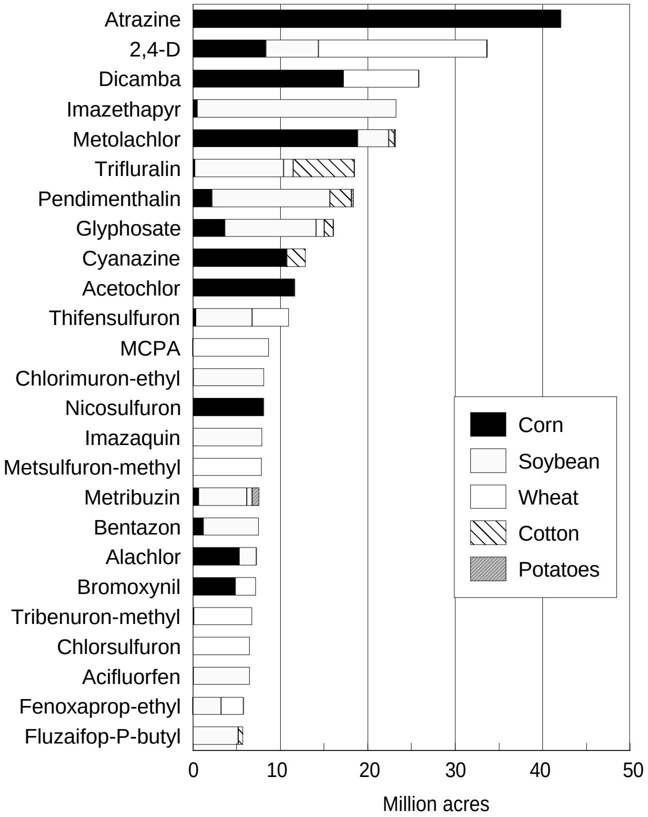
vegetables in 1995, up 13 percent from 1990. Contributing to the increased use was an expanded use of soil fumigants, defoliants, and fungicides on potatoes; expanded cotton acreage; more intensive insecticide treatments of cotton and potatoes; and an increased share of wheat acres treated with herbicides (table 3.2.2). During the same period, the total amount of pesticides applied to corn and soybeans was either unchanged or declined. In 1995, corn received more than double the pesticide amount of any other U.S. crop (fig. 3.2.2). Among the major crops, however, pesticide quantity per acre was by far greatest on fall potatoes.

Herbicides. Herbicides are the largest pesticide class, accounting for 57 percent of pounds of active ingredients in 1995 (table 3.2.1). Weeds compete with crops for water, nutrients, and sunlight, and cause reduced yields. Producers, in managing weeds, must consider infestation levels; weed species resistant to specific ingredients; the effect of treatment on following crops; control of soil weed seed populations; and the labor requirement, cost, and risk of using cultivation or other mechanical methods of weed control. Since 1990, herbicide use has remained relatively unchanged—between 324 million and 350 million pounds (table 3.2.1).

Although many herbicide active ingredients are used in agriculture, a relative few account for most of the use. Atrazine, 2,4-D, and dicamba, all widely used for more than 30 years, still account for the largest treated acreage among major field crops (table 3.2.3, fig. 3.2.3). Atrazine, which remains active in the soil throughout most of the growing season, is used to control many types of weeds in corn and sorghum. The herbicide 2,4-D has been widely used on wheat and corn, and more recently used on soybeans as a preplant application with no-till. Trifluralin, another ingredient available 30 years ago, continues to be the leading herbicide used on cotton and is still widely used on soybeans and many vegetable crops. Since the availability of imazethapyr and some other imidazalinone and sulfonyurea products in the 1980s, trifluralin use, especially on soybeans, has declined.

Insecticides. Insecticides accounted for 12 percent of the total quantity of pesticides applied in 1995 to the surveyed crops (fig. 3.2.1). Damaging insect populations can vary annually depending on weather, pest cycles, cultural practices such as crop rotation and destruction of previous crop residues, and other factors. Insecticide use includes both preventative treatments, which are applied before infestation levels are known, and intervention treatments, which are

Figure 3.2.3--Acres treated with commonly used herbicides, 1995



Source: USDA, ERS 1995 Cropping Practices Survey data.

Table 3.2.2—Estimated quantity of pesticide active ingredient applied to selected U.S. crops, 1964-95[1]

Commodities	1964	1966	1971	1876	1982	1990	1991	1992	1993	1994	1995
*1,000 pounds of **herbicides***											
Corn	25,476	45,970	101,060	207,061	243,409	217,500	210,200	224,363	201,997	215,636	186,314
Cotton	4,628	6,526	19,610	18,312	20,748	21,114	26,032	25,773	23,567	28,565	32,873
Wheat	9,178	8,247	11,622	21,879	19,524	16,641	13,561	17,387	18,304	20,708	20,054
Sorghum	1,966	4,031	11,538	15,719	15,738	13,485	14,156	na	na	na	na
Rice	2,559	2,819	7,985	8,507	14,089	16,139	16,092	17,665	na	na	na
Soybeans	4,208	10,409	36,519	81,063	133,240	74,400	69,931	67,358	64,092	69,257	68,126
Peanuts	2,894	2,899	4,374	3,366	4,927	4,070	4,510	na	na	na	na
Potatoes	1,297	2,220	2,178	1,764	1,636	2,361	2,547	2,152	2,504	2,866	2,894
Other vegetables	2,194	3,488	3,361	5,419	4,345	4,916	4,712	5,850	5,741	6,137	6,119
Citrus	207	353	546	4,756	6,289	5,652	6,076	5,545	5,086	4,793	4,665
Apples	278	389	156	575	649	396	429	419	445	605	767
Other fruit	692	1,782	615	560	504	1,659	1,690	1,687	1,774	1,882	1,978
*1,000 pounds of **insecticides***											
Corn	15,668	23,629	25,531	31,979	30,102	23,200	23,036	20,866	18,479	17,349	14,956
Cotton	78,022	64,900	73,357	64,139	19,201	13,583	8,159	15,307	15,429	23,882	30,039
Wheat	891	876	1,712	7,236	2,853	970	208	1,153	152	2,031	910
Sorghum	788	767	5,729	4,604	2,559	1,085	1,140	na	na	na	na
Rice	284	312	946	508	565	161	309	178	na	na	na
Soybeans	4,997	3,217	5,621	7,866	11,621	0	445	359	346	203	515
Peanuts	5,518	5,529	5,993	2,439	1,035	1,726	1,913	na	na	na	na
Potatoes	1,456	2,972	2,770	3,261	3,776	3,591	3,597	3,514	3,943	4,459	3,109
Other vegetables	8,290	8,163	8,269	5,671	4,465	4,709	4,466	5,482	5,305	5,591	5,573
Citrus	1,425	2,858	3,049	4,604	5,306	2,811	3,977	4,538	5,271	5,110	5,143
Apples	10,828	8,494	4,831	3,613	3,312	3,691	4,013	3,909	4,150	3,846	3,564
Other fruit	1,727	4,131	2,569	3,361	2,016	4,837	4,928	4,919	5,023	5,424	5,789
*1,000 pounds of **fungicides***											
Corn	0	0	0	20	69	0	0	0	0	0	19
Cotton	171	376	220	49	200	988	701	785	684	1,065	1,045
Wheat	0	0	0	862	1,088	172	73	1,154	688	1,012	500
Sorghum	0	0	0	0	0	0	0	na	na	na	na
Rice	0	0	0	0	80	194	426	388	na	na	na
Soybeans	0	0	0	176	71	0	0	85	0	45	13
Peanuts	1,106	1,108	4,431	6,834	4,739	7,321	8,114	6,725	na	na	na
Potatoes	3,229	3,531	4,124	4,168	4,031	2,808	3,172	3,616	4,369	6,358	7,973
Other vegetables	4,530	4,093	5,667	5,051	6,692	12,917	13,126	17,260	18,715	21,880	21,810
Citrus	4,929	4,056	9,257	5,897	4,881	2,555	3,598	3,429	3,322	3,582	4,019
Apples	7,750	8,496	7,207	6,489	5,667	4,177	4,544	4,377	4,599	4,627	4,680
Other fruit	1,558	2,685	2,833	3,921	2,520	4,146	4,224	4,216	4,206	4,491	4,745
*1,000 pounds of **other pesticides***											
Corn	76	546	443	483	130	0	0	0	0	0	0
Cotton	12,431	14,207	18,696	12,682	9,347	15,188	15,457	15,781	12,658	15,616	19,733
Wheat	0	47	245	0	0	0	0	0	0	0	0
Sorghum	0	40	0	266	44	0	0	na	na	na	na
Rice	0	0	0	0	17	0	0	109	na	na	na
Soybeans	0	49	52	2,030	2,430	0	0	0	0	0	0
Peanuts	6,990	7,005	471	1,188	1,627	2,364	2,620	na	na	na	na
Potatoes	91	9	6,397	8,576	15,188	35,069	45,626	49,671	157,494	79,809	72,928
Other vegetables	5,819	569	3,435	5,061	6,206	17,283	17,998	24,189	27,516	33,400	33,293
Citrus	1,539	681	1,280	214	7	10	15	31	49	108	179
Apples	1,037	1,079	548	574	421	73	73	66	65	79	93
Other fruit	386	1,560	614	1,120	504	276	282	281	27	627	1,221
*1,000 pounds of **all pesticide types***											
Corn	41,220	70,145	127,034	239,543	273,710	240,700	233,235	245,229	220,476	232,985	201,289
Cotton	95,252	86,009	111,883	95,182	49,497	50,873	50,349	57,646	52,338	69,128	83,689
Wheat	10,069	9,170	13,579	29,977	23,465	17,782	13,842	19,694	19,144	23,751	21,464
Sorghum	2,754	4,838	17,267	20,589	18,341	14,570	15,296	na	na	na	na
Rice	2,843	3,131	8,931	9,015	14,751	16,494	16,827	18,340	na	na	na
Soybeans	9,205	13,675	42,192	91,135	147,362	74,400	70,376	67,802	64,438	69,505	68,655
Peanuts	16,509	16,541	15,268	13,827	12,327	15,482	17,157	na	na	na	na
Potatoes	6,073	8,732	15,470	17,769	24,631	43,830	54,942	58,953	68,309	93,492	86,904
Other vegetables	20,833	16,313	20,732	21,202	21,707	39,824	40,302	52,781	57,277	67,008	66,795
Citrus	8,100	7,948	14,132	15,471	16,483	11,028	13,666	13,544	13,729	13,594	14,006
Apples	19,893	18,458	12,742	11,251	10,049	8,337	9,059	8,771	9,260	9,157	9,104
Other fruit	4,364	10,158	6,631	8,963	5,544	10,919	11,123	11,103	11,030	12,424	13,734

[1] Estimates are constructed for the total U.S. acreage of the selected commodities. In years when the surveys did not include all states producing the crop, the estimates assume similar use rates for those States. Petroleum distillates are excluded. Source: USDA, ERS, AER-717 (prior to 1993), and unpublished USDA survey data following 1993.

Table 3.2.3—Herbicide active ingredients used on field crops, major producing States, 1990-95[1]

Active ingredient	1990	1991	1992	1993	1994	1995
1,000 pounds						
Atrazine	45,144	44,439	46,203	41,878	45,586	38,611
Metolachlor	36,834	42,473	42,188	41,411	46,787	37,142
Cyanazine	22,024	24,118	27,238	27,367	29,519	24,066
Acetochlor	0	0	0	0	7,314	22,586
Trifluralin	17,892	18,426	16,585	13,975	13,722	13,392
Pendimethalin	8,779	10,595	11,303	12,685	13,702	16,024
2,4-D	9,055	6,800	7,753	10,962	12,207	12,266
Alachlor	41,476	45,992	45,146	36,561	27,270	11,144
EPTC	28,671	15,222	11,269	11,881	7,473	8,238
Glyphosate	1,963	3,048	2,606	5,809	6,491	8,117
Dicamba	4,488	3,803	5,307	5,051	7,098	6,139
Bentazon	4,910	3,889	4,414	3,969	4,959	4,364
MCPA	2,496	2,286	2,608	2,447	2,971	3,030
Butylate	10,510	5,975	5,979	3,850	2,117	1,609
Metribuzin	2,959	2,537	1,975	2,003	1,773	1,498
Imazethapyr	290	649	764	918	1,083	1,329
Sethoxydim	397	483	546	468	588	625
Imazaquin	607	541	589	617	758	564
Chlorimuron-ethyl	199	173	139	143	129	118
Other herbicides[2]	40,173	35,297	33,682	33,336	27,207	27,105
All herbicides	264,050	254,154	253,742	244,070	257,754	237,967
1,000 acres treated						
Atrazine	37,513	39,485	43,509	39,037	42,909	36,130
2,4-D	23,831	18,929	22,353	29,866	32,340	31,549
Dicamba	17,735	15,886	22,197	22,367	28,487	24,875
Imazethapyr	5,328	11,679	14,321	16,214	19,425	22,837
Metolachlor	19,539	22,307	22,617	22,078	24,328	19,452
Trifluralin	23,556	23,089	21,425	18,367	18,146	17,064
Pendimethalin	9,123	11,437	13,216	13,788	14,450	16,412
Glyphosate	3,626	5,962	6,043	11,848	12,911	14,971
Cyanazine	13,206	14,164	15,724	14,531	15,150	12,414
Acetochlor	0	0	0	0	4,103	11,284
MCPA	7,220	6,852	7,884	7,670	8,547	8,038
Bentazon	8,146	6,629	7,656	6,246	8,038	7,070
Chlorimuron-ethyl	8,339	7,509	7,461	7,232	6,787	6,633
Imazaquin	5,262	5,771	6,623	6,322	7,794	6,353
Alachlor	21,044	22,535	22,307	17,744	13,766	6,348
Metribuzin	8,924	7,706	6,705	6,437	5,811	5,892
Sethoxydim	2,255	2,643	3,079	2,591	3,228	3,532
EPTC	6,504	3,684	2,634	2,988	1,855	2,137
Butylate	2,715	1,564	1,439	1,021	630	465

[1] Represents planted area of corn (10 States), soybeans (8 States), cotton (6 States), winter wheat (11 States), spring and durum wheat (4 States), and fall potatoes (11 States). For States included, see "Cropping Practices Survey" in the appendix. For these crops, the area represented in 1995 was about 165 million acres, 75 percent of total planted acres of these crops.

[2] Total pounds of all other herbicides used. No single ingredient in any year exceeded 5 million pounds.

Source: USDA, ERS, Cropping Practices Surveys, 1990 to 1995.

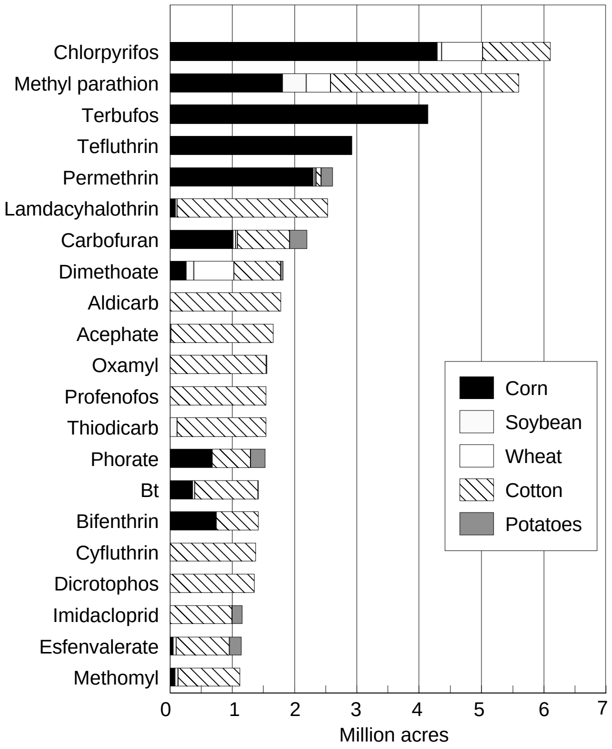
based on monitored infestation levels and expected crop damages. While the quantity of insecticides applied has increased in recent years, the amount is down significantly from the 1960's and early 1970's (table 3.2.1). The drop from earlier years is primarily due to the replacement of organochlorine insecticides, used prior the 1970's, with other insecticides that can be applied at much lower rates. The 69.4 million pounds of insecticide applied in 1995 was about half the quantity used in 1976 and earlier years. Since 1990, insecticide use has declined on corn (with fewer acres treated) but increased on cotton (with expanded area and more intensive treatments per acre) (table 3.2.2).

Three insecticide active ingredients (chlorpyrifos, methyl parathion, and terbufos) account for 43 percent of insecticides used on the five major field crops (fig. 3.2.4, table 3.2.4). Chlorpyrifos was the most used insecticide on corn, second most used on wheat, and applied to 9 percent of the cotton acreage. It is used to treat corn rootworm larvae, cutworms, Russian wheat aphid, and bollworms. Methyl parathion is used mostly on cotton to treat boll weevil and other cotton insects while terbufos is used for corn insects.

Fungicides. Fungicides are applied to fewer acres than are herbicides and insecticides and account for the smallest share of total pesticide use (table 3.2.1). Fungicides are mostly used on fruits and vegetables to control diseases that affect the health of the plant or quality and appearance of fruit. The 44.6 million pounds estimated for 1995 is up 21 percent from 1993 and 61 percent from 1990. A large share of this increase is attributed to diseases on potatoes and other vegetables. Several common fungicides used to treat potatoes for early and late blight (chlorothalonil, mancozeb, metalaxyl, and copper hydroxide) had a 40 to 400 percent increase in use over this period. Some cotton and wheat acres are treated for diseases, but these treatments account for only a small share of total fungicide use.

Other pesticides. Pesticides designated as "other," which include soil fumigants, growth regulators, desiccants, and harvest aids, had the largest increase in use of any of the pesticide classes (table 3.2.1, fig. 3.2.1). The use of these pesticides, whose function is not necessarily to destroy a pest organism, increased about 17 percent each year since 1990 and accounts for about 23 percent of the total pounds of all active ingredients applied to the surveyed crops. Growth regulators, desiccants, and harvest aids, normally applied at low rates, are used to affect the branching structure of plants, to control the time of maturity or ripening, to aid mechanical harvesting, to defoliate plants before harvest, and to alter other plant functions to improve quality or yield. Fumigants, normally applied at very high application rates, are used mostly on vegetable root crops susceptible to damage from soil nematodes and other soil organisms. Fumigants and some desiccants, with application rates that often exceed 200-300 pounds per acre, account for most of the quantity of pesticides in this class but only a small share of the area treated. Small changes in the use of such products, when averaged with other products applied at only a few pounds or less per acre, can grossly affect the significance of the overall change in pesticide use. USDA reports (NASS, 1991-96) show that the increase of 3 fumigants (methyl bromide, metam sodium, and dichloropropene) account for most of the increase in pesticide quantity between 1990 and 1995 but were applied to a relatively small share of the acres.

Figure 3.2.4--Acres treated with commonly used insecticides, 1995



Source: USDA, ERS 1995 Cropping Practices Survey data.

Table 3.2.4—Insecticide active ingredients used on field crops, major producing States, 1990-1994[1]

Active ingredient	1990[2]	1991	1992	1993	1994	1995
1,000 pounds						
Chlorpyrifos	5,511	7,141	6,382	6,242	6,370	5,933
Methyl parathion	531	2,421	3,837	4,794	7,429	5,996
Terbufos	8,831	5,331	5,528	4,571	4,290	3,268
Phorate	2,787	2,531	2,005	2,549	2,127	1,830
Profenofos	.	322	1,276	1,326	1,875	1,742
Carbofuran	1,773	1,803	1,207	720	748	1,290
Aldicarb	44	559	564	637	938	1,140
Fonofos	2,652	2,888	2,121	1,837	1,628	844
Methomyl	0	183	269	382	240	580
Dimethoate	165	307	483	639	619	484
Esfenvalerate	18	73	81	47	56	302
Permethrin	104	318	185	146	274	247
Carbaryl	255	164	131	56	186	218
Other insecticides[3]	4,620	7,999	8,910	8,922	12,045	11,313
All insecticides	26,705	30,567	31,271	31,107	36,341	35,187
1,000 acres treated						
Chlorpyrifos	4,467	6,468	6,340	5,835	6,457	5,753
Methyl parathion	1,255	3,104	3,834	3,964	5,078	4,881
Terbufos	7,847	4,855	5,083	4,293	4,050	3,139
Permethrin	812	2,826	1,598	1,190	2,459	2,226
Carbofuran	1,751	2,030	1,371	863	1,082	1,825
Aldicarb	17	1,033	1,030	1,164	1,532	1,784
Profenofos	363	993	1,227	1,532	2,400	1,543
Phorate	1,918	1,638	1,550	1,981	1,810	1,513
Dimethoate	576	989	1,674	1,276	2,016	1,504
Esfenvalerate	345	1,560	1,228	703	773	1,011
Methomyl	0	636	723	778	613	1,077
Fonofos	2,569	2,646	1,789	1,813	1,504	895
Carbaryl	370	370	176	73	167	137

[1] Represents planted area of corn (10 States), soybeans (8 States), cotton (6 States), winter wheat (11 States), spring and durum wheat (4 States), and fall potatoes (11 States). For States included, see "Cropping Practices Survey" in the appendix. For these crops, the area represented in 1995 was about 165 million acres, 75 percent of total planted acres of these crops.

[2] Does not include insecticides applied to cotton.

[3] Total pounds of all other herbicides used. No single ingredient in any year exceeded 1 million pounds.

Source: USDA, ERS, Cropping Practices Surveys, 1990 to 1995.

Indicators of Potential Pesticide Impact or Risk

Pesticide use in the United States, as traditionally reported in pounds of active ingredient applied, reached a record level in 1994 (table 3.2.1). However, pesticide weight, as a measure of use, has two particularly notable drawbacks when evaluating the potential for harm to human health and the environment. First, the more than 350 pesticide active ingredients used in U.S. agricultural production in the last 40 years vary widely in terms of toxicity per unit of weight, irrespective of the scale used to measure toxicity.[1] Second, weight does not account for the persistence of the pesticide in the environment. The longer a pesticide ingredient remains active in the environment, the more potential there is for it to come in contact with non-target species. Persistence varies widely between active ingredients, but many modern pesticides have half-lives (the typical measure of persistence) of 10-100 days in the fields where they are applied. This is significantly less than some organochlorine products banned from use in the 1970's, which had half-lives as high as 30 years.

Many new pesticide ingredients are applied at lower rates (in ounces rather than pounds per acre) and are

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[1] There are numerous measures of toxicity for individual pesticide active ingredients, including those designed to measure chronic and acute toxicity to humans, and toxicities to various avian, aquatic, and beneficial insect species. The relative toxicity of each pesticide ingredient varies depending upon which measure is used; for a given measure, there is wide variation in toxicity among pesticide ingredients.

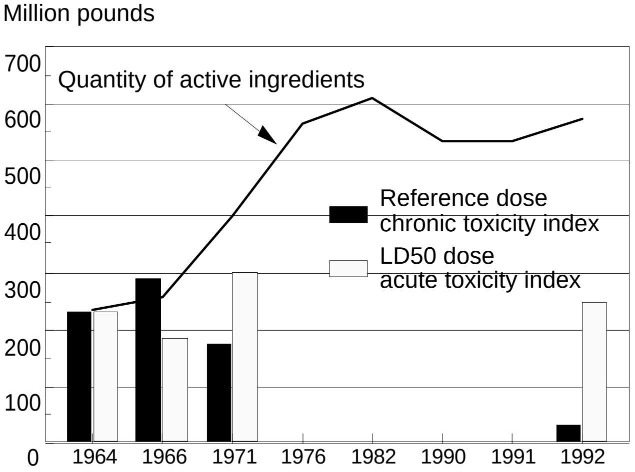
less persistent in the environment. In addition, many (formerly) widely used, but highly toxic and persistent, ingredients have been restricted or banned by the Environmental Protection Agency. In order to account for these differences in exposure and toxicity, adjustment factors were used to convert historic pesticide-use data (published in terms of pounds applied) into indicators of risk that are more meaningful with respect to potential environmental or health impacts. The adjustment creates a common denominator that accounts for variation in toxicity and persistence among individual pesticide ingredients. Thus, the amount of each pesticide active ingredient applied is aggregated in common units that are consistent across time, regions, pesticide types, toxicity, and persistence. Other researchers have created indexes using related methodology to make assessments of aggregate changes in pesticide toxicity (Kovach and others, 1992; Levitan and others, 1995).

The potential risk indicators are based on indexes of the combined toxicity and persistence of each individual ingredient. (See box, "Estimating Pesticide Impact or Risk.") The indexes are created by calculating the number of units (Reference Dose or LD50) contained in 1 pound of each pesticide active ingredient and multiplying that value by the estimated number of days (as measured by half-life) that an application of the ingredient remains active in the environment. The calculated index value for each ingredient can be multiplied by the pounds applied and then summed over all ingredients to obtain an aggregate indicator of potential risk.

The analysis first compares pounds of active ingredient applied, then compares two potential risk indicators (table 3.2.5). Both of the risk indicators adjust for persistence, but each employs an alternative measure of toxicity. An indicator of potential chronic risk is based on Reference Dose, which is a measure of long-term (chronic) toxicity. An indicator of potential acute risk is based on the Oral LD50, and measures acute toxicity associated with ingestion of the pesticide.

For most consumers, chronic intake through food and water is the principal health concern stemming from pesticide use in agriculture. A health-risk measure, based on Reference Dose, was chosen to represent this long-term risk to health. The acute measure, based on LD50, is of more interest to farmers, farmworkers, and pesticide applicators who are more prone to acute exposure.

Figure 3.2.5--Comparison of indicators of pesticide use and risk



Source: USDA, ERS, based on USDA, 1960; USDA, 1968; USDA, 1974; Gianessi, 1995.

While the total pounds of active ingredients applied in 1992 was up 247 percent from 1964, the total potential chronic risk from the 1992 pesticides was actually less than the risk from the pesticides applied in 1964 (fig 3.2.5). Much of the reduction in the potential chronic risk indicator reflects the removal of many organochlorine insecticides, such as aldrin, DDT, chlordane, and toxaphene.

Even with the ban on highly toxic and persistent organochlorine insecticides and other reductions in use, insecticides continue to account for most of the potential risk (table 3.2.5). Insecticides accounted for about 92 percent of the total potential acute risk and more than half of the total potential chronic risk in 1992. While the total potential risk associated with herbicides and fungicides increased 7 to 8 times over the 28-year time period, these pesticide classes still accounted for under 20 percent of the total potential chronic risk and 5 percent of the total potential acute risk in 1992. The potential chronic risk from all other classified pesticides—mostly soil fumigants—increased about 75 percent in this period and accounted for over 30 percent of the total potential chronic risks in 1992.

The results also suggest that when toxicity is defined in acute terms, potential risk from pesticide application may be slightly greater in 1992 than it was in 1964. The acute measure may be most meaningful to farmers, pesticide applicators, and farmworkers, all of whom have higher probabilities of acute exposure. However, the Environmental Protection Agency and State agencies have instituted a number of farmworker safety regulations (protective clothing, enclosed application systems, field re-entry

Estimating Pesticide Impact or Risk

Impact or risk from pesticides can be estimated from some combination of toxicity and exposure factors. Ideally, procedures and estimated measurements used to account for the potential environmental and human-health impacts of pesticide applications would include factors related to mobility of pesticides, persistence in the environment, exposure route (proportion of pesticide likely to enter the air, run off in surface water, adhere to sediment, percolate into ground water, and remain as residue on food), toxicity to each of many species, and size of the populations potentially subject to exposure. Toxicity varies by species, and varies depending upon whether the exposure is chronic or acute. Likewise, persistence is not an inherent characteristic of a pesticide active ingredient, but varies with temperature, moisture, and exposure to sunlight and to microbial degradation. Further, the data generally available on persistence are for the first soil half-life, which itself is but one indicator of persistence, and are not necessarily equal to subsequent half-lives. The amount of pesticide in runoff, leachate, and soil particles depends not only on the amount of rainfall, but its intensity and the interval between pesticide application and the occurrence of the rain. Each of these factors is occurrence-specific.

A system capable of accounting for all of these factors cannot be realistically constructed, especially for large areas. Data requirements would be prohibitive, and the relevance of the measure would be site-specific, unsuitable for analysis of trends on a national scale. Even if the volume of data could be modeled and managed, measures of relevant attributes do not exist for many of the more than 350 pesticide active ingredients that have been used as inputs to agricultural production over the past several decades.

The risk indicators reported here are a simplified calculation of pesticide risk, developed to be workable for analysis of historical trends at the national level. Other researchers have created indexes using related methods to conduct pesticide impact assessments for other purposes, relying on less aggregate analysis (Kovach and others, 1992; Levitan and others, 1995). By necessity, many relevant environmental and safety factors are not taken into account in the estimates reported here making these indicators less than ideal. Nevertheless, these risk indicators are superior to the information contained in data on pounds applied or acres treated. To emphasize the abstraction of this indicator from variation that exists in the real world, we view the indicators as a measure of the “potential” impact from pesticide use.

The Chronic risk index was created by combining Reference Dose as the indicator of chronic toxicity and soil half-life as an indicator of potential exposure. Use of Reference Dose implies that the units relate to human health, and may not necessarily be useful indicators of potential impact on other species. For active ingredients for which it was available, the EPA’s Reference Dose measure was used. If that measure was not available, a Reference Dose estimate from the Office of Pesticide Programs (EPA), characterized by less rigorous review, was substituted. Lacking either of those indicators of toxicity for some active ingredients, estimates reported by the World Health Organization were used. Averages for the active ingredient’s chemical family were used in other cases. Using Reference Dose does not take into account carcinogenic potential that is built into other health measures from the EPA, such as health advisory levels and maximum contaminate levels. These latter measures are available only for a very limited number of active ingredients, however.

The soil half-life measures are taken from databases constructed by the Agricultural Research Service. As such, the indicators for each active ingredient are midpoints of the range of soil half-lives reported in the literature, which in turn are based on estimates derived under a variety of soil, moisture, and temperature conditions.

The acute risk index was created by combining an Oral LD50 measure of toxicity and the same soil half-life measure of potential exposure. Where available, the Oral LD50 for rats was used. For some active ingredients, this measure was not available, and an Oral LD50 for a related mammal, usually mice, was substituted. This procedure is less than ideal in that acute toxicity varies widely among species. No adjustment was made to translate the rat LD50 into human terms. The Oral LD50 is a severe threshold, implying the ingestion of an amount of active ingredient sufficient to kill 50 percent of the treated animals. Such a severe level of exposure is unlikely in reality. Despite its limitation, Oral LD50 for rats or related mammals should provide a relative indicator of risk to humans and other species from acute exposure. EPA has developed less severe indicators in the form of 1- and 10-day health advisory levels, but they are available only for a limited number of active ingredients.

Table 3.2.5—Indicators of pesticide use and risk on major crops, selected years 1964-92[1]

Pesticide type	Measures[2]	1964	1966	1971	1992
		Percent of total pesticides			
Herbicides	pounds a.i.	23.58	34.26	49.83	67.30
	chronic risk indicator	0.21	0.27	0.93	15.26
	acute risk indicator	0.77	1.40	1.85	4.93
Insecticides	pounds a.i.	55.07	47.74	34.52	10.13
	chronic risk indicator	97.72	97.97	95.45	54.04
	acute risk indicator	91.32	94.82	88.84	91.76
Fungicides	pounds a.i.	9.33	8.49	7.74	6.57
	chronic risk indicator	0.05	0.06	0.08	2.95
	acute risk indicator	0.01	0.03	0.02	0.09
Other pesticides	pounds a.i.	12.02	9.50	7.91	16.00
	chronic risk indicator	2.02	1.70	3.53	30.75
	acute risk indicator	7.89	3.75	9.29	3.22
		Index: 1964 = 100			
Herbicides:	pounds a.i.	100	159	362	706
	chronic risk indicator	100	163	344	838
	acute risk indicator	100	145	283	705
Insecticides:	pounds a.i.	100	95	107	45
	chronic risk indicator	100	125	75	5
	acute risk indicator	100	382	115	111
Fungicides:	pounds a.i.	100	100	142	174
	chronic risk indicator	100	133	120	648
	acute risk indicator	100	179	160	744
Other pesticides:	pounds a.i.	100	87	113	329
	chronic risk indicator	100	105	134	173
	acute risk indicator	100	38	139	45
Total pesticides:	pounds a.i.	100	109	171	247
	chronic risk indicator	100	125	76	11
	acute risk indicator	100	80	118	110

[1] Estimates include corn, soybeans, wheat, cotton, sorghum, rice, peanuts, potatoes, other vegetables, citrus, and apples. See table 3.2.2 for pesticide quantities. [2] See glossary for definitions. Source: USDA, ERS, preliminary estimates.

intervals, and training) to reduce farmworkers' exposure to pesticides.

Factors Affecting Pesticide Use

Prior to the development of synthetic pesticides following World War II, a farmer's solution to weed, insect, and disease problems was primarily the use of physical and cultural practices. Weeds were controlled by tillage, mowing, site selection, crop rotation, use of seeds free of weedseeds, and hoeing or pulling by hand. Insect pests and diseases were controlled through seed selection, crop rotations, adjustment of planting dates, and other cultural practices, but the risk of severe infestations, yield losses, and even abandoned production was still ever-present.

Between 1950 and 1980, chemical pest control was widely adopted on most crops (table 3.2.2). Public and private research introduced new pesticides (and other innovations) that could increase yields and substitute for some farm labor, machinery, and fuel. Higher prices for energy and other manufactured inputs along with rising wage rates promoted this trend. By 1980, herbicide use climbed toward 100 percent of the acreage of corn, soybeans, cotton, and many other crops. Insecticides and other pesticides were also widely used.

Although the adoption of pesticides as a crop production technology was nearly complete by the mid 1970's, many factors continue to affect the use of pesticides. Changes in planted acres or shifts in production between commodities and regions can affect the number of acres treated and applied quantities. Pest cycles and annual fluctuations caused by weather and other environmental conditions often determine whether infestation levels reach treatment thresholds. Changes in pesticide regulations, prices, new products, and pest resistance to pesticides also affect the producer's selection of active ingredients, application rates, and methods of treatment. (See chapter 4.4, *Pest Management* for more information.)

Federal Agricultural Programs

Federal commodity and conservation programs provide mixed incentives to both increase and decrease pesticide use. Acreage restrictions and set-aside provisions in past commodity programs and the Conservation Reserve Program reduced planted acreage and, hence, pesticide use on those acres that otherwise would have been in production. Pesticide use dropped in 1983 with the large feedgrain acreage idled under the payment-in-kind program (PIK) and has subsequently paralleled other major changes in planted acreage (Aspelin, 1994). On the other hand, Federal programs can provide incentives to increase pesticide use on the land that is not set aside. When planted acreage was constrained and price expectations included program payments, producers tended to substitute nonland inputs, including fertilizer and pesticide, to boost yields and capture higher returns on their eligible planted acreage. Participants in Federal commodity programs used higher nitrogen fertilizer and herbicide application rates than producers who did not participate (Ribaudo and Shoemaker, 1995).

The Federal Agriculture Improvement and Reform Act of 1996 removes the link between income support payments and current farm production and will likely remove most incentives for producers to substitute yield increasing inputs per acre of planted land. However, producers' greater planting flexibility could lead to increased pesticide use as idled land returns to production. Producers are now permitted to plant 100 percent of their total base acreage plus additional acreage to any crop (with some exceptions for fruits and vegetables) without loss of Federal subsidy.

Pesticide Prices

Aggregate pesticide use is negatively related, but relatively unresponsive, to changes in pesticide prices (Fernandez-Cornejo, 1992; McIntosh and Williams, 1992; and Oskam and others, 1992). That is, the percentage change in quantity of pesticide use is relatively less than the percentage change in the price of pesticides. Given the evidence that pesticide demand is relatively unresponsive to pesticide price changes, along with relatively small annual pesticide price changes over the last several years, we would expect that pesticide use, in general, has been largely unaffected by prices.

While overall pesticide use may not be very responsive to small price changes, individual product use can vary from year to year. When different pesticide products are perfect or near-perfect substitutes, small price changes can result in significant changes in the mix of products used as farmers attempt to maximize profits. Pesticide prices, as measured by the agricultural chemicals price index, increased 2-5 percent annually from 1991 to 1995 (table 3.2.6). In total over the 1991-95 period, herbicide prices increased about 12 percent while fungicide prices rose nearly 16 percent, and insecticide prices showed a 19-percent increase. Fungicide prices, which ranged from a 2-percent annual decline (1993-94) to a 7-percent annual increase (1994-95), were the most variable.

Reflecting the price changes and increased use, pesticide expenditures for all farm uses increased about 2 to 7 percent annually over 1991-95 (USDA, Aug. 1996). Pesticide costs per acre for cotton, soybeans, and wheat remained relatively unchanged between 1991 and 1995, but the pesticide costs for corn increased about 4 percent each year. Pesticide costs for corn edged over $25 per acre in 1994, accounting for 13 percent of total fixed and variable cash production expenses. Pesticide expenditures on cotton, with the largest cost for insecticides, were about $50 per acre and accounted for 15 percent of cash production expenses. Pesticide costs on soybeans ($24 per acre) accounted for 13 percent of cash production expenses while costs on wheat ($6 per acre) accounted for 8 percent.

Index numbers are useful aggregate measures for monitoring price changes, but indexes can mask movements in individual components of the index. Common pesticide active ingredients showed different price trends between 1991 and 1995 (table 3.2.6). These price changes typically reflect shifts in factors such as cost of manufacturing and distribution, price of competing products, patent protection, and planted acreage of the treated crop.

Among insecticides, carbaryl, methyl parathion, and phorate had price increases of 25 percent or more.

Table 3.2.6—Selected April pesticide prices, 1991-1995

Active ingredient	1991	1992	1993	1994	1995	1991-92	1992-93	1993-94	1994-95	1991-95
	Dollars per pound of active ingredient					*Annual percent change*				
Insecticides:										
Aldicarb	22.20	na	22.07	24.67	24.33	na	na	11.8	-1.4	9.6
Carbaryl	4.44	4.95	5.36	5.41	5.74	11.5	8.3	0.9	6.0	29.3
Carbofuran	10.40	10.87	12.20	12.80	12.73	4.5	12.3	4.9	-0.5	22.4
Chlorpyrifos	10.65	11.30	12.03	12.10	12.33	6.1	6.4	0.6	1.9	15.7
Dimethoate	na	11.12	11.05	9.70	10.11	na	-0.7	-12.2	4.2	
Esfenvalerate	187.88	192.42	200.00	210.61	219.70	2.4	3.9	5.3	4.3	16.9
Methomyl	21.44	21.60	22.43	24.14	24.36	0.8	3.8	7.6	0.9	13.7
Methyl parathion	5.10	5.35	5.83	5.98	6.83	4.9	8.9	2.6	14.2	33.8
Permethrin	45.94	46.88	48.13	47.81	48.13	2.0	2.7	-0.6	0.7	4.8
Phorate	7.80	8.05	8.80	9.15	9.90	3.2	9.3	4.0	8.2	26.9
Fungicides:										
Benomyl	31.60	32.60	34.00	35.80	36.00	3.2	4.3	5.3	0.6	13.9
Captan	5.12	5.74	5.96	6.16	6.62	12.1	3.8	3.4	7.5	29.3
Chlorothalonil	7.30	8.04	8.63	8.67	8.75	10.2	7.4	0.4	1.0	19.9
Iprodione	40.40	43.60	45.60	46.60	46.00	7.9	4.6	2.2	-1.3	13.9
Mancozeb	3.54	3.79	3.94	3.87	4.01	7.3	3.7	-1.6	3.7	13.5
Maneb	3.13	na	3.24	3.16	3.38	na	na	-2.3	6.7	8.0
Metalaxyl	74.50	74.00	76.50	81.00	85.00	-0.7	3.4	5.9	4.9	14.1
Sulfur	0.73	0.69	0.53	0.39	0.37	-4.3	-24.2	-26.0	-5.4	-49.3
Triadimefon	108.40	100.00	112.40	115.60	120.20	-7.7	12.4	2.8	4.0	10.9
Ziram	3.24	na	3.61	3.70	3.66	na	na	2.6	-1.1	13.0
Herbicides:										
2,4-D	2.83	2.93	3.20	3.38	3.55	3.5	9.4	5.5	5.2	25.7
Alachlor	6.15	6.35	6.45	6.48	7.03	3.3	1.6	0.4	8.5	14.2
Atrazine	na	2.88	3.15	3.45	3.60	na	9.6	9.5	4.3	
Bentazon	15.38	15.75	16.40	16.98	18.28	2.4	4.1	3.5	7.7	18.9
Chlorimuron	1139.20	1145.60	1152.00	1171.20	1184.00	0.6	0.6	1.7	1.1	3.9
Cyanazine	5.65	5.83	5.95	6.55	7.08	3.1	2.1	10.1	8.0	25.2
Dicamba	17.45	18.18	19.48	19.40	21.88	4.2	7.2	-0.4	12.8	25.4
Glyphosate	13.85	na	13.03	13.40	13.53	na	na	2.9	0.9	-2.3
Imazaquin	134.67	135.33	137.33	140.67	142.67	0.5	1.5	2.4	1.4	5.9
MCPA	3.25	3.25	3.65	3.68	3.98	0.0	12.3	0.7	8.2	22.3
Metolachlor	7.49	7.69	7.79	7.85	8.46	2.7	1.3	0.8	7.8	13.0
Metribuzin	31.73	32.67	34.27	36.27	36.67	2.9	4.9	5.8	1.1	15.5
Pendimethalin	8.85	9.27	9.24	9.12	8.76	4.8	-0.3	-1.3	-4.0	-1.0
Sethoxydim	82.00	76.67	75.33	76.00	74.67	-6.5	-1.7	0.9	-1.8	-8.9
Trifluralin	7.50	8.00	8.08	8.13	8.20	6.7	0.9	0.6	0.9	9.3
Agricultural chemicals price index (1990-92 = 100)	101	103	107	112	115	2.0	3.9	4.7	2.7	13.9
Herbicides	101	102	106	110	113	1.0	3.9	3.8	2.7	11.9
Insecticides	101	104	110	117	120	3.0	5.8	6.4	2.6	18.8
Fungicides & others	101	105	111	109	117	4.0	5.7	-1.8	7.3	15.8

na = not available.
Source: USDA, ERS, based on NASS farm supply dealers annual survey.

These latter three insecticides are widely used on corn as well as several minor fruit and vegetable crops. Most fungicide prices rose over 10 percent, while captan and chlorothalonil increased more than 20 percent. Both captan and chlorothalonil are used extensively on fruit, vegetable, and nut crops such as apples (captan) and peanuts (chlorothalonil) while sulfur (which dropped in price) is heavily applied to grapes.

Among herbicides, the price of sethoxydim dropped while those for 2,4-D, atrazine, cyanazine, dicamba, and MCPA rose. With the exception of MCPA, which is used primarily on wheat and barley, the herbicides with the greatest price increases were extensively used in corn production. However, 2,4-D and dicamba are also used on pasture and wheat land; atrazine is heavily used on corn and sorghum; and cyanazine is a major cotton herbicide.

Pesticide Legislation

The U.S. Environmental Protection Agency (EPA) registers pesticides and ensures they are safe. The Food Quality Protection Act of 1996 defines safe for dietary consumption products as "a reasonable certainty that no harm will result from aggregate exposure" including food, drinking water, and nonoccupational exposures. Under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and its amendments, the EPA decides which pesticides are registered and prescribes labeling and other regulatory requirements on their use to prevent unreasonable adverse effects on health and the environment. EPA also regulates pesticides under the Federal Food, Drug, and Cosmetic Act (FFDCA), which requires that tolerances for residues on food and drinking water be established. These tolerances are enforced through monitoring and inspections conducted by the Food and Drug Administration and USDA. (See box, “Pesticide Tolerance and Dietary Risks.")

The Clean Air Act (1970), Clean Water Act (1972), Resource Conservation and Recovery Act (1976), and the Comprehensive Environmental Response, Compensation, and Liability Act (1980) (or Superfund) also contain provisions that apply to pesticide manufacturers that affect their cost of production. The Clean Air Act mandates discharge limits on pollutants, RCRA specifies how to dispose of toxic substances, and the Superfund stipulates who pays for the cleanup of toxic dump sites. All of these regulatory requirements affect the development time and cost of pesticide production. Recent estimates suggest that the research and development of a new

Pesticide Tolerance and Dietary Risks

The Food Quality Protection Act of 1996 sets a consistent safety standard for pesticide use on all foods, and for all health risks. Under the new law, both fresh and processed foods may contain chemical residues at tolerance levels that have been determined to be safe by the EPA. Previously, the largely unenforced "Delaney Clause" of the Federal Food, Drug, and Cosmetic Act prohibited processed foods, but not fresh foods, from containing even trace amounts of carcinogenic chemical residues. The new law contains provisions that "ensure that there is reasonable certainty that no harm will result to infants and children from aggregate exposure." The EPA is required to reassess existing tolerances of all pesticides within 10 years, with priority given to pesticides that may pose the greatest risk to public health.

USDA’s pesticide monitoring by the Agricultural Marketing Service (AMS) measures residues on both domestic and imported samples of fresh fruits and vegetables common in the diets of the U.S. population. The AMS monitoring is used not only to respond to food safety concerns but also to provide the EPA with data to assess the actual dietary risk posed by pesticides. Without actual exposure data, the pesticide registration process assumes all producers apply maximum allowable amounts. This assumed maximum risk may significantly exceed actual risk and jeopardize the registration process for products important to agricultural production. Some pesticide residues were found on 71 percent of the samples in 1993 and 46 percent of the samples in 1994; however, few exceeded established tolerance levels (USDA, AMS, 1996). Of 7,589 samples analyzed in 1994, 4 residue samples exceeded established tolerance and 88 samples had residues where no tolerance was established. Even though the use of DDT has been banned since 1972, 5.5 percent of the 1994 detections were for DDT or its metabolites. Once applied, DDT is slow to degrade in the soil and can continue to occur on crops grown in that soil. The DDT residues were found primarily in root crops and none exceeded tolerance levels. On samples where any pesticide residue was detected, 38 percent were from postharvest pesticide products normally applied to produce to prevent spoilage during storage and transportation.

pesticide takes 11 years and can cost manufacturers between $50 and $70 million (Ollinger and Fernandez-Cornejo, 1995). Results of a study of the impact of pesticide product regulation on innovation and the market structure in the U.S. pesticide industry indicate that regulation encourages the development of less toxic pesticide materials but discourages new chemical registrations, encourages firms to abandon pesticide registrations for minor crops, and favors large firms over smaller ones. Pesticide regulation also encourages firms to develop biological pesticides as an alternative to chemical pesticides (Ollinger and Fernandez-Cornejo, 1995).

States are also active in regulating pesticide use. In 1996, most States had some regulations related to pesticide use in agriculture and/or lawn care, and over half have groundwater laws, posting requirements, and pesticide reporting regulations (Meister Publishing, 1996). Over a third of the States had health advisory levels, containment regulations, and bulk chemical regulations, and 13 States had requirements for reporting pesticide illnesses.

The majority of States also have pesticide registration fees, many of which have increased in the last several years. Nine States tax pesticide products or have other special taxes (Meister Publishing, 1996) that have been used to fund research on pesticide alternatives. For example, the Leopold Center for Sustainable Agriculture, which conducts research on environmentally friendly alternatives, is partially supported from a tax on pesticide and fertilizer sales.

Pesticide Registrations

The EPA registration process requires manufacturers to provide scientific data to substantiate that a proposed product is safe and poses no unreasonable adverse effects to human health or the environment. Tests pertaining to toxicology, reproduction disorders and abnormalities, and potential for tumors from exposure to the pesticide are required. Other required tests evaluate the effect of pesticides on aquatic systems and wildlife, farm worker health, and the environment. The registration process can require up to 70 different types of tests to substantiate the safety of the product. Since 1989, the number of pesticide active ingredients for sale in the United States has decreased by 50 percent and further declines are expected due to reregistration requirements and costs (Pease and others, 1996).

The recently enacted Food Quality Protection Act of 1996 requires periodic re-evaluation of pesticide registrations to ensure that the scientific data supporting registrations remain current. The new law mandates a screening program for estrogenic and other endocrine or synergistic effects and sets a goal for all pesticides to be reviewed and updated on a 15-year cycle. The registration and re-registration process also prescribes those commodities on which the pesticides can be used, at what concentration they can be applied, when and how they are to be applied, and what safety precautions are to be used during and after application. Table 3.2.7 identifies some of the key regulatory action taken against agricultural pesticides and gives the status of special reviews being conducted for reregistration.

The EPA is currently conducting a special review of triazine herbicides (atrazine, cyanazine, and simazine). In 1995, the manufacturers of cyanazine voluntarily withdrew its registration rather than proceed with the special review. Cyanazine, which is identified as a carcinogenic material, is the third most used herbicide on corn and cotton and is also commonly used on sorghum and other crops to control grasses and broadleaf weeds. The manufacturer has agreed to stop selling products containing cyanazine by 1999.

Mevinphos and propargite are insecticides that have been voluntarily canceled by their manufacturers. Mevinphos was canceled for all uses in 1994 due to concerns about acute toxicity and farmworker safety. Because this pesticide degrades quickly after application, it requires only a short interval before harvesting. It was used for aphid control on many fresh fruits and vegetables late in the growing season when other agents could not be applied. Propargite was withdrawn in early 1996 due to concern about residues on fresh market produce and possible exposure to infants and children. It was canceled for use on apples, apricots, cranberries, figs, green beans, lima beans, peaches, pears, plums, and strawberries.

In 1993, regulatory action was taken for methyl bromide under the Clean Air Act because of its adverse affect on the ozone layer in the upper atmosphere. Production and use will be terminated in 2001 and annual production until that date is limited to the 1991 level.

Pesticide Resistance

Pesticide resistance is most likely to develop when a pesticide with a single mode of action is used over and over in the absence of any other management measures to control a specific pest. If a weed, insect, or fungi species contains an extremely low number of biotypes resistant to the killing mode of the pesticide,

Table 3.2.7—EPA regulatory actions and special review status on selected pesticides used in field crops production, 1972 - June 1995

Pesticide	Regulatory action and date
Alachlor	Uses restricted and label warning, 1987; under EPA review for groundwater contamination
Aldicarb	Use canceled on bananas, posing dietary risk, 1992
Aldrin	All uses canceled except for termite control, 1972
Captafol	All uses canceled, 1987
Chlordimeform	All uses canceled, 1988. Use of existing inventory until 1989
Cyanazine	Manufacturers voluntarily phasing out production by 2000 but stock can be used until 2003
DDT	All uses canceled except control of vector diseases, health quarantine, and body lice, 1972
Diazinon	All use on golf course and sod farms canceled, 1990
Dimethoate	Dust formulation denied and label changed, 1981
Dinoseb	All uses canceled, 1989
EBDC (Mancozeb, Maneb,Metiram, Nabam, Zineb)	Protective clothing and wildlife hazard warning, 1982
Endrin	All uses canceled, 1985
EPN	All uses canceled, 1987
Ethalfluralin	Benefits exceeded risks, additional data required, 1985
Heptachlor	All uses canceled except homeowner termite product, 1988
Linuron	No regulatory action needed, 1989
Methyl Bromide	Annual production and use limited to 1991 levels with use to be terminated in 2001, 1993
Mevinphos	Voluntary cancellation of all uses, 1994
Monocrotophos	All uses canceled, 1988
Parathion	Use on field crops only, 1991; under EPA review with toxicological data requested
Propargite	Registered use for 10 crops canceled, 1996. Use for other crops remains legal
Toxaphene	Most uses canceled except emergency use for corn, cotton, and small grains for specific insect infestation, 1982
Trifluralin	Restrictions on product formulation, 1982
2,4-D (2,4-DB, 2,4-DP)	Industry agreed to reduce exposure through label change and user education, 1992

Source: USDA, ERS, based on information in EPA, 1995.

then those species that survive the pesticide treatment reproduce future generations containing the pesticide resistant trait. As this process repeats, the resistance trait multiplies and begins to account for a significant share of the species' population.

Although herbicide-resistant weeds have been documented since the early 1950's, their prominence in the last two decades has increased, resulting in management strategies that seek to minimize development of pesticide-resistant species. Rotating pesticides with different modes of action, applying mixtures of herbicides, reducing application rates, and combining mechanical or nonchemical control practices are some management strategies to reduce pesticide resistance (Meister Publishing, 1966). Resistance to triazine herbicides (atrazine, cyanazine, and simazine) is one of the more common weed-resistant problems in corn and sorghum. Farmers responding to USDA's Cropping Practices Survey in 1994 reported that 16 percent of the corn acreage had triazine-resistant weeds. To deter these and other weed resistance problems, producers reported that they alternated herbicides on the majority of corn, soybean, and cotton acreage. In recent years, producers also have reported using different active ingredients on each treated acre and lowering the application rates, both practices prescribed to deter herbicide resistance.

Similar to the development of weeds resistant to herbicides, the incidence of insects, mites, and disease-causing fungi species resistant to pesticides also causes producers to switch to different chemicals or pest controls (NRC, 1986). Once insect or fungi species develop resistance to one ingredient, the time required to develop resistance to other ingredients of the same chemical family is often much less. Over a short period of time, species resistant to an entire family of ingredients can develop and require a different mode of treatment. At least partially due to development of insecticide resistance, cotton insecticide families shifted from mostly organochlorines prior to the 1970's to organophosphates and carbamates and more recently to synthetic pyrethroids (Benbrook, 1996). Scouting to determine economic thresholds for treatments, alternating the use of pesticide families, and several other management strategies to combat resistance are now in use (see chapter 4.4, *Pest Management*).

New Pest Control Products and Technology

Each year, the EPA registers several new pesticides which producers may adopt if they offer improved pest control and are profitable. Acetachlor was granted conditional registration in 1994 as an herbicide for use on corn that would help reduce overall herbicide usage. The registration allows automatic cancellation if the use of other herbicide products is not reduced or if acetachlor is found in ground water. In 1995, about 23 million pounds of the new product were applied to 20 percent of U.S. corn acreage (table 3.2.3). The reduced pounds of alternative herbicides (alachlor, metolachlor, atrazine, EPTC, butylate, and 2,4-D) more than offset the pounds of acetachlor.

Other pesticide products have significantly affected the quantity of total use. For example, Imazethapyr, first registered for use on soybeans in 1989, has become the most widely used soybean herbicide in the United States. This herbicide, applied at less than 1 ounce per acre, often replaced trifluralin and other older products, applied at rates many times higher than imazethapyr.

Transgenic corn and cotton seeds have been marketed recently in the hope of reducing the need to apply insecticides. These seeds were bioengineered to produce Bt, a bacterial insecticide that can control cotton bollworms, European corn borer, and other insects when they eat plant tissues containing the Bt bacteria. Some scientists are concerned that the plants do not produce sufficient levels of pesticides and that the pest survival rates will speed up the evolution of pest resistance to Bt, including Bt sprays. Resistance management plans are often prescribed when these products are adopted (*Science*, 1996). About 13 percent of the U.S. cotton acreage was reported planted with this transgenic cotton seed in 1996. Bt, as a spray insecticide, was applied to 9 percent of the 1995 cotton acres, but only 1 percent of the corn acres.

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Glossary

Acute Risk Indicator—An indicator of the potential human and environmental health risk from an acute exposure to pesticides. An indicator value equal to 1 is the presence of 1 LD50 dose in the environment for 1 day. (See box, "Estimating Pesticide Impact or Risk," p. 124)

Amount of pesticide applied is the total pounds of all pesticide active ingredient (excluding carrier materials) applied. Because this sum can include materials applied at very different rates, differences in the amount applied do not necessarily represent differences in the intensity of the treatment or potential health and environmental risks.

Chronic Risk Indicator—An indicator of the potential human health risk from a chronic exposure to pesticides. An indicator value equal to 1 is the presence of 1 Reference Dose in the environment for 1 day.

LD50 dose—The constructed measure reflects the pesticide dose level (mg/kg of body weight) which results in 50 percent mortality of laboratory test animals. The LD50 values used in constructing the acute risk indicator relate to ingestion of the active ingredient (Oral LD50).

Land receiving pesticides represents an area treated one or more times with a pesticide material. Pesticide materials include products used to kill weed, plant, and fungi pests, as well as products used as growth regulators, soil fumigants, desiccants, and harvest aids.

Number of acre-treatments applied represents total number of ingredients applications made throughout the growing season. A single treatment containing two ingredients is counted as 2 acre-treatments as is 2 treatments containing a single ingredient.

Number of ingredients applied represents the total number of different active ingredients applied throughout the growing season on a field. It does not reflect repeat applications of the same ingredient during the production year.

Number of treatments applied represents the number of application passes made over a field to apply pesticides. One or more pesticide materials may be applied with each treatment. This measurement reflects labor and pesticide application equipment usage.

Pesticide, according to the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), is "... any substance or mixture of substances intended for preventing, destroying, repelling or mitigating any insects, rodents, nematodes, fungi, or weeds, or any other forms of life declared to be pests; and any substance or mixture of substances intended for use as a plant regulator, defoliant, or desiccant." Types or classes of pesticides are:

- **Fungicides—**Control plant diseases and molds that either kill plants by invading plant tissues or cause rotting and other damage to the fruit before and after it can be harvested.

- **Herbicides**—Control weeds which compete for water, nutrients, and sunlight and reduce crop yields. Herbicides that are applied before weeds emerge are referred to *preemergence herbicides.* Preemergence herbicides have been the foundation of row crop weed control for the past 30 years. Herbicides applied after weeds emerge are referred to as *postemergence herbicides.* Postemergence herbicides are sometimes considered more environmentally sound than preemergence herbicides because they normally have little or no soil residual activity. Treatments applied prior to any tillage or planting to kill existing vegetation are referred to as *burndown applications*. Burndown applications are often a part of no-till systems.

- **Insecticides—**Control insects that damage crops. Also include materials used to control mites and nematodes.

- **Other Pesticides—**Include soil fumigants, growth regulators, desiccants, and other pesticide materials not otherwise classified.

Reference Dose—The constructed measure reflects the long-term safety/toxicity of pesticides to humans. It is measured as the no-observable-effect level of a pesticide ingredient multiplied by an uncertainty factor, which adds an additional safety factor in translating animal no-observable-effect levels to human no-observable-effect levels. The constructed value represents the "dose" (mg./lb. of body weight) which could be consumed daily over a 70-year life span by a person weighing 70 kg. without having adverse health effects.

Recent ERS Research on Pesticide Issues

"Phasing Out Registered Pesticide Uses as an Alternative to Total Bans: A Case Study of Methyl Bromide," *Journal of Agribusiness*, Vol. 15, No. 1, 1997. (Walt Ferguson, Jet Yee) This article examines how a phase-out strategy, in place of an immediate ban on all crops, would affect consumers and producers and still achieve much of the human health and environmental benefits of an immediate and total ban.

Agricultural Chemical Usage, 1995 Fruits Summary (Ag CH1 96), July 1996. This report continues a series of biennial reports of chemical use on most fruit commodities produced in the United States. This summary contains state estimates of primary nutrients and pesticide active ingredients use in the on-farm production of these commodities.

Agricultural Chemical Usage, 1995 Field Crop Summary. (Ag CH 1 96), March 1996. This report continues a series of annual field crop summaries since 1990 that estimate on farm fertilizer and pesticide use on U.S.-produced corn, cotton, potatoes, soybeans, and wheat. This summary contains State estimates of the primary nutrients and pesticide active ingredients used in the production of these commodities.

Pesticide Residues, Reducing Dietary Risks. AER-728, Jan. 1996. (Fred Kuchler, Katherine Ralston, Laurian Unnevehr, Ram Chandran) New data on pesticide residues, food consumption, and pesticide use are used to analyze the sources of consumers' dietary intake of pesticide residues and the benefits of research to develop safer alternatives to pesticide use. This study reports that canceled but persistent chemicals appear among the highest risk indicators; postharvest uses account for the largest share of dietary intake of residues; residue levels vary among domestic and imported commodities; and consumption patterns, especially those of children, influence risks from pesticide residues.

Regulation, Innovation, and Market Structure in the U.S. Pesticide Industry. AER-719, 1995. (Michael Ollinger, Jorge Fernandez-Cornejo) This report examines how EPA regulation affects new chemical pesticide registrations, new chemical pesticide safety and use, industry composition, and technology choice.

"The Effect of Feedgrain Program Participation on Chemical Use." *Agricultural and Resource Economics Review*, Oct. 1995. (Marc Ribaudo, Robbin Shoemaker) This journal article addresses whether commodity programs create economic incentives and conditions that result in higher per-acre use of chemicals than would occur under free-market conditions. The feedgrain program appears to provide incentives for participants to apply more fertilizer and herbicides than nonparticipants.

Agricultural Chemical Usage, 1994 Vegetable Summary. (Ag CH1 95), July 1995. This report continues a series of biennial reports of chemical use on most vegetable commodities produced in the United States. This summary contains State estimates of primary nutrients and pesticide active ingredients used in the on farm production of these commodities.

Pesticide and Fertilizer Use and Trends in U.S. Agriculture. AER-717, May 1995. (Biing-Hwan Lin, Merritt Padgitt, Len Bull, Herman Delvo, David Shank, Harold Taylor) Trends in fertilizer and pesticide use since 1964 along with economic analysis of factors influencing agricultural chemical use are contained in this report.

Adoption of Integrated Pest Management in U.S. Agriculture. AIB-707, Sept 1994. (Marc Ribaudo, Robbin Shoemaker) This report summarizes information on the extent of adoption of integrated pest management (IPM) techniques in the production of fruits, vegetables, and major field crops. Levels of IPM vary widely among crops and regions, but about half of all fruit, vegetable, and major field crop acreage uses some IPM techniques.

Atrazine: Environmental Characteristics and Economics of Management. AER-699, 1994. (Marc Ribaudo, A. Bauzaher) This report presents the costs and benefits of an atrazine ban, a ban on pre-plant and pre-emergent applications, and a targeted ban to achieve a surface water standard. A complete atrazine ban is hypothesized to be the costliest strategy, while the targeted strategy is the least costly.

Economic Effects of Banning Methyl Bromide for Soil Fumigation. AER-677, 1994. (Walt Ferguson, A. Padula) This report estimates the consequences for producers and consumers of banning the use of methyl bromide for agricultural uses.

(Contact to obtain reports: Merritt Padgitt, (202) 219-0433 [mpadgitt@econ.ag.gov])

3.3 Energy

Agriculture uses energy directly for operating machinery and equipment on the farm and indirectly in fertilizers and pesticides produced off the farm. Since a 1978 peak, total energy use in agriculture (excluding electricity) fell by 25 percent to 1.6 quadrillion British thermal units (Btu) in 1993, due to improved energy efficiency. An additional 1 quadrillion Btu of energy is used by the food processing industry. Agriculture also supplies renewable energy in the form of biomass for electricity generation and as feedstocks, mostly corn, for production of alternative fuels such as ethanol.

Contents

Different types of energy are often required for different activities in food production. Energy used to produce food is classified as either direct or indirect. Direct energy, mostly refined petroleum products, is used on farms for planting and harvesting, fertilizer and pesticide application, and transportation, while electricity is used for irrigation and other purposes. Dairies require a major input of electricity for cooling milk, operating milking systems, and supplying hot water for sanitation. Indirect energy, on the other hand, is consumed off the farm for manufacturing fertilizers and pesticides. In addition, substantial amounts of energy, including natural gas, oil, electricity, and coal, are used in manufacturing or processing of food after it leaves the farm. Most food processing firms use energy to provide steam, hot water, and process heating.

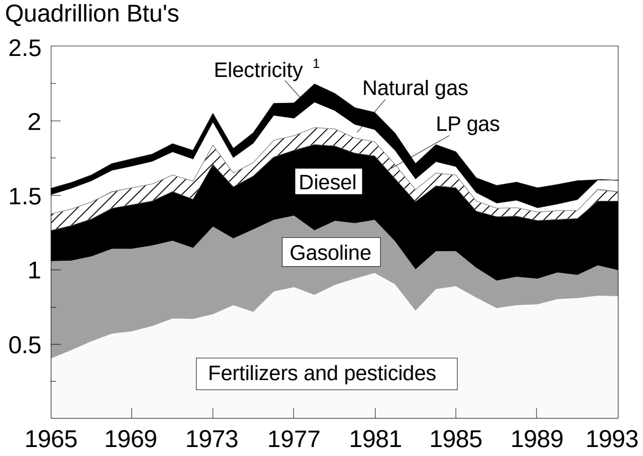
The agricultural sector also supplies energy. The Clean Air Act Amendment of 1990 (CAA) has increased the demand for ethanol—already used as a fuel extender and octane enhancer—by requiring oxygenates in about 35 percent of the Nation's gasoline. Ethanol primarily uses corn as a feedstock, but can use other biomass as well. On a larger scale, biomass from agricultural and forestry sources is used directly as fuel for electricity generation.

Energy Use in Agricultural Production

Agricultural energy use peaked at 2.2 quadrillion Btu in 1978. However, oil price shocks during the late 1970's and early 1980's forced farmers to become more energy-efficient. Many farmers have switched from gasoline-powered to fuel-efficient diesel-powered engines, adopted energy-conserving tillage practices, shifted to larger multifunction machines, and adopted energy-saving methods of crop drying and irrigation. Between 1978 and 1993, energy (excluding electricity) used by agriculture declined 25 percent, primarily due to a reduction in the direct use of energy (gasoline, diesel, liquefied petroleum or LP gas, and natural gas); energy used to produce fertilizers and pesticides declined only slightly. (Separate electricity expenditures in agriculture have not been available since 1991.)

In addition, the composition of energy use has changed significantly. Gasoline use has dropped from 42 percent of total energy use in 1965 to only 11 percent in 1993, while diesel's share of diesel fuel has risen from 13 percent to 29 percent (fig 3.3.1). This

Figure 3.3.1--Composition of energy use in agriculture, 1965-93



[1] No data on electricity use since 1991.

Source: USDA, ERS.

Table 3.3.1—Fuel purchased for farm use, 1974-94[1]

Year	Gasoline	Diesel	LP gas
		Billion gallons	
1974	3.7	2.6	1.4
1975	4.5	2.4	1.0
1976	3.9	2.8	1.2
1977	3.8	2.9	1.1
1978	3.6	3.2	1.3
1979	3.4	3.2	1.1
1980	3.0	3.2	1.1
1981	2.7	3.1	1.0
1982	2.4	2.9	1.1
1983	2.3	3.0	0.9
1984	2.1	3.0	0.9
1985	1.9	2.9	0.9
1986	1.7	2.9	0.7
1987	1.5	3.0	0.6
1988	1.6	2.8	0.6
1989	1.3	2.5	0.7
1990	1.5	2.7	0.6
1991	1.4	2.8	0.6
1992	1.6	3.1	0.9
1993	1.4	3.3	0.7
1994	1.4	3.5	0.9

[1] Excludes Alaska, Hawaii, and fuels used for household and personal business.

Source: USDA, ERS, based on NASS, Farm Production Expenditures Summaries, and unpublished data.

change reflects the shift away from gasoline-powered machinery toward more efficient, diesel-powered machinery.

While farm energy use declined by 25 percent between 1978 and 1993, agricultural output increased by almost 47 percent (in 1987 dollars, Economic Report of the President, 1995). As a result, the ratio of energy use to agricultural output fell by 50 percent between 1978 and 1993.

Demand for refined petroleum products such as diesel fuel, gasoline, and LP gas in agricultural production is determined mainly by the number of acres planted and harvested, price of energy, and weather. Farm fuel use in 1994 was greater than in 1993. Diesel fuel use, at 3.5 billion gallons, was up 6 percent from 1993 while LP gas, at 0.9 billion gallons, increased 3 percent (table 3.3.1). This increase was due principally to lower fuel prices and a slight increase in the number of acres planted and harvested. Gasoline consumption, at 1.4 billion gallons, was unchanged from the 1993 level.

Farm fuel prices in the United States are heavily influenced by international market conditions, particularly crude oil supplies by the Organization of Petroleum Exporting Countries (OPEC). Historically, each 1-percent increase in the U.S. price of imported crude oil has translated into a 0.7-percent rise in the farm price of gasoline and diesel fuel. Following the Arab Oil Embargo of 1973-74, world oil prices rose rapidly. They escalated again due to the Iranian crisis in 1979, peaked in 1981, then fell steadily until 1985, and fell sharply in 1986 due to a glut of oil in the world market. Oil prices rose sharply again in 1990 and 1991 following the Persian Gulf war and have since been falling gradually. Farm gasoline prices mirrored world oil prices, rising, for example, from 47 cents per gallon in 1974 to $1.29 in 1981. Between 1992 and 1994, gasoline prices fell steadily, then rose slightly in 1995 (table 3.3.2). During the first half of 1996, gasoline prices were on the rise due to increased seasonal demand.

Farm fuel expenditures represented 3.5 percent of total farm production expenses in 1994, down from 3.6 percent in 1993 (table 3.3.3). In 1994, farm fuel expenditures totaled $5.55 billion, an increase of less than 1 percent from 1993. An increase in the number of acres planted and harvested in 1994, even with lower energy prices, accounted for this slight increase in total expenditures. The Corn Belt, at $1.02 billion, was the farm production region with the highest total energy expenditures, followed by the Northern Plains at $704 million (fig. 3.3.2). Farm expenditures for

Table 3.3.2—Average U.S. farm fuel prices, 1974-95[1]

Year	Gasoline[2,3]	Diesel[3,4]	LP gas[3]
		$/gallon[5]	
1974	0.47	0.37	0.30
1975	0.50	0.39	0.30
1976	0.53	0.41	0.33
1977	0.57	0.45	0.39
1978	0.60	0.46	0.40
1979	0.80	0.68	0.44
1980	1.15	0.99	0.62
1981	1.29	1.16	0.70
1982	1.23	1.11	0.71
1983	1.18	1.00	0.77
1984	1.16	1.00	0.76
1985	1.15	0.97	0.73
1986	0.74	0.58	0.55
1987	0.92	0.71	0.59
1988	0.93	0.73	0.59
1989	1.05	0.76	0.58
1990	1.17	0.95	0.83
1991	1.19	0.87	0.75
1992	1.15	0.82	0.72
1993	1.14	0.82	0.78
1994	1.08	0.77	0.72
1995[6]	1.11	0.77	0.73

[1] Based on surveys of farm supply dealers conducted by the National Agricultural Statistics Service (NASS), USDA.

[2] Leaded regular gasoline survey item discontinued after 1992, and unleaded gasoline survey item added January, 1993.

[3] Includes Federal, State, and local per gallon taxes.

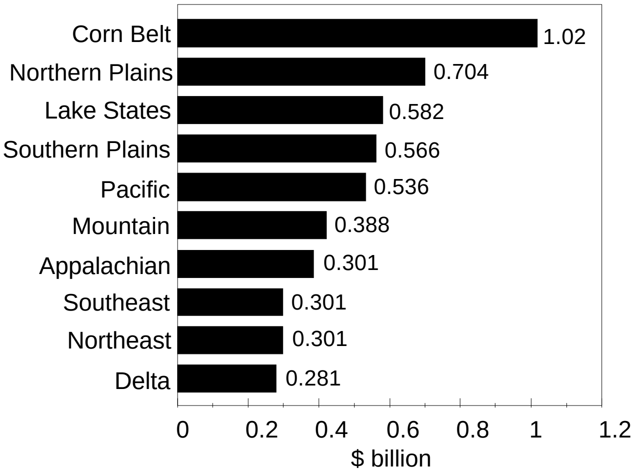
[4] Excludes Federal excise tax.

[5] Bulk delivery.

[6] Prices based on April 1995 survey of farm supply dealers conducted by NASS, USDA.

Source: USDA, ERS.

Figure 3.3.2--Farm sector fuel expenditures, by region, 1994



Source: USDA, ERS, based on NASS, Farm Production Expenditures, 1994 Summary.

electricity were an additional $2.33 billion in 1991, the last year separate data were gathered. If a similar expenditure for electricity occurred in 1994, total farm energy expenditures would be $7.9 billion or 4.9 percent of total farm production expenses.

Energy Use in Food Processing

Energy is an important input to manufacturing and processing food after it leaves the farmgate. Food and kindred products, SIC (Standard Industrial Classification) 20, is the Nation's largest manufacturing sector with the value of its shipment as high as $404 billion in 1993. The sector's firms process foods and beverages largely for human consumption, as well as related products such as animal feed. Food manufacturing and processing firms use power-driven machines and material-handling equipment and, in 1991, consumed 4.7 percent (1 quadrillion Btu) of total energy.

Industries within the food and kindred products sector use different types of energy and at various intensities. Eight industries of the sector's 49 accounted for nearly half of the total energy consumed (table 3.3.4). The most common energy sources are natural gas, electricity, coal, LP gas, and residual and distillate fuel oil. Beet sugar is the most energy-intensive industry at 28,300 Btu per dollar of shipments, compared with meat packing at 1,000 Btu.

The sector's output rose 25 percent between 1977 and 1991, while its energy use fell 2 percent, mainly due to improvements in efficiency such as waste heat recovery and the substitution of membrane separation for thermal separation.

Energy from Agricultural Biomass

Biomass (plant and animal matter) includes a broad range of biological materials—such as agricultural and forestry products and wastes including animal manure—that can be used to produce energy. These feedstocks may be used for direct combustion, gasified, and/or processed into biofuels such as ethanol, methanol, ethyl or methyl esters, methane, and biocrude. Biomass could provide clean energy and thereby reduce the emissions of greenhouse gases and other pollutants.

Table 3.3.3—Farm energy expenditures, 1980-94

Year	Gasoline	Diesel	LP gas	Other	Total fuel	Fuel share of farm production expense	Electricity		Total energy
							Non-irrigation	Irrigation	
			$billion			*Percent*		*$billion*	
1980	3.31	3.12	0.67	0.82	7.92	5.9	1.22	0.54	9.68
1981	3.36	3.35	0.70	0.81	8.22	6.2	1.32	0.66	10.20
1982	2.87	3.25	0.76	0.85	7.73	5.9	1.42	0.69	9.83
1983	2.64	3.15	0.66	0.89	7.34	5.6	1.62	0.59	9.55
1984	2.40	3.06	0.72	0.82	7.00	5.4	1.64	0.59	9.23
1985	2.16	2.92	0.69	0.68	6.45	5.1	1.56	0.65	8.68
1986	1.51	2.04	0.49	0.65	4.33	4.1	1.42	0.58	6.69
1987	1.37	2.13	0.38	0.47	4.35	3.9	2.03	0.43	6.81
1988	1.42	2.12	0.38	0.53	4.45	3.8	2.17	0.48	7.10
1989	1.44	2.12	0.38	0.51	4.45	3.6	1.69	0.64	6.78
1990	1.65	2.42	0.53	0.57	5.14	3.9	1.65	0.65	7.47
1991	1.50	2.34	0.44	0.65	4.93	3.8	1.57	0.76	7.25
1992	1.72	2.65	0.65	0.63	5.65	3.9	na	na	na
1993	1.58	2.69	0.58	0.67	5.52	3.6	na	na	na
1994	1.50	2.70	0.62	0.73	5.55	3.5	na	na	na

na = not available.

Source: USDA, ERS, based on NASS, Farm Production Expenditures, 1980-1994 Summaries. Data for 1992-94 are from the NASS, unpublished data.

Table 3.3.4—Consumption of energy by industry group, 1991

Standard Industrial Classification	Industry group[1]	Total	Net electricity[2]	Residual fuel oil	Distillate fuel oil[3]	Natural gas [4]	LP gas	Coal
					Trillion Btu			
20	Food and kindred products	956	169	27	17	W	5	154
2011	Meatpacking plant	49	12	1	1	32	1	1
2033	Canning fruits & vegetables	44	5	2	1	36	*	Q
2037	Frozen fruits & vegetables	40	10	2	*	26	*	0
2046	Wet-corn milling	140	14	*	*	52	*	68
2051	Bread, cake, & related prod.	32	8	*	1	23	*	0
2063	Beet sugar	67	1	W	*	19	*	43
2075	Soybean oil	51	6	*	*	25	*	13
2082	Malt beverage	50	8	3	*	23	*	16

[1] Only the eight largest subcategories of food and kindred products are shown.

[2] "Net electricity" is the sum of purchases in and generation from noncombustible renewable resources, minus quantities sold and transferred out.

[3] Includes Nos. 1, 2, and 4 fuel oils and Nos. 1, 2, and 4 diesel fuels.

[4] Includes natural gas obtained from utilities, transmission pipe lines, and any other supplier(s) such as brokers and producers.

* Estimate less than 0.5.

Q = Withheld because of relative standard error greater than 50 percent.

W = Withheld to avoid disclosing data for individual establishments.

Source: USDA, ERS, based on U.S. Department of Energy/Energy Information Administration, 1994.

With the improvement in technologies, many agricultural products are now used for producing electricity and liquid fuel for transportation. In 1993, over three quadrillion Btu of biomass energy were consumed in the United States, representing about 3.7 percent of total U.S. energy consumption. Energy from wood accounted for 87 percent of total biomass energy consumption, while energy from solid waste and corn-ethanol made up 10 and 3 percent. Wood was consumed in the United States for industrial and utility (two-thirds) as well as residential use (one-third). Wood energy use in the commercial sector was estimated to be over 20 billion Btu in 1986, the last year of available data.

Consumption of wood in the residential sector has been declining, due to people moving from rural to urban areas; the scarcity of inexpensive fuel wood; environmental restrictions on the burning of wood, especially in populated areas; and the emergence of clean-burning and more efficient gas fireplaces.

Biomass Electricity

During the 1980's national interest grew in wood-burning electric-generating plants as a result of the National Energy Policy Act and state utility regulatory actions. More than 5,800 megawatts of power from wood-fueled electricity were added to the 200 existing in 1979. Of nearly a thousand wood-fired plants ranging from 1 to over 100 megawatts, only a third offer electricity for sale. The rest are owned and operated by paper and wood production industries for their own use.

Biomass-based electricity is most economical in those regions where electricity is relatively expensive and wood is cheap.

Despite rapid growth in the 1980s, the biomass power industry is now in a low-growth phase because of low fossil fuel prices, excess capacity, competitive bidding for power sales, and costly permitting procedures. Competition from efficient natural gas-turbine generators has also dampened the market for biomass projects. Natural gas has benefited from its low investment cost per kilowatt hour (Kwh), affordability and abundance due to new drilling technology, and ability to burn cleaner than coal, wood, and oil.

Energy crops (wood and grass) could become important feedstocks for the production of liquid fuels, electricity, chemicals, and other industrial products. With increases in yield and competitive conversion technologies, biomass crops such as herbaceous plants and wood might compete with fossil fuels for a broad range of uses. A biomass industry could also provide new income for farmers, jobs in rural areas, and markets for agricultural residues. Key to this scenario are increases in fossil fuel prices; more rapid advances in biomass gasification, gas clean-up, and gas-turbine power generation; and market development for biomass coproducts such as pulp wood chemicals. Policies that restrict greenhouse gas emissions or promote biomass production on idled land could also help.

Fuel Ethanol Production Processes

Ethanol is produced from corn by two standard production processes: wet- and dry-milling. With the exception of the initial separation process, the two processes are very similar. In dry-milling, the first step consists of grinding the corn, which is then slurried with water to form the mash and cooked. Enzymes convert the starch in the mash to sugar and, in the next stage, yeast ferment the sugars to produce beer. In the dry-mill process, the beer, containing alcohol, water, and dissolved solids, is separated from solids. It is then distilled and dehydrated to create anhydrous ethanol. The solids are dried and sold as distillers' dried grain with solubles (DDGS), commonly used as an animal protein feed. Using current technology, a bushel of corn when processed will yield 2.6 gallons of fuel-grade ethanol and 16.5-17.5 lbs. of DDGS. Carbon dioxide may also be collected from a fermentation tank.

In wet-milling, the first step involves soaking the corn kernels in water and sulfur dioxide and separating the corn into its major components: the germ, fiber, gluten, and starch. All other components of the corn kernel are removed prior to fermentation of starch. These components are used to produce three coproducts: corn oil, corn gluten feed (CGF), and corn gluten meal (CGM). A bushel of corn, when processed by wet-milling, can produce 1.6 lbs. of corn oil, 12.5 lbs. of CGF, and 2.5 lbs. of CGM. The remaining starch is saccharified, fermented, and distilled as in the dry-milling production process.

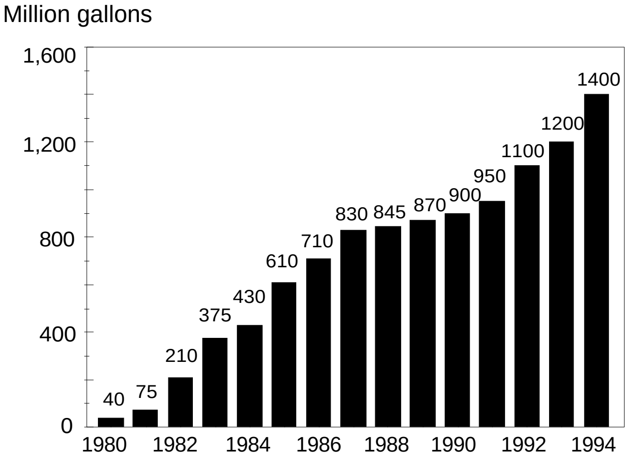
The Federal Government offers incentives for commercially competitive biomass energy, including unconventional fuel credits (99.3 cents per million Btu); power production tax credits (1.6 cents per kwh); alcohol fuel credits (60 cents per gallon of ethanol or methanol from biomass, in addition to 10 cents per gallon for “small” ethanol producers); accelerated depreciation (5 years versus 15-20 years) for certain biomass energy facilities; tax-exempt financing; cash subsidies (1.5 cents per kwh); and investment tax credits (6.5 percent) for growing energy crops exclusively for conversion of biomass to electricity (direct combustion and gasification) and liquid fuels. Given its uncertain competitiveness, biomass depends on projects that successfully demonstrate its utility for energy production in the United States. The U.S. Department of Energy (DOE) and the U.S. Department of Agriculture (USDA) are collaborating to develop technologies and to foster business arrangements that integrate electricity generation and rural development through biomass-based renewable energy (see chapter 5.1, *Agricultural Technology Development*). USDA will participate in these projects using existing authorities and programs, and DOE will share costs under authority of the Energy Policy Act of 1992 and the President’s Climate Change Action Plan.

Fuel Ethanol

The oil embargoes of 1973 and 1979 renewed interest in alcohol fuels, primarily fuel ethanol from grain. Energy security, new Federal gasoline standards, and government incentives have driven the grain-based fuel ethanol industry. When the energy crisis first exposed U.S. vulnerability to energy supply interruptions, fuel ethanol from agricultural resources was viewed only as a potential gasoline extender. In 1990, ethanol emerged as an octane enhancer after the Environmental Protection Agency (EPA) began to phase out lead in gasoline. More recently, ethanol production received a major boost with the passage of EPA’s Clean Air Act Amendments (CAA) of 1990 establishing the Oxygenated Fuels Program and Reformulated Gasoline (RFG) Program to control carbon monoxide (CO) and to mitigate ground-level ozone problems. Both programs require oxygen levels in gasoline of 2.7 percent (by weight) for oxygenated fuel and 2.0 percent for reformulated gasoline. The three leading oxygen additives are ethanol; ethyl tertiary butyl ether (ETBE), made from ethanol; and methyl tertiary butyl ether (MTBE) made from methanol, which is derived from natural gas.

Adding ethanol, ETBE, or MTBE to gasoline to create "oxygenated" blends reduces the amount of CO released into the atmosphere. These three additives compete closely for markets. Methanol had been a cheaper oxygen additive than ethanol, but RFG programs and other chemical applications increased the demand for methanol, pushing methanol prices to $1.40 per gallon in 1994 from 35 cents in 1993. A temporary shutdown of a large methanol producing plant due to an explosion also caused methanol prices to rise. That gave ethanol, a substitute for methanol, a temporary boost. The methanol situation is expected to ease in 1997 as additional capacity comes on line. In addition, the Treasury Department announced in 1994 that the ethanol portion of ETBE was eligible for an exemption from the Federal excise tax of 18.4 cents per gallon, now available to ethanol. As gasoline blended with ETBE contains 5.6 percent ethanol, the tax break per gallon of ETBE amounts to 3 cents. For gasohol (gasoline containing 10 percent ethanol), the exemption is 4.5 cents. This ruling increased ETBE’s competitiveness with other qualifying alcohols in the RFG market. Ethanol’s competitiveness will also improve as producers adopt energy-efficient technologies and other cost-saving innovations.

Figure 3.3.3--U.S. ethanol production, 1980-94



Source: USDA, ERS, based on Renewable Fuels Association, 1994.

Fuel ethanol production in the United States has grown from just a few thousand gallons in the mid-1970’s to 1.4 billion gallons in 1994 (fig. 3.3.3). As of July 1995, U.S. fuel ethanol industry was comprised of 41 operational facilities in 15 States. Several large producers dominate the industry. Archer Daniels Midland alone had 59 percent of U.S. annual operational production capacity (1.7 billion gallons) in 1995. About 71 percent of fuel ethanol’s production capacity is in the Corn Belt region, followed by the Northern Plains with 14 percent. U.S. ethanol production capacity is nearly 2.2 billion gallons per year, including capacity under construction or in the engineering/financing stage and capacity which is shut down at present. The two main processes for producing ethanol from corn are wet-milling and dry-milling (see box, "Fuel Ethanol Production Processes," p. 139). Wet-milling accounts for about 60 percent of total ethanol production.

Ethanol production costs vary greatly, depending largely on net feedstock cost (grain cost minus value of byproducts). For 1981-91, net feedstock cost ranged from 10 to 67 cents per gallon of ethanol, due mainly to large swings in the price of corn ($1.58 to $3.16 per bushel). Changes in coproduct prices also contributed to this variation. Together, capital and operating costs for wet milling ranged from 78 cents to $1.07 per gallon, bringing the cost of ethanol to $0.88-1.74 per gallon. With an expected price of corn of about $3 per bushel in the 1995/96 marketing year, total cost of producing ethanol could rise 20 to 23 cents per gallon due to higher net corn cost, lowering its competitiveness with other fuels. Higher corn prices have reduced profits for fuel ethanol producers and, consequently, production has been cut. In May 1996, the market price of corn reached a record $4.98 per bushel and some large ethanol producers further cut back production.

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Recent ERS Reports on Energy Issues

Farm Energy, AREI Update, 1995 No. 16 (Mohinder Gill). Farm fuel prices are influenced by crude oil prices especially imported crude oil. In 1994, compared with 1993, farm fuel prices fell by 5 - 8 percent as the imported crude oil price fell by 4 percent. Farm energy expenditures, at $5.56 billion in 1994, were 1 percent less, compared with 1993 an estimated 5.8 billion gallons of fuel was consumed in 1994, 7 percent higher than 1993, because of increased planted acreage.

"The Agricultural Demand for Electricity in the United States," *International Journal of Energy Research*, 1995 Vol. 19 (Noel D. Uri and Mohinder Gill). The price of electricity is a factor impacting the quantity of electricity demanded by farmers for irrigation and nonirrigation uses, but there is no indication that other types of energy are substitutes for electricity. Number of acres irrigated and number of acres planted are important factors driving the demand for electricity for irrigation and nonirrigation uses.

(Contact to obtain reports: Mohinder Gill, (202) 219-0447 [mgill@econ.ag.gov].

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3.4 Farm Machinery

Increasingly complex farm machinery is an essential contributor to the productivity gains of U.S. agriculture. Expenditures on farm machinery in 1995 made up 13 percent of total production expenditures. Farm machinery sales in 1995 and 1996 leveled off somewhat after showing significant increases in 1993 and 1994. The increased value of farm assets and higher farm cash receipts have helped maintain farm machinery sales.

Contents

Farm machinery and equipment are increasing in complexity, price, and, in many cases, size. Expenditures on farm machinery make up 13 percent of total production expenditures and farm machinery assets are 9 percent of total farm assets (USDA, ERS, 1996b; USDA, NASS, 1996b). Trends toward conservation tillage and no-till have prompted inventions such as the air drill and the coulter chisel plow. Precision farming is the impetus for new inventions, including continuous yield monitoring equipment and variable-input gaging devices, and will likely inspire more inventions in the near future.

Operation of farm machinery can cause soil compaction and contribute to engine emissions. These environmental effects can be lessened by using specific farming practices and special exhaust systems and fuels. Engine exhaust emissions will be reduced as new tractors meet EPA requirements by the year 2000 (USDA, ERS, 1994b). The risks in operating farm machinery make agriculture one of the Nation’s most hazardous occupations, but improved safety measures are reducing accidents and injuries (see box, “Farm Machinery Safety”).

Farm Machinery Sales

After showing a significant increase in 1994, purchases of farm machinery continued to increase through 1996, but at a slower rate. Farm tractor purchases increased 9 percent from 1993 (57,800 units) to 1994 (63,200). From 1994 to 1995, the increase in purchases was 2 percent (to 64,600 units) (table 3.4.1, fig. 3.4.1). Purchases increased 4 percent in 1996. Combine sales were also up in 1995, increasing by 8 percent, but slowed in 1996. Tractor and combine sales are indicators of the general farm machinery economy; retail sales data on other machinery are not available.

Several demand factors were favorable for increased purchases of tractors and farm machinery in 1996, and purchases increased in most horsepower classes. Tractor sales in the 40-99 horsepower category increased 4 percent in 1996. Tractor sales in the 100-and-over horsepower category also increased 4 percent. Purchases of four-wheel-drive tractors stayed the same.

Farm Machinery Safety

Agriculture is one of the Nation's most hazardous occupations. Estimates of annual agricultural deaths vary between 26 and 50 workers per 100,000, compared with an annual rate of 11 for all industries combined (USDHHS, 1992; MMS, 1995).

Little data are available on farm accidents, injuries, and illnesses. The census of agriculture included questions on the number of injuries and deaths on farms for the first time in 1992. Runyan, in 1993, published a review and synopsis of data sources on farm accidents. Nationally, some data are available from several sources: the Department of Labor, Department of Commerce, Product Safety Commission, Department of Health and Human Services, National Safety Council, Department of Agriculture, and the State Workers' Compensation Systems. Also, some data are available from State and local sources, including newspapers, coroners, hospitals, and medical personnel.

Farm-related injuries totaled 64,813 in 1992 according to the census of agriculture (USDC, 1994a). There were 673 farm-related deaths. The census does not report the cause of injuries and deaths, but many were likely related to machinery use. A recent study of farm accidents in Kentucky found that 82 percent of tractor-related fatalities were due to rollovers. Most of these occurred while mowing (32 percent). All the victims were male. The median age of the tractors was 23 years, ranging from 2 to 41 years. Most of the fatalities could have been prevented had the tractor been equipped with rollover protection (ROPS) and seatbelts. ROPS and seatbelts were not required on new tractors until 1976 (MMS, 1995).

The farm machinery industry has done much to improve farm safety. Rollover protection is provided on new tractors. Fully enclosed cabs offer protection on most larger tractors, combines, and other self-propelled equipment. Power take-off shields have been standard equipment for many years. Warning decals are placed near hazardous locations. More effort to educate farmers, their families, and farmworkers about the dangers in operating farm machinery and equipment could help reduce injuries and fatalities.

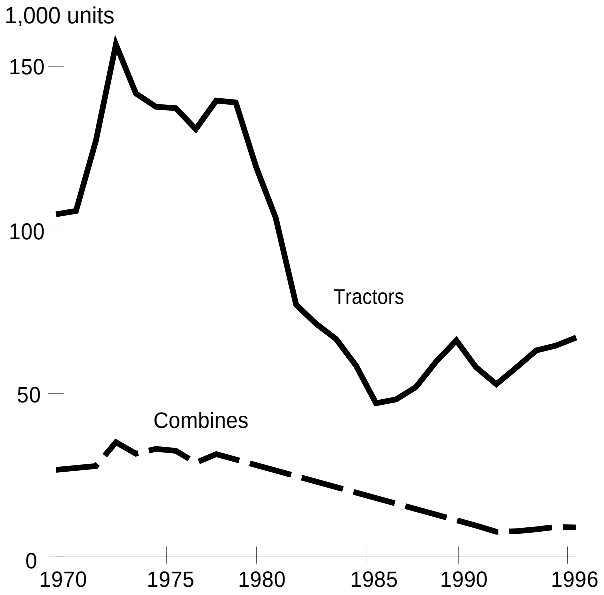
There are economic costs associated with deaths, injuries, and illnesses from farm-related causes. A New York study of people killed in farm accidents estimated that from $218,001 to $362,047 (adjusted to 1987 dollars) of lifetime expected income and opportunity costs (per person) were foregone due to farm accidents (Kelsey, 1991). Costs include health care, discounted future earnings, and special devices such as wheelchairs and lifts. In some cases, the farm has to be sold to help pay for medical expenses. Society also bears many of the costs of farm accidents when the family is unable to pay medical costs and expenses.

Table 3.4.1—Domestic farm machinery unit sales, 1986-96

Machinery category	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
						Units					
Tractors:											
Two-wheel-drive--											
40-99 hp	30,800	30,700	33,100	35,000	38,400	33,900	34,500	35,500	39,100	39,700	41,200
100 hp and over	14,300	15,900	16,100	20,600	22,800	20,100	15,600	19,000	20,400	20,500	21,400
Four-wheel-drive	2,000	1,700	2,700	4,100	5,100	4,100	2,700	3,300	3,700	4,400	4,400
All farm wheel tractors	47,100	48,400	51,700	59,700	66,300	58,100	52,800	57,800	63,200	64,600	67,000
Self-propelled combines	7,700	7,200	6,000	9,100	10,400	9,700	7,700	7,850	8,500	9,200	9,000

Source: USDA, ERS, based on Equipment Manufacturers Institute, various years.

Figure 3.4.1--Farm tractor and combine unit sales, 1970-96



Tractors-40 HP & up and self-propelled combines.

Source: USDA, ERS, based on Equipment Manufacturers Institute, various years.

Table 3.4.2—Plant capacity utilization in the farm machinery and equipment industry (fourth quarter)

Year	Capacity utilization rates[1]
	Percent
1980	62
1981	48
1982	31
1983	38
1984	41
1985	37
1986	24
1987	43
1988	54
1989	66
1990	66
1991	64
1992	56
1993	59
1994	66

[1] For 1989 and later, percent of full production; for 1988 and earlier, percent of "practical capacity."

1993 and 1994 estimated.

Source: USDA, ERS, based on USDC, 1994b and Federal Reserve, 1995.

Farm machinery plant capacity being utilized was estimated at 66 percent for 1994, compared with 24 percent in 1986 (table 3.4.2). Plant capacity utilization increased every year since 1992. The low rate in 1986 followed several years of low demand for farm machinery and large dealer inventories. Total or full production capacity was low throughout most of the 1980’s as farm machinery manufacturers cut back, consolidated, and merged in response to low sales and economic pressures. The same capacity utilization rate in the 1970’s produced more farm machinery since full production for the industry was higher. Also, capacity utilization was higher, 83-85 percent throughout the 1970’s, as the farm machinery industry responded to high demand caused by high farm incomes, large exports, and high real estate asset values (USDC, 1994b).

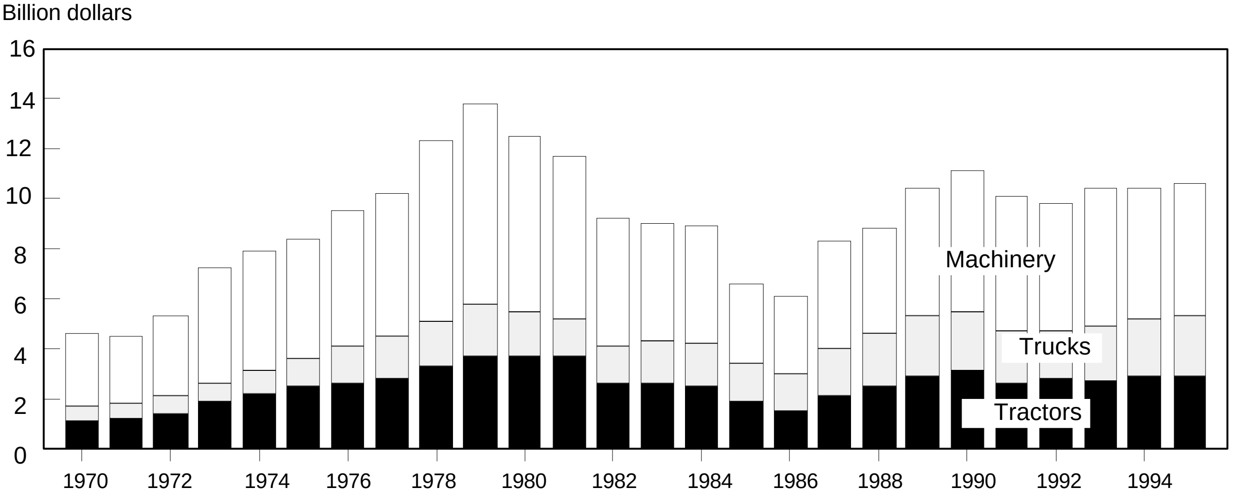
Capital Expenditures and Depreciation

Another indicator of the economic health of the farming sector is the difference between capital expenditures and depreciation, which represents the amount of capital accumulation or depletion. Capital expenditures are the dollar value investment in tractors, trucks, farm autos, and farm machinery as opposed to *units* of tractors and combines sold. Capital expenditures are the purchases of new and used durable machinery and equipment (less trade-ins) that will be used (and depreciated) over a number of years (USDA, ERS, 1988). Depreciation, also referred to as economic depreciation or capital consumption (as opposed to depreciation for income tax purposes), measures the amount of capital stock used up in the production process (McGath and Strickland, 1995).

Capital expenditures on tractors, trucks, and farm machinery, in nominal dollars, reached a peak in 1979 and, despite recent gains, are still $3 billion below that peak (fig. 3.4.2, table 3.4.3). In real terms (adjusted for inflation), depreciation of farm machinery has exceeded capital expenditures every year since 1980 (fig. 3.4.3). In 1985, real depreciation reached $8.5 billion and real capital expenditures were $4.2 billion, a gap of $4.3 billion. In 1995, capital depletion was $1.1 billion, about the same as in 1994.

Capital depletion in the farming sector may be due to several reasons. The mechanization of agriculture is changing. Tractors, combines, and other powered machinery have been getting larger and more efficient. Tillage practices have been changing from conventional tillage, which involved working the soil many times prior to planting, to reduced and no-till

Figure 3.4.2--Farm machinery capital expenditures, 1970-95

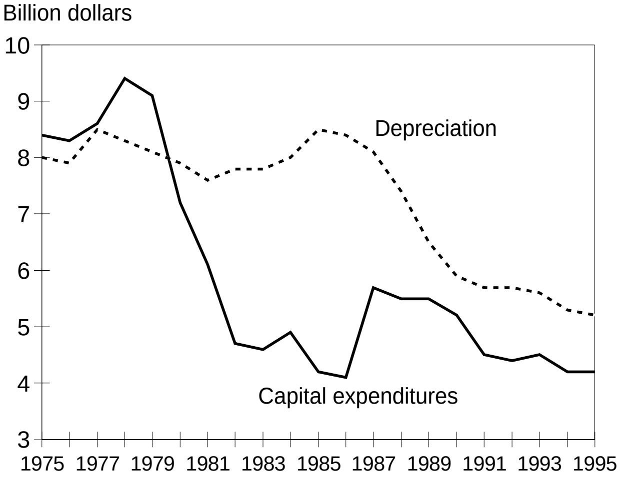


1995 forecast.
Nominal dollars.

Source: USDA, ERS, 1994a and other ERS sources.

practices, which require fewer times over the soil, help conserve soil, and prolong the useful life of tractors and equipment. Also, farming was very profitable in the late 1970's, which encouraged farmers to buy more and larger tractors and machinery than needed for efficient operations. More than 157,000 farm tractors were sold in 1973, compared with only 47,000 in 1986. In the early 1980's, farm income declined, farmers bought less machinery, and the farming sector remained productive by keeping old machinery in repair and using the extra machinery capacity built up during the late 1970's. Delaying expenditures on farm machinery can result in higher repair costs, but there is usually a period of time when the difference in cost between keeping an old machine and buying a new one is small.

Figure 3.4.3--Machinery capital expenditures and depreciation, 1975-95



Adjusted to 1975 dollars; 1995 estimated.

Source: USDA, ERS, 1994a and other ERS sources.

At some point in the future, capital investment should equal and surpass depreciation. The gap between capital expenditures and depreciation narrowed in the late 1980's, but increased again in 1991. Capital depletion has been a little over $1 billion each year since 1993. However, this was only about 3 percent of the total capital inventory stock of machinery on farms and likely represents adjustments due to efficiencies in technology and changes in farming practices. More farmers are buying the specialized machinery needed to comply with conservation plans. Also, capital expenditures likely increased in 1996. These factors should soon bring back capital accumulation in the farming sector.

Factors Affecting Machinery Demand

Farm machinery demand is affected by various factors, including machinery prices, interest rates, farm equity, farm income, and cropland used for crops (see box, "Factors Affecting Demand for Farm Machinery," p. 148). Machinery prices and interest rates determine the cost of purchasing farm equipment. Farm equity is the result of assets minus debt and is a measure of the collateral available to

Table 3.4.3—Trends in U.S. farm investment expenditures and factors affecting farm investment demand, 1988-96

Item	1988	1989	1990	1991	1992	1993	1994	1995	1996F
Capital expenditures:					*$ billion*				
Tractors	2.54	2.90	3.12	2.59	2.83	2.69	2.89	2.91	2.90-2.98
Other farm machinery	4.22	5.09	5.59	5.41	5.13	5.49	5.18	5.05	5.15-5.30
Total	6.76	7.99	8.71	8.00	7.96	8.18	8.07	7.96	8.05-8.28
Repairs	4.16	4.71	4.50	4.55	4.18	4.46	4.35	4.56	4.49-4.60
Trucks and autos	2.37	2.58	2.63	2.40	2.30	2.50	2.56	2.80	2.62-2.82
Farm buildings[1]	2.39	2.53	2.80	2.75	2.37	3.39	3.25	3.01	3.10-3.23
Factors affecting demand:									
Interest expenses	14.3	13.9	13.4	12.1	11.2	10.8	11.8	12.8	13.0
Production expenses	137.8	144.9	153.7	153.4	152.5	160.5	167.4	175.6	183.1
Farm business assets:									
Real estate assets[2]	595.5	615.7	618.4	624.4	642.8	673.4	706.9	755.7	808.6
Other assets[2]	205.6	214.1	220.3	219.4	226.1	231.1	231.2	222.3	226.5
Farm business debt[2,3]	139.4	137.2	138.0	139.2	139.0	141.9	146.8	150.8	155.4
Equity[2]	661.7	692.4	700.7	704.6	729.9	762.6	791.3	827.2	879.7
Agricultural exports[4]	35.3	39.6	39.4	39.2	42.9	42.6	45.7	55.8	60.4
Cash receipts	151.2	161.1	169.4	167.8	171.3	177.6	180.8	185.8	200.4
Net farm income	38.0	47.9	44.8	38.4	48.0	43.6	48.4	34.8	51.7
Net cash income	54.5	54.2	52.9	50.4	55.5	58.9	50.5	48.8	57.4
Government payments	14.5	10.9	9.3	8.2	9.2	13.4	7.9	7.3	7.8
					Million acres				
Idled acres[5]	77.7	60.8	61.6	64.5	54.9	59.8	49.2	54.8	34.4
Interest rates:					*Percent*				
Real prime rate[6,7]	5.4	6.5	5.7	4.5	3.5	3.4	4.8	6.3	6.2
Nominal farm machinery loan rate[7]	11.7	12.8	12.3	11.3	9.3	8.7	8.6	10.3	9.7
Real farm machinery loan rate[6,7]	8.4	8.4	8.0	7.5	6.5	5.3	6.3	7.8	7.6
Debt-asset ratio[8]	17.4	16.5	16.4	16.5	16.0	15.7	15.6	15.4	15.0

F-forecast.

[1] Includes service buildings, structures, and land improvements.

[2] Calculated using nominal dollar balance sheet data, excluding farm households, for December 31 of each year.

[3] Excludes Commodity Credit Corporation loans.

[4] Fiscal year.

[5] Includes acres idled through commodity programs and acres enrolled in the Conservation Reserve Program.

[6] Deflated by the Gross Domestic Product deflator.

[7] Average annual interest rate. From the quarterly sample survey of commercial banks: Agricultural Financial Databook, Board of Governors of the Federal Reserve System.

[8] Outstanding farm debt divided by the sum of farm real and nonreal estate asset values.

Sources: USDA, ERS, 1997, 1996b, 1994a; FRS, 1995.

Table 3.4.4—Prices paid indexes for selected production items and interest, annual averages[1]

Year	Farm machinery	Trucks and autos	Fuels	Feed	Livestock and poultry	Interest	Production items, interest, taxes and wage rates	GDP price deflator
				1990-92 = 100				*1992=100*
1984	85	78	93	112	73	124	91	76
1985	85	83	93	95	74	106	87	78
1986	83	86	76	88	73	98	85	81
1987	85	88	76	83	85	96	87	83
1988	89	90	77	104	91	100	92	86
1989	94	93	83	110	93	106	97	90
1990	96	97	100	103	102	107	99	94
1991	100	100	104	98	102	100	100	97
1992	104	102	96	99	96	93	101	100
1993	107	105	93	101	104	87	102	103
1994	113	107	95	105	94	94	105	105
1995	121	107	94	105	82	101	109	108
1996	125	108	105	130	75	105	114	110
1997, Jan.-Apr., avg.	127	110	109	125	89	106	116	111

[1] Indexes are current, actual (undeflated) prices, weighted by the relative importance of component items that make up each individual category and converted to the base year 1990-92=100 (USDA, 1990). First quarter, for 1997 GDP.

Source: USDA, ERS, based on NASS, 1996a, 1997; Council of Economic Advisers, 1997.

back farm machinery loans. Farm income is determined from cash receipts, less production expenses, and is an indication of cash flow available to purchase farm machinery.

Farm machinery prices rose 4 percentage points from 1995 to 1996 (table 3.4.4). Increased machinery prices depress farm machinery demand (Conley, 1992; Cromarty, 1959). The April 1997 prices-paid index (1990-92=100) for farm machinery was 127, 2 points above 1996; prices for trucks and autos also rose 2 points. The price index for all production items rose only 2 points.

The farm machinery nominal interest rate decreased to 8.6 percent in 1994, the lowest in 9 years. However, the real prime rate (adjusted for inflation) reached a low in 1993 and steadily rose to 6.3 percent in 1995 (table 3.4.3). Both the nominal and real farm machinery interest rates lag behind the prime rate and fell in 1996—to 9.7 percent and 7.6 percent. Higher interest rates have a negative effect on farm machinery investments (Kolajo and Adrian, 1986). As interest rates rise, the total cost of machinery bought on credit increases, dampening purchases. While the real rate reflects the actual cost of borrowing, the nominal rate likely has more effect on machinery purchases because it is more obvious to farmers. The importance of real versus nominal interest rates depends on the extent that farmers take into account expectations about inflation rates.

One of the more favorable farm machinery demand indicators has been sizable increases every year since 1991 in the value of farm equity (assets minus debt). Equity increased from $705 billion in 1991 to $880 billion in 1996. The increase in equity is due to large jumps in asset values, primarily real estate. The value of farm real estate assets has also increased every year since 1991 (table 3.4.3). Total assets include both real estate and nonreal estate items, and, when increasing, have a positive effect on farm machinery demand (Cromarty, 1959). Farm business assets were $1,035 billion in 1996, an increase of $57 billion (6 percent) from 1995. Farm business debt, which has a dampening effect on farm machinery demand, was up $4.6 billion in 1996, an increase of 3 percent. When farm equity increases, more collateral is available to finance farm machinery capital expenditures. Farm equity increased again in 1996. The ratio of debts to assets decreased to 15 percent

Factors Affecting Demand for Farm Machinery

Agricultural exports—Exports of U.S. agricultural products (fiscal year October 1 through September 30).

Cash receipts—Sales of all crop and livestock commodities. Cash receipts are like "money in the pocket" and correlate closely with purchases of farm machinery.

Debt-asset ratio—Farm business debt divided by farm business assets. Lower debt/asset ratios mean more favorable borrowing positions and more investment in tractors, combines, and other farm machinery.

Equity—Total assets minus debt. Farm equity represents a farmer's net worth; the greater the equity, the more collateral the farmer has available to back loans for capital investment.

Farm business debt—Real estate and nonreal estate debt.

Farm machinery loan rate—Average annual interest rate as reported in the quarterly survey of commercial banks by the Federal Reserve System (FRS, 1995). An inverse relationship exists between interest rates and the purchase of farm machinery. Lower interest rates imply greater purchases of farm machinery.

Idled acres—Cropland idled through commodity programs or enrolled in the Conservation Reserve Program. More land idled means less cropland to be cultivated, seeded, and harvested. Machinery is used less, prolonging useful life.

Interest expenses—Interest on both real estate and nonreal estate debt.

Net cash income—Gross cash income (cash receipts, direct government payments, and farm-related income) minus cash expenses.

Net farm income—Gross cash income, nonmoney income, and inventory adjustments minus total production expenses. Net farm income has a high correlation with machinery purchases when purchases are lagged several months behind income.

Nonreal estate assets—Includes livestock, crops, machinery, motor vehicles, and financial assets.

Real estate assets—Land and service structures. Increasing assets place a farmer in a more favorable position for obtaining capital investment loans.

Real prime rate—Bank prime rate, adjusted for inflation by the gross domestic product deflator.

Total production expenses—Total of cash expenses (inputs purchased, such as feed, seed, fertilizer, pesticides, fuel, repairs, custom work, and labor; interest; rent; and property taxes) plus noncash expenses, which include capital replacement and accidental damage.

from 1995 to 1996, the lowest ratio since the early 1960's, indicating a favorable borrowing position.

Farm income has a lagged effect on machinery sales, with higher purchases a year or more from the year of increased income (Rayner and Cowling, 1968). Increases in income have a positive effect on farmers' expectations about future income, which spurs machinery demand. Net farm income is cash income plus or minus the value of inventory changes, nonmoney income, noncash expenses, and operator dwelling expenses. Net farm income was up 7 percent in 1996 to $51.7 billion, from the previous high of $48.4 billion in 1994 (table 3.4.3). Cash receipts were up every year, 1992-96.

Commodity prices, a major determinant of cash receipts, rose significantly in 1996, especially for wheat, corn, and soybeans. Increased commodity prices, alone, with no changes in other input factors, would normally brighten the outlook for the farm economy and increase the demand for farm machinery. Higher crop prices, coupled with large inventory adjustments, resulted in high net farm income in 1996. Higher commodity prices are the result of low world carryover stocks, primarily caused by drought and adverse weather conditions in major grain growing countries. High prices also reflect the high export demand for several major commodities. Commodity exports were $60.4 billion in 1996, up $4.6 billion from 1995, an 8-percent increase (table 3.4.3). This is the highest level of commodity exports in at least 10 years. Wheat, feedgrains, and oilseeds compose the largest share of commodity exports. The upward trend in commodity exports favors increased investment in farm machinery.

In 1996, idled land decreased to 34 million acres from a high of 77.7 million in 1988. As Conservation Reserve Program (CRP) contracts expire, some of that land will come into production, possibly spurring demand for farm machinery. Some farmers will still have the same complement of machinery that existed before they signed up for the CRP. Others who may have put the entire farm in the CRP and reduced their machinery inventories will need to obtain more equipment. The overall effect of reductions in CRP acreage should be some increase in demand for farm machinery.

Changes in Farming Practices and Machinery

Two major change factors influencing the farm machinery industry are the emerging interest in precision farming and the continuing adoption of conservation tillage and crop residue management practices.

Precision Agriculture

The newest innovation in agriculture is the trend toward computerized equipment that allows precise quantity and placement of inputs such as fertilizer, seed, and pesticides (Christensen and Krause, 1995). This new technology is known variously as precision farming, site-specific farming, soil-specific crop management, prescription farming, focused fertilizing, spatially variable controlled crop production, and site-specific nutrient management systems. Ideally, precision farming will improve input efficiency and reduce the use of chemicals and fertilizers.

However, unresolved questions need further research. For example, what size of farming operation will benefit most from precision farming? The complexity and expense of the machinery and operations may make precision farming more plausible by large-scale operations, perhaps further concentrating U.S. agriculture. On the other hand, the costs of yield monitors, global positioning computers, and other precision farming equipment is decreasing. And expensive variable-rate fertilizer, pesticide, and seeding equipment is being increasingly supplied by dealers on a custom or rental basis, forestalling large investments at the farm level for equipment that will quickly become obsolete as newer technology is developed. The issue then becomes one of managerial time required to learn and apply the technology. Large-scale farmers may not be able to spend as much time on this technology as medium-scale farmers. Also, small-scale farmers who spend a lot of time working off the farm may not be able to devote much time to precision farming.

Precision farming generally employs satellite technology, which tracks equipment location within a few meters in a field. Site-specific information is important because crop yields can differ significantly throughout a field. Computers record crop yields, soil characteristics, and other data continuously within each field. Fertilizers and pesticides can then be specified from information in the computer data base. This information is used to vary seed, fertilizer, and pesticide quantities to site-specific field locations (Robert and others, 1992).

Precision farming is still in its infancy. Equipment is expensive; variable-rate fertilizer applicators cost as much as $250,000. However, prices are declining as manufacturers develop more efficient ways of producing the specialized computers, receivers, metering devices, and variable-rate seeders, sprayers, and fertilizing equipment. Farmers also face time constraints in learning precision farming. Few courses or training sessions are available and most of the subject matter is highly technical, involving computers and space-age locating, monitoring, and metering equipment.

Researchers at ARS (Agricultural Research Service, USDA) and several universities are investigating the relationships between soil conditions, moisture, nutrient balances, and crop yields, and how these relationships bear on input applications (USDA, NAL, 1994). The farm equipment industry also researches precision farming and has outpaced public research in many areas. Preliminary research indicates improved efficiencies in the use of fertilizers and pesticides. Instead of broadcasting nutrients and chemicals across the field, precision farming prescribes appropriate amounts by soil, moisture, nutrient balance, and other site-specific factors. In addition to improving input inefficiency, precision farming has the potential to lessen adverse environmental effects of current farming practices. By improving input efficiency, precision farming can reduce residual quantities that may otherwise enter streams and groundwater.

While precision farming more commonly refers to site-specific field tracking technology and computerized metering equipment, it may also apply to other innovations. Among the newest is a cultivator that tills between plants within a row (Paulson, 1995). It incorporates video cameras and computer technology with robotics to eliminate weeds to within one-third inch of the plant. It can operate at speeds of up to 10 miles per hour, can be used at night, and can distinguish between weeds and crops. While still in the testing stage, it has promise for the cultivation of row crops such as corn, cotton, lettuce and tomatoes. This technology could reduce the need for herbicides used to eliminate weeds.

Crop Residue Management

The other major change occurring in the farm machinery industry is the continuing development of conservation tillage machinery and equipment used for crop residue management. Tillage equipment used to practice conservation tillage involves several designs aimed at leaving at least 30 percent of the soil surface covered with crop residue. This new and innovative machinery goes by various names, including air drill, mulchmaster, mulch tiller, and conservation disk chisel. Machinery is designed to leave residue on the surface by tilling the ground under the past crop residue instead of turning the ground over and burying residue as was done with moldboard plows and large offset disks.

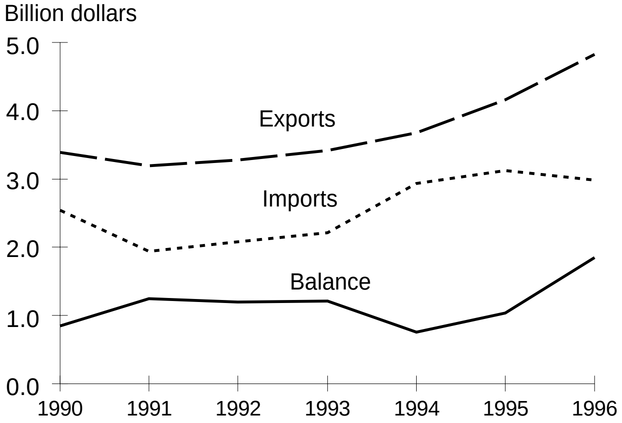
With conservation tillage, the ground is worked fewer times during a crop cycle than with conventional tillage, leaving more residue on the surface. Increased residue helps prevent soil erosion. No-till engages the ground just once, when planting the seed.

Other benefits of crop residue management (and fewer times over the field) are less machinery and equipment wear and lower maintenance. Capital expenditures are reduced as are fuel and labor costs. (See chapter 4.2, *Crop Residue Management*, for a discussion of trends in conservation tillage. See also USDA, ERS, 1994b, page 114, for a discussion of the effects of these trends on farm machinery purchases.)

Farm Machinery Trade

The United States had a trade surplus in farm machinery of $1.85 billion in 1996, up from $1.04 billion in 1995. Exports of farm machinery have exceeded imports for the last 7 years (fig. 3.4.4). Major export and import countries were Canada, the United Kingdom, Germany, and Japan.

Figure 3.4.4--Farm machinery exports, imports, and trade balance (exports minus imports), 1990-96



Source: USDA, ERS, based on unpublished U.S. Department of Commerce data.

Total imports and exports, and consequently the farm machinery trade balance, can be volatile from year to year. A single large sale of combines or irrigation equipment can significantly affect total exports. Changes in factors that affect U.S. demand for farm machinery will affect import totals. Both imports and exports can increase and the trade balance decrease, as happened in 1994 (fig. 3.4.4).

Exports of farm machinery totaled $4.8 billion in 1996, up 16 percent from 1995 (table 3.4.5). Imports for 1996, $3.0 billion, decreased 4 percent from 1995 (table 3.4.6).

The largest export category—tractor gear boxes, axles, chassis, engines, brakes, differentials, wheels, mufflers, exhausts, steering assembles, and parts and accessories not elsewhere classified—accounted for 22 percent of farm machinery exports ($1.0 billion) in 1996. Farm tractors over 100 horsepower made up 14 percent of 1996 exports. Other big export items included combines and harvesters, horticultural equipment, irrigation equipment, and agricultural engines.

Canada was the major export market in 1996, accounting for 32 percent of U.S. farm machinery exports. Canada was also the major supplier of farm machinery imports into the United States, accounting for 22 percent of all 1996 imports (USDA, ERS, 1996b).

Table 3.4.5—U.S. farm machinery exports, 1990-96[1]

Item	1990	1991	1992	1993	1994	1995	1996
				Million dollars			
Total	3,392	3,196	3,280	3,419	3,684	4,158	4,830
Tractors							
Wheel tractors, 40-100 HP	16	12	18	31	45	98	109
Wheel tractors, over 100 HP	331	335	356	445	417	525	691
Wheel tractors, used & misc.	91	84	76	88	87	86	103
Crawlers, less than 160 HP[2]	13	14	13	16	15	16	12
Crawlers, over 160 HP[2]	296	356	327	232	312	310	325
Crawlers, used[2]	17	25	21	16	21	18	16
Self-propelled combines	182	163	205	310	275	288	496
Other combines and harvesters	196	171	141	162	200	218	257
Balers	74	60	66	77	78	68	71
Mowers	42	46	47	55	65	51	42
Other haying equipment	49	34	34	52	52	46	43
Moldboard plows	2	1	1	1	1	0	0
Disc and other plows	9	10	11	15	15	12	17
Harrows and cultivators	28	27	29	43	45	40	50
Seeders and planters	36	29	34	46	52	39	82
Fertilizing equipment	18	22	22	23	27	22	26
Spraying equipment	10	22	24	22	23	25	26
Other seeding, fert., & spray equipment	61	80	84	94	119	116	124
Irrigation equipment	183	174	185	200	157	154	197
Horticultural equipment	179	95	154	176	180	185	229
Crop market preparation equipment	57	65	69	78	61	91	75
Cleaning and grading equipment	21	18	21	17	20	23	27
Dairy equipment	53	54	58	64	72	82	79
Poultry equipment	65	95	101	88	113	132	142
Other livestock equipment	43	49	48	56	60	54	70
Agricultural tools	24	27	41	21	22	20	24
Agricultural engines[2]	315	269	312	253	197	316	427
Gear boxes, axles, and assemblies[2]	969	846	758	711	925	1,096	1,046
Trailers, wagons and parts	13	13	20	27	26	25	24

[1] Some items may not be comparable to previous ERS trade data due to reclassification. Total exports may differ from those derived by other agencies due to inclusion or exclusion of specific categories.

[2] Includes industrial and other non-agricultural uses.

Source: USDA, ERS, based on unpublished U.S. Department of Commerce data.

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Table 3.4.6—U.S. farm machinery imports and trade balance, 1990-96[1]

Item	1990	1991	1992	1993	1994	1995	1996
				Million dollars			
Total	2,545	1,945	2,083	2,210	2,932	3,120	2,981
Tractors							
Wheel tractors, 40-100 HP	718	547	569	565	699	722	623
Wheel tractors, over 100 HP	183	172	188	137	202	220	232
Wheel tractors, used & misc.	97	46	38	59	129	133	115
Crawlers, less than 160 HP	129	82	93	149	204	187	184
Crawlers, over 160 HP	9	2	47	15	36	140	82
Crawlers, used	4	1	1	5	8	4	4
Self-propelled combines	22	18	15	16	25	25	17
Other combines and harvesters	124	95	93	121	113	130	136
Balers	79	71	62	55	67	77	55
Mowers	77	60	60	64	72	73	65
Other haying equipment	33	26	21	33	45	50	35
Moldboard plows	6	6	3	3	1	1	1
Disc and other plows	44	32	27	22	22	21	24
Harrows and cultivators	190	128	118	122	143	138	155
Seeders and planters	40	19	26	56	53	47	66
Fertilizing equipment	17	14	15	16	16	14	14
Spraying equipment	20	12	13	14	14	15	19
Other seeding, fert., & spray equipment	22	21	22	25	29	26	33
Irrigation equipment	7	13	19	17	11	12	16
Horticultural equipment	37	27	27	36	43	44	41
Crop market preparation equipment	20	16	19	20	23	24	29
Cleaning and grading equipment	8	9	9	15	17	12	10
Dairy equipment	18	11	19	18	18	21	20
Poultry equipment	21	27	25	22	25	25	31
Other livestock equipment	25	18	21	23	28	31	29
Agricultural tools	55	35	39	40	43	44	45
Agricultural engines	87	58	71	69	104	127	80
Gear boxes, axles, and assemblies	446	376	419	468	734	746	804
Trailers, wagons and parts	7	4	4	6	8	9	12
Balance: exports minus imports	847	1,251	1,197	1,209	753	1,039	1,849

[1] Some items may not be comparable to previous ERS trade data due to reclassification. Total imports may differ from those derived by other agencies due to inclusion or exclusion of specific categories.

Source: USDA, ERS, based on unpublished U.S. Department of Commerce data.

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4.1 Production Management Overview

Production management deals with how farmers combine land, water, commercial inputs, labor, and their management skills into systems and practices that produce food and fiber. To sustain production over time, farmers must make a profit and preserve their resource and financial assets. Society wants food and fiber products that are low-cost, safe to consume, and aesthetically pleasing; and production systems that preserve or even enhance the environment. These often competing goals and pressures get reflected not only in the inputs made available for production, but also in how the inputs are combined and managed at the farm level. Increasingly, farmers are facing economic and societal pressures to change from traditional or conventional systems to improved or alternative ways of managing production.

Production management encompasses various challenges that the farmer must meet to produce food and fiber:

- **Crop residue management**—deciding how much crop residue to leave on the soil surface to protect soil and conserve moisture, based on topography, soil conditions and erosion, pests, and climate.

- **Cropping management**—deciding what crops to grow and in what sequence, based on rate of return, weather, soil, government programs, pests, and available machinery.

- **Pest management**—determining pest threats to crop growth and quality and what actions to take, mindful of food and worker safety and environmental impacts.

- **Nutrient management**—determining and applying the nutrients required to foster crop yields and farm profitability, while reducing nutrient loss to the environment.

- **Irrigation water management**—determining water needed for crop growth and applying that water efficiently, considering water availability and offsite water quantity/quality impacts.

These management challenges are each examined more fully in chapters 4.2-4.6, including the types and prevalence of conventional and alternative systems and practices, and the economic and other factors affecting their use. New technology (such as precision agriculture and genetically engineered seeds) and increasing interest in organic and sustainable agriculture are affecting some farmers' production management decisions.

4.2 Crop Residue Management

Crop residue management (CRM), which calls for fewer and/or less intensive tillage operations and preserves more previous crop residue, is designed to protect soil and water resources and to provide additional environmental benefits. CRM is generally cost-effective in meeting conservation requirements and can lead to higher farm economic returns by reducing fuel, machinery, and labor costs while maintaining or increasing crop yields. Conservation tillage, the major form of CRM, was used on almost 104 million acres in 1996, over 35 percent of U.S. planted cropland area.

Contents

Crop residue management (CRM) systems include reduced tillage or conservation tillage practices such as no-till, ridge-till, and mulch-till as well as the use of cover crops and other conservation practices that provide sufficient residue cover to help protect the soil surface from the erosive effects of wind and water (see box, "Crop Residue Management and Tillage Definitions," p. 156).

Why Manage Crop Residue?

Historically, crop residues were removed from farm fields for livestock bedding, feed, and/or other off-field purposes. Whatever residues remained on the fields after harvest were burned off primarily to control pests, plowed under, or tilled into the soil. Culturally, some farmers take pride in having their fields "clean" of residue and intensively tilled to obtain a smooth surface in preparation for planting. More recently, farmers have adopted CRM practices—with government encouragement—because of new knowledge about the benefits of leaving greater residue and the availability of appropriate technology. CRM can benefit society through an improved environment, and farmers through enhanced farm economic returns. However, adoption of CRM may not lead to clear environmental benefits in all regions and, similarly, may not be economically profitable on all farms. Some questions remain. Public and private interests are continuing cooperative efforts to address the barriers to realizing greater benefits from CRM practices. For example, recent advances in planting equipment permit seeding new crops through heavier surface residue into untilled soil and even directly into killed sod. Long-term effects of CRM can include:

Reduced Erosion. Tillage systems that leave substantial amounts of crop residue evenly distributed over the soil surface reduce wind erosion and the kinetic energy impact of rainfall, increase water infiltration and moisture retention, and reduce surface sediment and water runoff (Edwards, 1995). Several field studies (Baker and Johnson, 1979; Glenn and Angle, 1987; Hall and others, 1984; Sander and others, 1989) conducted on small watersheds under

Crop Residue Management and Tillage Definitions

Little or no management of residue	Crop Residue Management (CRM)			
Conventional tillage	**Reduced tillage**	**Conservation tillage**		
		Mulch-till	**Ridge-till**	**No-Till**
Moldboard plow or intensive tillage used	No use of moldboard plow and intensity of tillage reduced	Further decrease in tillage (see below)	Only ridges are tilled (see below)	No tillage performed (see below)
< 15% residue cover remaining	15-30% residue cover remaining	-----30% or greater residue cover remaining-----		

Crop Residue Management (CRM) is a year-round conservation system that usually involves a reduction in the number of passes over the field with tillage implements and/or in the intensity of tillage operations, including the elimination of plowing (inversion of the surface layer of soil). CRM begins with the selection of crops that produce sufficient quantities of residue to reduce wind and water erosion and may include the use of cover crops after low residue-producing crops. CRM includes all field operations that affect residue amounts, orientation, and distribution throughout the period requiring protection. Site specific residue cover amounts needed are usually expressed in percentage but may also be in pounds. Tillage systems included under CRM are conservation tillage (no-till, ridge-till, and mulch-till) and reduced tillage.

Conservation Tillage—Any tillage and planting system that covers 30 percent or more of the soil surface with crop residue, after planting, to reduce soil erosion by water. Where soil erosion by wind is the primary concern, any system that maintains at least 1,000 pounds per acre of flat, small grain residue equivalent on the surface throughout the critical wind erosion period. Two key factors influencing crop residue are 1) the type of crop, which establishes the initial residue amount and its fragility, and 2) the type of tillage operations prior to and including planting.

Conservation Tillage Systems include:

> ***No-till***—The soil is left undisturbed from harvest to planting except for nutrient injection. Planting or drilling is accomplished in a narrow seedbed or slot created by coulters, row cleaners, disk openers, in-row chisels, or roto-tillers. Weed control is accomplished primarily with herbicides. Cultivation may be used for emergency weed control.
>
> ***Ridge-till***—The soil is left undisturbed from harvest to planting except for nutrient injection. Planting is completed in a seedbed prepared on ridges with sweeps, disk openers, coulters, or row cleaners. Residue is left on the surface between ridges. Weed control is accomplished with herbicides and/or cultivation. Ridges are rebuilt during cultivation.
>
> ***Mulch-till***—The soil is disturbed prior to planting. Tillage tools such as chisels, field cultivators, disks, sweeps, or blades are used. Weed control is accomplished with herbicides and/or cultivation.

Reduced Tillage (15-30% residue)—Tillage types that leave 15-30 percent residue cover after planting, or 500-1,000 pounds per acre of small grain residue equivalent throughout the critical wind erosion period. Weed control is accomplished with herbicides and/or cultivation.

Conventional Tillage (less than 15% residue)—Tillage types that leave less than 15 percent residue cover after planting, or less than 500 pounds per acre of small grain residue equivalent throughout the critical wind erosion period. Generally includes plowing or other intensive tillage. Weed control is accomplished with herbicides and/or cultivation.

Conventional Tillage Systems (as defined in the Cropping Practices Survey):

> ***Conventional tillage with moldboard plow***—Any tillage system that includes the use of a moldboard plow.
>
> ***Conventional tillage without moldboard plow***—Any tillage system that has less than 30 percent remaining residue cover and does not use a moldboard plow.

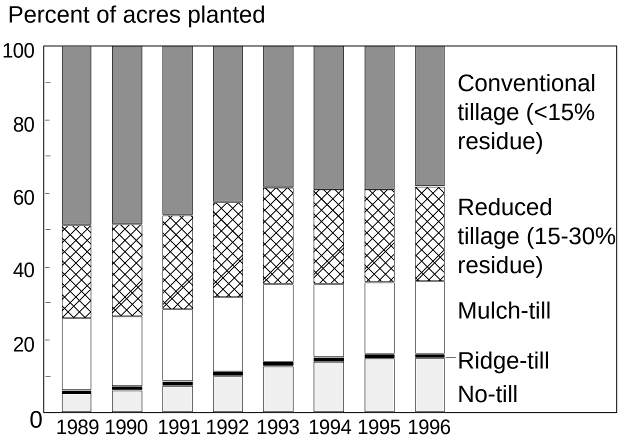
Source: USDA, ERS, based on Bull, 1993, and Conservation Tillage Iinformation Center, 1996.

natural rainfall on highly erodible land (14 percent slope) have compared erosion rates among tillage systems. Compared with the moldboard plow, no-till reduces soil erosion by as much as 90 percent and mulch-till and ridge-till by up to 70 percent.

Cleaner Surface Runoff. Surface residues help intercept nutrients and chemicals and hold them in place until they are used by the crop or degrade into harmless components (Dick and Daniel, 1987; Helling, 1987; Wagenet, 1987). In addition, the filtering action of increased organic matter in the top layer of soil results in cleaner runoff (by reducing contaminants such as sediment and adsorbed or dissolved chemicals), and thus benefits water quality in lakes and streams (Onstad and Voorhees, 1987; Conservation Technology Information Center or CTIC, 1996). Studies under field conditions indicate that while the quantity of water runoff from no-till fields was variable depending on the frequency and intensity of rainfall, clean-tilled soil surfaces produce substantially more runoff (Edwards, 1995). Runoff from no-till and mulch-till fields averaged about 30 and 40 percent of the amounts from moldboard-plowed fields (Baker and Johnson, 1979; Glenn and Angle, 1987; Hall and others, 1984; Sander and others, 1989). Average herbicide runoff losses from treated fields with no-till and mulch-till systems for all products and all years were about 30 percent of the runoff levels from moldboard-plowed fields (Fawcett and others, 1994). Under normal production conditions, the presence of increased crop residue reduces the volume of contaminants associated with runoff to surface waters by constraining sediment losses and enhancing infiltration (Edwards, 1995; Fawcett, 1987).

Higher Soil Moisture and Water Infiltration. Crop residues on the soil surface slow water runoff by acting as tiny dams, reduce surface crust formation, and enhance infiltration (Edwards, 1995). The channels (macropores) created by earthworms and old plant roots, when left intact with no-till, improve infiltration to help reduce or eliminate field runoff. This raises the prospect of increased water infiltration carrying agricultural chemicals into the groundwater in specific situations (more discussion later of groundwater effects). Combined with reduced water evaporation from the top few inches of soil and with improved soil characteristics, the higher level of soil moisture can contribute to higher crop yields in many cropping and climatic situations (CTIC, 1996). However, in some areas, soil moisture levels can also be too high for optimal crop growth or leave soils too cool and wet at planting time, thereby reducing yields.

Figure 4.2.1--National use of crop residue management, 1989-96



Source: USDA, ERS, based on Conservation Technology Information Center data.

Possible Higher Economic Returns. CRM may result in higher economic returns from increased or stable crop yields and lower input costs. CRM systems usually involve fewer trips over a field, resulting in reduced fuel and labor requirements and lower machinery operating costs. Whether CRM in fact reduces total costs of production for farmers depends on the magnitude of the cost savings from reduced tillage operations relative to the other possible costs affected by CRM practices. For example, there may be increased costs associated with the need for specialized equipment to handle high residue on the soil surface, and increased management, labor, and materials to effectively control pest infestations. Moreover, whether CRM results in higher net returns from farming depends on the effects of CRM practices on yields as well as costs. Farmers continually face tradeoffs between advantages and limitations in choosing the tillage system most appropriate for their conditions.

Improved Long-Term Soil Productivity. Less intensive tillage reduces the breakdown of crop residues and the loss of soil organic matter. The less a soil is tilled, the more carbon is sequestered in the soil to build organic matter and maintain long-term productivity. No-till improves soil structure (tilth) by increasing soil particle aggregation (small soil clumps), which facilitates water movement through the soil and enables plants to expend less energy to establish roots. No-till can also help to minimize soil compaction through fewer trips over the field and reduced weight and horsepower requirements (CTIC, 1996).

Table 4.2.1—National use of crop residue management practices, 1989-96[1]

Item	1989	1990	1991	1992	1993	1994	1995	1996
	Million acres							
Total area planted[2]	279.6	280.9	281.2	282.9	278.1	283.9	278.7	290.2
Area planted with:								
No-till	14.1	16.9	20.6	28.1	34.8	39.0	40.9	42.9
Ridge-till	2.7	3.0	3.2	3.4	3.5	3.6	3.4	3.4
Mulch-till	54.9	53.3	55.3	57.3	58.9	56.8	54.6	57.5
Total conservation tillage	71.7	73.2	79.1	88.7	97.1	99.3	98.9	103.8
Other tillage types:								
Reduced tillage (15-30% residue)	70.6	71.0	72.3	73.4	73.2	73.1	70.1	74.8
Conv. tillage (< 15% residue)	137.3	136.7	129.8	120.8	107.9	111.4	109.7	111.6
Total other tillage types	207.9	207.7	202.1	194.2	181.0	184.6	179.7	186.4
Percentage of area with:	*Percent*							
No-till	5.1	6.0	7.3	9.9	12.5	13.7	14.7	14.8
Ridge-till	1.0	1.1	1.1	1.2	1.2	1.3	1.2	1.2
Mulch-till	19.6	19.0	19.7	20.2	21.2	20.0	19.6	19.8
Total conservation tillage	25.6	26.1	28.1	31.4	34.9	35.0	35.5	35.8
Other tillage types:								
Reduced tillage (15-30% residue)	25.3	25.3	25.7	25.9	26.3	25.8	25.2	25.8
Conv. tillage (< 15% residue)	49.1	48.7	46.1	42.7	38.8	39.3	39.3	38.4
Total other tillage types	74.4	73.9	71.9	68.6	65.1	65.0	64.5	64.2

[1] For tillage system definitions, see box "Crop Residue Management and Tillage Definitions," p. 156.

[2] Total area planted does not include newly established permanent pastures, fallow, annual conservation use, and Conservation Reserve Program (CRP) acres. However, it does include newly seeded alfalfa and other rotational forage crops in the year they are planted.

Source: USDA, ERS, based on Conservation Technology Information Center (CTIC) data from Crop Residue Management Surveys.

Reduced Release of Carbon Gases and Air Pollution. Intensive tillage contributes to the conversion of soil carbon to carbon dioxide, which in the atmosphere can combine with other gases to affect global warming. Increased crop residue and reduced tillage enhance the level of naturally occurring carbon in the soil and contribute to lower carbon dioxide emissions. In addition, CRM requires fewer trips across the field and less horsepower, which reduces fossil fuel emissions. Crop residues reduce wind erosion and the generation of dust-caused air pollution (CTIC, 1996).

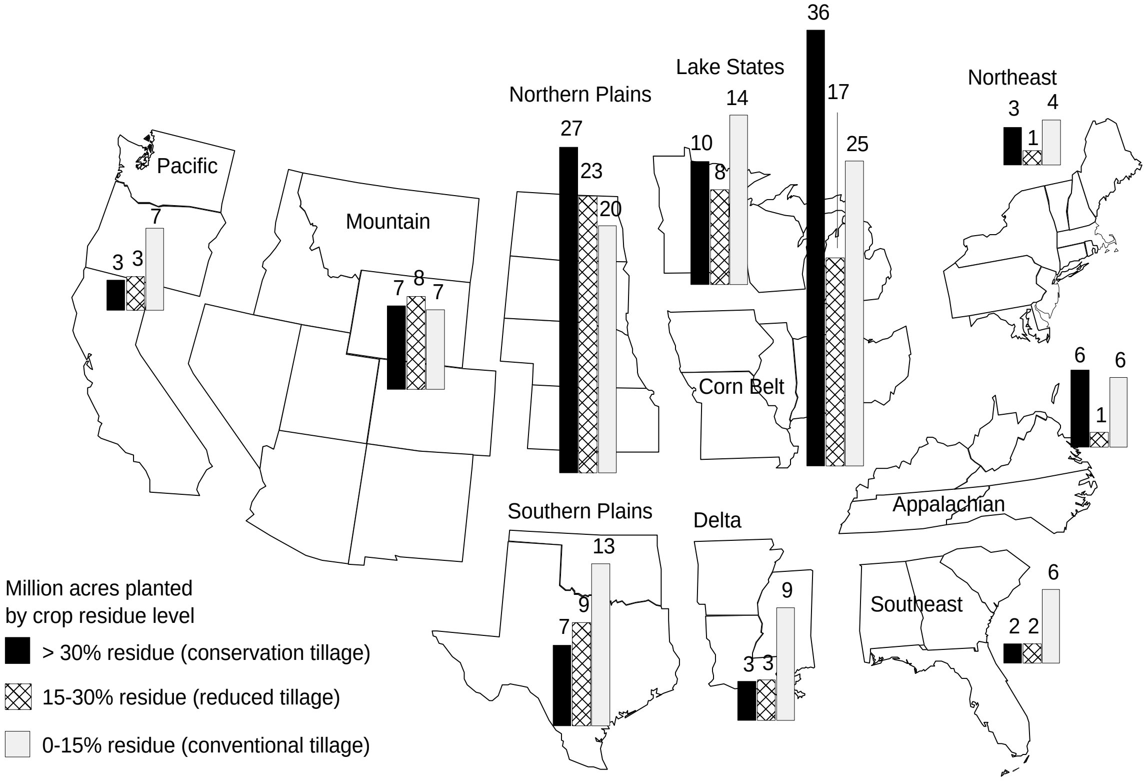
National and Regional CRM Use

In 1996, U.S. farmers practiced conservation tillage on almost 104 million acres, up from 72 million acres in 1989 (table 4.2.1). Conservation tillage now accounts for more than 35 percent of U.S. planted crop acreage (fig. 4.2.1). Most of the growth in conservation tillage since 1989 has come from expanded adoption of no-till, which can leave as much as 70 percent or more of the soil surface covered with crop residues. Use of no-till practices increased as farmers implemented conservation compliance plans from 1990 to 1995 as required under the Food Security Act and subsequent farm legislation.

The Corn Belt and Northern Plains, with 51 percent of the Nation’s planted cropland, accounted for three-fifths of total conservation tillage acres in 1996 (fig. 4.2.2). These regions, plus the Lake States, Mountain region, and Southern Plains, have substantial acreage with 15-30 percent residue cover which, with improved crop residue management, has the potential to qualify as conservation tillage (which requires 30 percent or more surface residue cover).

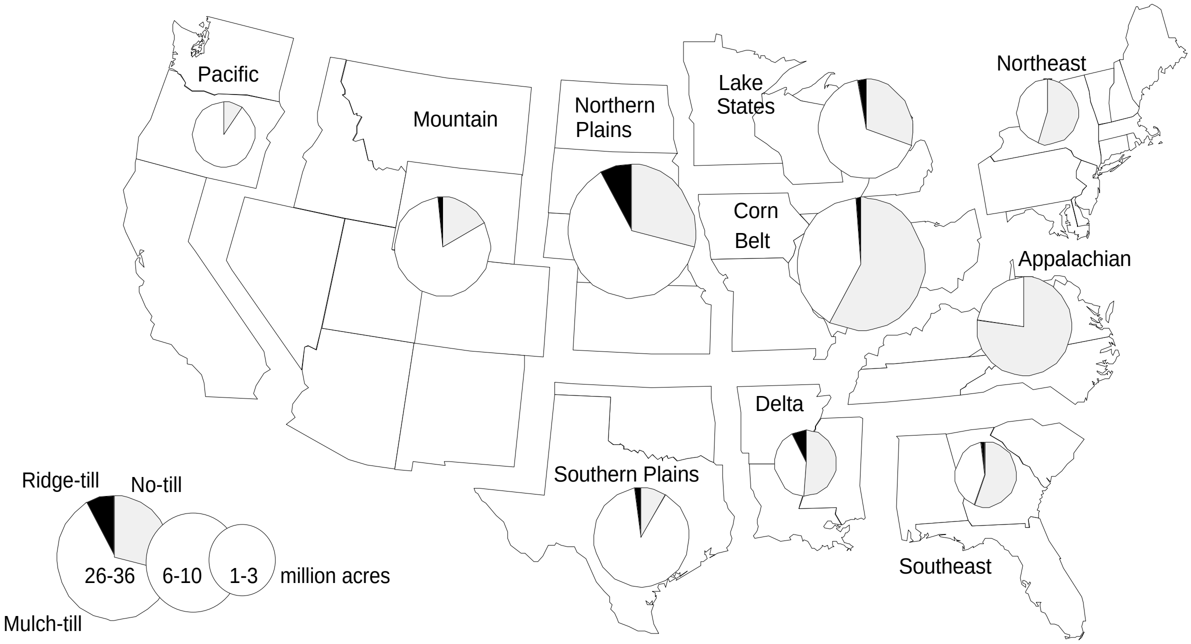
U.S. crop area planted with no-till tripled to almost 43 million acres between 1989 and 1996, while the area planted with clean tillage systems (less than 15 percent residue cover) declined by about one-fifth. Since 1989, no-till’s share of conservation tillage acreage has increased while the share with mulch-till and ridge-till has remained fairly stable (fig. 4.2.1). No-till’s share of conservation tilled area is greater in the six eastern regions than elsewhere (fig. 4.2.3). The aftereffects of the 1993 Midwest floods resulted in a slight decline during 1994 in acres planted (percent) with conservation tillage, mostly in mulch tillage, in the Corn Belt and Lake States (fig. 4.2.4).

Figure 4.2.2--Crop residue levels on planted acreage by region, 1996



Source: USDA, ERS, based on Conservation Technology Information Center data.

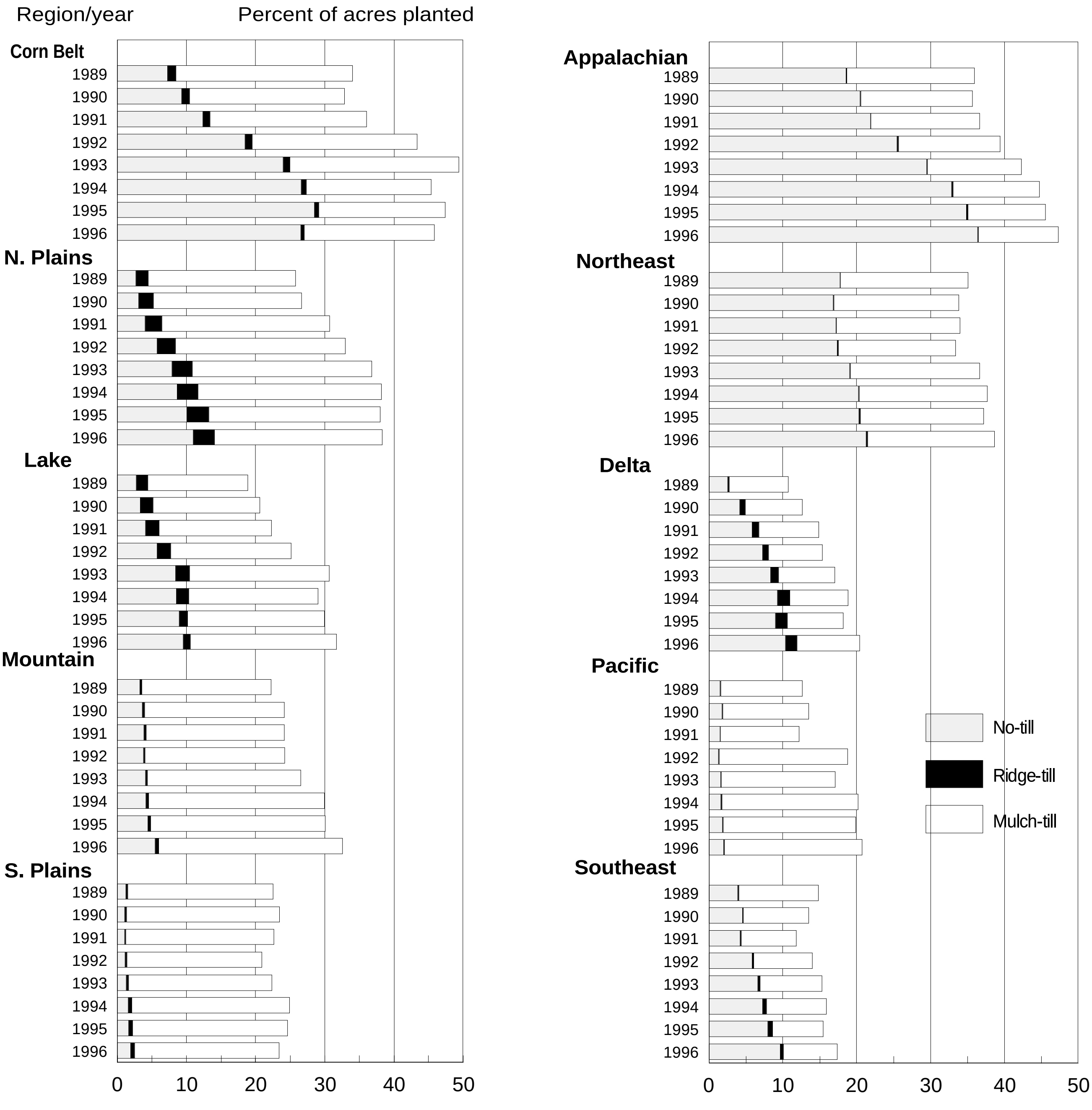
Figure 4.2.3--Applied conservation tillage practices, 1996



Circle size represents conservation tillage area in million acres (range in ascending size).

Source: USDA, ERS, based on Conservation Technology Information Center data.

Figure 4.2.4--Conservation tillage use by region, 1989-96



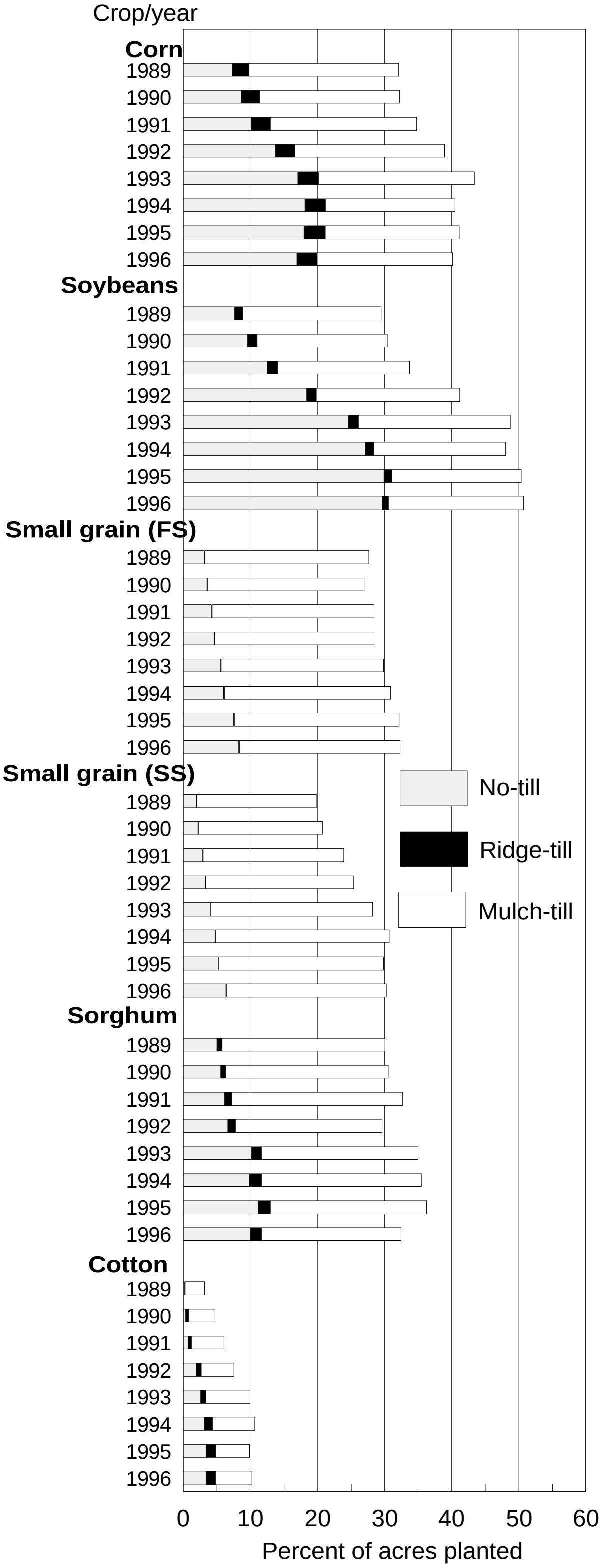
Source: USDA, ERS, based on Conservation Technology Information Center data.

Over 1989-96, the share of acres planted with no-till showed an increase for most years in nearly all regions (fig. 4.2.4).

CRM Use on Major Crops

Conservation tillage was used mainly on corn, soybeans, and small grains in 1996. Over 45 percent of the total acreage planted to corn and soybeans was conservation-tilled. Expanded use of no-till has been greater for row crops (that is, corn and soybeans) than for small grains or sorghum (fig. 4.2.5). Fields planted to row crops tend to be more susceptible to erosion because these crops provide less vegetative cover, especially earlier in the growing season. On double-cropped fields, conservation tillage was used on more than two-thirds of soybean acreage, more than half of corn acreage, and about half of sorghum acreage. The use of no-till with double-cropping

Figure 4.2.5--Conservation tillage use by major crop, 1989-96



FS = Fall seeded SS = Spring seeded

Source: USDA, ERS, based on Conservation Technology Information Center data.

facilitates getting the second crop planted quickly and limits potential moisture losses from the germination zone in the seedbed, allowing greater flexibility in cropping sequence or rotation (Sandretto and Bull, 1996).

The 1988-95 Cropping Practices Surveys (CPS) provide detailed data on residue levels and tillage systems for individual field crops in major producing States (for more discussion, see "Cropping Practices Survey" in the appendix). The advantages of the CPS for analysis of CRM is that it allows the linking of CRM practices to other relevant details about the farm production system, such as the type of tillage equipment used and the number of trips made over a field. These annual surveys indicate a decline in the use of the moldboard plow and other conventional tillage systems and an increase in the use of all types of conservation tillage for most of the major field crops. Less than 10 percent of the surveyed area in major producing States used a moldboard plow in 1995, down from 20 percent in 1988.

Corn. Tillage systems used for corn production in the 10 major producing States indicate a trend toward the use of conservation tillage systems (table 4.2.2). No-till systems were used on 17 percent of the acreage in 1995, up from only 5 percent in 1989, and exceeded 20 percent in several Corn Belt States. Ridge-till systems increased to 3 percent of the total acreage, but this expansion was mainly confined to Nebraska and Minnesota. A moldboard plow was used on 8 percent of 1995 corn acres, down from 20 percent in 1988.

Soybeans. Soybean production also indicated a trend toward greater use of conservation tillage systems. The 14 major soybean producing States were divided into northern and southern areas. The northern area showed a steady increase in no-till system use from 3 percent of the acreage in 1988 to 30 percent in 1995. At the same time, mulch-till increased from 14 to 24 percent and use of the moldboard plow dropped from 28 to 8 percent. The small share of soybean acreage with ridge-till was located mainly in Nebraska and Minnesota, where some soybeans are grown in rotation with ridge-till corn. The southern area increased no-till system use from 7 percent of the acreage in 1988 to 25 percent in 1995.

Cotton. Nearly all cotton was produced using conventional tillage methods in the six major cotton States. However, use of the moldboard plow decreased to less than one-half of the 1988 level. Arizona, California, and parts of Texas have State

Table 4.2.2—Tillage systems used in field crop production in major producing States, 1988-95[1]

Item	Unit	1988	1989	1990	1991	1992	1993	1994	1995
Corn (10 States)	*1,000 acres*[2]	53,200	57,900	58,800	60,350	62,850	57,350	62,500	55,850
Residue remaining after planting	*Percent*	19	19	22	24	27	29	30	29
Conventional tillage	*Percent of acres*	80	78	74	70	61	58	57	59
With moldboard plow		20	19	17	15	12	9	8	8
Without moldboard plow		60	59	57	55	49	49	49	51
Conservation tillage		21	22	27	30	39	42	43	41
Mulch-till		14	17	18	20	25	24	23	21
Ridge-till		*	*	*	*	2	3	3	3
No-till		7	5	9	10	12	15	17	17
Northern soybeans (7 States)	*1,000 acres*[2]	36,550	37,750	36,400	38,850	38,150	42,500[3]	43,750[4]	41,700
Residue remaining after planting	*Percent*	17	19	19	25	28	35	36	38
Conventional tillage	*Percent of acres*	83	77	74	66	59	52	47	45
With moldboard plow		28	26	23	18	12	8	9	8
Without moldboard plow		55	51	51	48	47	44	38	37
Conservation tillage		17	22	27	35	41	48	53	54
Mulch-till		14	18	21	25	26	25	26	24
Ridge-till		*	*	*	*	1	1	1	1
No-till		3	4	6	10	14	22	26	30
Southern soybeans (7 States)	*1,000 acres*[2]	12,200	13,380	11,850	10,800	10,480	NA[4]	NA[4]	10,140
Residue remaining after planting	*Percent*	14	15	19	17	18	NA	NA	27
Conventional tillage	*Percent of acres*	88	87	81	83	79	NA	NA	68
With moldboard plow		3	4	4	3	3	NA	NA	1
Without moldboard plow		85	82	78	80	76	NA	NA	67
Conservation tillage		12	15	19	17	24	NA	NA	32
Mulch-till		5	5	7	6	8	NA	NA	7
Ridge-till		*	*	*	*	id	NA	NA	nr
No-till		7	10	12	11	14	NA	NA	25
Upland cotton (6 States)	*1,000 acres*[2]	9,700	8,444	9,730	10,860	10,200	10,360	10,023	11,650
Residue remaining after planting	*Percent*	2	2	3	3	3	2	3	3
Conventional tillage	*Percent of acres*	100	99	98	97	100	99	99	98
With moldboard plow		28	15	14	21	12	16	10	13
Without moldboard plow		72	84	84	76	88	83	89	85
Conservation tillage		id	id	2	2	id	1	1	2
Mulch-till		id	id	1	1	id	**	**	**
No-till		id	id	1	1	id	1	1	1
Winter wheat (12-15 States)[5]	*1,000 acres*[2]	32,830	34,710	40,200	34,180	36,990	37,210	34,590	34,265
Residue remaining after planting	*Percent*	17	17	18	17	19	18	18	20
Conventional tillage	*Percent of acres*	82	84	81	84	79	80	83	78
With moldboard plow		15	16	12	12	11	6	8	11
Without moldboard plow		67	68	69	72	68	76	75	67
Conservation tillage		17	16	20	16	21	18	17	22
Mulch-till		16	15	17	13	18	14	12	15
No-till		1	1	3	3	3	4	5	7
Spring and durum wheat (4-5 States)[6]	*1,000 acres*[2]	12,280	19,580	18,900	16,500	19,550	18,900	19,700	18,700
Residue remaining after planting	*Percent*	18	22	22	24	23	25	25	22
Conventional tillage	*Percent of acres*	77	68	73	66	68	65	64	73
With moldboard plow		14	8	10	7	8	8	7	6
Without moldboard plow		63	60	63	59	60	57	57	67
Conservation tillage		23	32	27	34	32	35	36	29
Mulch-till		22	31	25	31	26	28	30	22
No-till		1	1	2	3	6	7	6	5
Total acres surveyed	*1,000 acres*[2]	156,760	171,764	175,880	171,040	178,220	166,320	170,563	172,305
Conventional tillage	*Percent of acres*	82	79	77	74	69	65	63	64
With moldboard plow		19	17	15	14	11	8	8	8
Without moldboard plow		63	62	62	60	58	57	55	56
Conservation tillage		18	21	23	26	31	35	37	36
Mulch-till		13	17	17	19	21	21	21	19
Ridge-till		*	*	*	*	1	1	1	1
No-till		5	4	6	7	9	13	15	16

id = Insufficient data. * = Included in no-till for these years. ** = Less than 1 percent. NA = Not available.[1] For the States included, see "Cropping Practices Survey" in the appendix. For tillage system definitions, see box "Crop Residue Management and Tillage Definitions." [2] Preliminary. Planted acres except for winter wheat (harvested). [3] May not add due to rounding. [4] Arkansas in 1993 and 1994 is included in Northern area. Previously, Arkansas was included with GA, KY, LA, MS, NC, and TN (all not surveyed in 1993 and 1994) to comprise Southern area. [5] Winter wheat includes 15 States in 1988-89 and 1991-92; 12 States in 1990; and 13 States in 1993-95. [6] Spring wheat includes 5 States in 1988-89 and 4 States in 1990-95. Durum wheat includes only ND. Source: USDA, ERS, Cropping Practices Survey data.

"plow-down" laws requiring that the cotton plant be disposed of to eliminate the over-winter food source for bollworms and boll weevils. Some producers have misinterpreted these laws to mean that the previous crop must be plowed under with a moldboard plow. California producers mainly use multiple passes with a heavy disk. In some areas of Texas, the moldboard plow is also used to bring up clay subsoil in order to cover the soil surface with clods to help control wind erosion. The large number of tillage trips across the field (averaging 6.1) leaves very little residue, even without use of the moldboard plow. Research is being conducted in a number of cotton producing States on the use of strip-till and no-till systems and the "stale seedbed" system, which uses cover crops or weeds to provide vegetative cover on the field from harvest to the next planting season.

Winter Wheat. Except for 1994 and 1995, a steady decline in moldboard plow use occurred in winter wheat production since 1988 (table 4.2.2). Meanwhile, no-till and conventional tillage without the plow showed a corresponding increase. The heavy rains and flooding in some States during 1993 affected planting of the 1994 crop. Siltation from flooding and the impact from heavy rains may have contributed to increased use of the moldboard plow in 1994 and 1995 (Bull and Sandretto, 1996).

Spring and Durum Wheat. Variations in the type of tillage system used in the production of spring and durum wheat may be partly due to weather-soil relationships in the areas producing these crops. Much of the wheat produced in the Great Plains and the Western States is grown after a fallow period. Implement passes made during the fallow year are included in determining residue levels, hours per acre, and trips over the field. Normal fallow procedure in these regions starts with chisel plowing and other noninversion tillage operations in the fall instead of a pass with a moldboard plow. For these regions, therefore, more trips over the field occur under conventional tillage without the moldboard plow than for tillage with the moldboard plow.

Factors Affecting CRM Adoption

The trend toward adoption of conservation tillage and a corresponding decline in clean tillage has been stimulated by the prospect of higher economic returns with conservation tillage and by public policies and programs promoting conservation tillage for its conservation benefits. The major limitations to adoption of soil-conserving tillage systems for some farmers include additional management skill requirements, expectations of lower crop yields and/or economic returns in specific geographic areas or situations, negative attitudes or perceptions, and institutional constraints.

Prospects for Higher Economic Returns

Higher economic returns with CRM result primarily from some combination of increased or stable crop yields and an overall reduction in input costs, with both heavily dependent on characteristics of the resource base and appropriate management (Clark and others, 1994).

Yield Response. Yield response with soil-conserving tillage systems varies with location, site-specific soil characteristics, climate, cropping patterns, and level of management skills. In general, long-term field trials on well-drained to moderately well-drained soils or on sloping land show slightly higher no-till yields, particularly with crop rotations, compared with conventional tillage (Hudson and Bradley, 1995; CTIC, 1996). Experienced no-till farmers claim greater yields from increased infiltration and improved soil properties such as reduced erosion and soil compaction, increased soil organic matter and earthworm activity, and improved soil structure (tilth) in 4-7 years from when the system becomes established (CTIC, 1996). A mulch-till system may be more appropriate where soil varies greatly within a field, where pre-plant incorporated herbicides are used for weed control, or where equipment or management limitations preclude the use of no-till or ridge-till (CTIC, 1996).

The benefits from improved moisture retention in the root zone—that derive from reduced water runoff, increased infiltration, and suppressed evaporation from the soil surface—usually increase crop yields, especially under dry conditions. In some areas of the northern Great Plains, these benefits permit a change in the cropping pattern to reduce the frequency of moisture-conserving fallow periods (Clark and others, 1994).

Increased crop residue on the soil surface tends to keep soils cooler, wetter, and less aerated (Mengel and others, 1992). These characteristics under cool, wet planting conditions, especially in some Northern States, have been blamed for delayed plantings, uneven stands, and lower corn yields (Griffith and others, 1988). However, with hot, dry weather later in the growing season, the effects of increased organic matter, improved moisture retention and permeability, and reduced nutrient losses from erosion all benefit crop yields. No-till is particularly well suited for double-cropping because farmers can plant

Table 4.2.3—Pesticide use on corn by tillage system, 10 major producing States, 1994[1]

Item	Conventional tillage		Mulch tillage	No tillage	Ridge tillage
	with moldboard plow	without moldboard plow			
	Treated acres as a percent of total planted				
Herbicides					
Any herbicide	93.4	98.0	98.6	99.2	99.0
(Avg. lbs./treated acre)	(2.2)	(2.8)	(2.7)	(3.3)	(2.0)
Major active ingredients:					
Atrazine	52.3	66.5	66.6	84.0	78.1
Cyanazine	19.5	18.4	18.5	35.0	10.5
Acetochlor	2.2	7.6	8.3	4.4	6.2
Alachlor	18.0	17.2	16.4	18.1	21.3
Metolachlor	24.1	32.9	35.4	28.4	42.3
Nicosulfuron	18.1	12.5	14.7	10.4	7.9
Pendimethalin	5.2	2.6	2.1	1.7	*
2,4-D	8.9	11.2	11.6	25.8	15.3
Dicamba	29.0	28.7	36.0	20.6	22.4
Glyphosate	1.3	0.9	1.7	18.7	4.4
Bromoxynil	8.5	9.9	11.7	6.0	10.9
Insecticides					
Any insecticide	24.2	23.9	26.9	26.6	51.9
(Avg. lbs./treated acre)	(1.0)	(0.8)	(0.8)	(0.7)	(0.9)
Major active ingredients:					
Chlorpyrifos	10.2	7.5	7.7	6.7	6.0
Fonofos	3.9	2.3	1.9	1.2	9.6
Methyl parathion	*	1.8	1.8	2.7	20.6
Terbufos	4.7	6.1	7.6	6.2	10.2
Permethrin	*	2.7	2.3	6.7	6.8
Tefluthrin	*	3.4	4.4	3.9	5.8
Fungicides	nr	nr	nr	nr	nr

[1] For States included, see "Cropping Practices Survey" in the appendix.
nr = none reported. * = insufficient sample size.
Source: USDA, ERS, 1994 Cropping Practices Survey data.

the second crop quickly, minimizing moisture loss from the germination zone (Sandretto and Bull, 1996).

The crop grown in the previous year can have a great influence on the success of conservation tillage systems, especially no-till. The kind, amount, and distribution of previous crop residue can influence soil temperature, seed germination, and early growth. Lower seed germination and lack of early growth sometimes result from an allelopathic (negative) effect due to placing seed under or near decaying residue from the same crop or a closely related species (Griffith and others, 1992; CTIC, 1996). No-till, mulch-till, and even conventional tillage systems are more likely to be successful with crop rotation than with monoculture. Ridge-till is best suited to row crops, and therefore is often used with monoculture. However, monoculture often results in lower yields and generally requires greater fertilizer and pesticide use compared with crop rotations, regardless of tillage system (Bull and Sandretto, 1995).

Crop yields can be significantly affected by pest populations, which frequently change under different tillage systems. Maintaining or increasing yields when changing tillage systems requires skillful use of the various means of pest control, including pesticide application, cultivation, cover crops, crop rotation, scouting, and other integrated pest management practices (see box, “Weed Control and Tillage,” p. 168, for more detail).

Changes in Pesticide Use. Pesticide use on major crops differs among tillage systems, but it is difficult to distinguish the effects related to tillage systems

Table 4.2.4—Pesticide use on soybeans by tillage system, 8 major producing States, 1994[1]

Item	Conventional tillage with moldboard plow	Conventional tillage without moldboard plow	Mulch tillage	No tillage	Ridge tillage
	Treated acres as a percent of total planted				
Herbicides					
Any herbicide	97.9	98.1	99.4	98.0	94.1
(Avg. lbs./treated acre)	(1.0)	(1.1)	(1.1)	(1.3)	(0.9)
Major active ingredients:					
Alachlor	6.9	7.0	6.1	6.8	31.4
Metolachlor	8.2	8.1	6.8	9.3	10.1
2,4-D	0.5	1.2	3.9	35.4	25.3
Acifluorfen	4.4	12.1	8.7	8.0	nr
Fenoxaprop-ethyl	5.5	4.8	3.3	6.1	5.1
Fluazifop-P-butyl	7.7	7.4	6.9	9.9	5.1
Quizalofop-ethyl	5.2	5.6	6.2	8.6	nr
Chlorimuron-ethyl	13.6	14.4	13.0	20.1	5.1
Thifensulfuron	16.0	11.1	15.2	15.9	10.1
Imazaquin	9.0	22.0	14.2	16.7	nr
Imazethapyr	47.9	36.2	49.9	41.6	54.6
Pendimethalin	14.0	24.9	26.1	26.6	nr
Trifluralin	31.5	31.5	29.1	1.5	nr
Metribuzin	11.0	11.1	6.1	13.2	10.1
Glyhposate	1.2	1.5	4.6	54.5	40.5
Bentazon	16.0	14.0	15.4	12.6	nr
Lactofen	6.5	2.9	4.7	5.0	12.1
Sethoxydim	2.3	5.2	7.6	9.3	8.2
Insecticides	*less than 1 percent overall*				
Fungicides	*less than 1 percent overall*				

[1] For States included, see "Cropping Practices Survey" in the appendix.
nr = none reported. * = insufficient sample size.
Source: USDA, ERS, 1994 Cropping Practices Survey data.

from differences in pest populations between areas and from one year to the next, and from use of other pest control practices. Factors other than tillage that affect pest populations may have greater impact on pesticide use than type of tillage (Bull and others, 1993). The 1994 CPS data for major field crops also illustrate that differences among tillage systems tend to be more in the combinations of active ingredients applied than in the proportion of acres treated or the amount applied per treated acre.

In 1994, nearly all **corn** acres under all tillage systems were treated with herbicides (table 4.2.3). The overall application rate (pounds per acre treated) was highest for no-till and lowest for ridge-till. Differences between tillage systems were shown to be greater among the active ingredients applied than in the overall average amount applied per treated acre. Of the 11 most commonly used herbicides on corn, 2 were applied most frequently with conventional-till, 3 with mulch-till, 4 with no-till, and 2 with ridge-till. A comparison between no-tilled and conventionally tilled corn acreage shows that 6 of the 11 most commonly used herbicides were more frequently used with conventional-till and 5 were more frequently used with no-till.

The share of corn acreage treated with insecticides was slightly over one-half of ridge-tilled acres, but only about one-fourth with other tillage systems (table 4.2.3). No-till acres received slightly less insecticide per treated acre than did acreage with other tillage systems. No fungicide use was reported on surveyed corn acreage.

Most **soybean** acres under all tillage systems were treated with herbicides, but few or none were treated with insecticides or fungicides. A greater variety of herbicides were used on soybeans than on corn or wheat (table 4.2.4). Differences in the specific herbicide active ingredients applied existed between tillage systems, but the overall average amounts applied per treated acre were similar, although slightly higher for no-till. Of the 18 most commonly applied herbicides on soybeans, 5 were applied most frequently with conventional-till, 9 with no-till, and 4 with ridge-till.

A much smaller share of **winter wheat** acreage than corn or soybeans was treated with herbicides, ranging from 39 percent of no-till acreage to 51 percent of conventionally tilled acreage (table 4.2.5).

Survey results for recent years indicate lower rates of insecticide use with no-till than with other tillage systems, partly because no-till systems are often used in combination with crop rotations. Greater and more frequent insecticide use was reported for moldboard plowing and ridge-till, respectively, both of which are characterized by continuous production of a single crop. No-till corn and soybeans received slightly higher applications of herbicides than did other tillage systems, but the additional pesticide costs are usually more than offset by substantial cost savings from reduced field operations (CTIC, 1996). Employing integrated pest management practices such as scouting to limit spraying to isolated problem areas can reduce costs and the amount of pesticide used, regardless of tillage system (Sandretto and Bull, 1996).

Impacts on Production Costs. Choice of tillage system affects machinery, chemical, fuel, and labor costs. In general, decreasing the intensity of tillage or reducing the number of operations results in lower machinery, fuel, and labor costs. These cost savings may be offset somewhat by potential increases in chemical costs depending on the herbicides selected for weed control and the fertilizers required to attain optimal yields (Siemens and Doster, 1992). The cost of pesticides with alternative tillage systems is not simply related to the total quantity of all pesticides used. Alternative pesticides (active ingredients) and/or different quantities of the same or similar pesticides are often used with different tillage systems. Newer pesticides are often used at a much lower rate but are quite often more expensive. This complicates the prediction of cost relationships between tillage systems. When making comparisons among tillage systems, the cost calculation must be based on the specific quantity and price of each pesticide used (Bull and others, 1993).

Table 4.2.5—Pesticide use on winter wheat by tillage system, 13 major producing States, 1994[1]

	Coventional tillage			
Item	with mldbd. plow	w/out mldbd. plow	Mulch tillage	No tillage
	Treated acres as a percent of total planted			
Herbicides				
Any herbicide	49.4	50.6	43.1	38.7
(Avg. lbs./treated acre)	(0.45)	(0.35)	(0.38)	(0.43)
Major active ingredients:				
2,4-D	14.4	24.4	28.9	14.2
MCPA	7.7	4.9	3.0	8.5
Chlorsulfuron	25.5	15.1	4.5	nr
Metsulfuron-methyl	7.9	13.7	17.9	nr
Thifensulfuron	5.8	4.2	3.3	13.3
Tribenuron-methyl	6.1	4.2	4.2	14.2
Triasulfuron	5.3	5.6	3.6	*
Dicamba	5.1	10.3	8.7	*
Insecticides	*less than 1 percent overall*			
Fungicides	*less than 1 percent overall*			

[1] For States included, see "Cropping Practices Survey" in the appendix.
nr = none reported. * = insufficient sample size.
Source: USDA, ERS, 1994 Cropping Practices Survey data.

The reduction in labor requirements per acre for higher residue tillage systems can be significant and can result in immediate cost savings. Less hired labor results in direct savings, while less operator or family labor leaves more time to generate additional income by expanding farm operations or working at off-farm jobs. However, the benefits from tillage systems that reduce labor and time requirements may be greater than perceived from just the cost savings per acre. Consideration must be given to the opportunity cost of the labor and time saved. Farmers who spend less time in the field have more time for financial management, improved marketing, or other activities to improve farm profitability (Sandretto and Bull, 1996).

Making fewer trips over the field also means that equipment lasts longer and/or can cover more acres. In either case, machinery ownership costs per acre are reduced (Monson and Wollenhaupt, 1995). In addition, the size and number of machines required decline as the intensity of tillage or the number of operations is reduced. This can result in significant savings in operation and maintenance costs. Fewer trips alone can save an estimated $5 per acre on machinery wear and maintenance costs (CTIC, 1996). While new or retrofitted machinery may be required to adopt conservation tillage practices, machinery costs usually decline in the long run because a smaller complement of machinery is needed for high-residue no-till systems. Conservation tillage equipment designs have improved over the last decade and these improvements enhance the opportunity for successful conversion to a CRM system. Farm equipment manufacturers are now producing a wide range of conservation tillage equipment suitable for use under a variety of field conditions (Sandretto and Bull, 1996).

Reducing the intensity or number of tillage operations also lowers fuel and maintenance costs. Fuel costs, like labor costs, can drop nearly 60 percent per acre by some estimates (Monson and Wollenhaupt, 1995; Weersink and others, 1992). If fuel prices increase, conservation tillage practices become relatively more profitable.

Several studies report that on a range of soil types, higher residue tillage systems such as no-till and ridge-till result in greater economic returns for a given crop than lower residue systems. Even in some northern areas with heavy wet soils where no-till yields have sometimes been slightly lower, net returns have often been better because per-acre costs were lower (Doster and others, 1994; Fox and others, 1991).

The net returns on the entire operation can increase even if returns for a particular crop on a farm do not. For example, a tillage system that requires substantially less labor per acre and reduces returns per acre slightly but that permits application of the labor savings to more acres could result in larger total returns (Sandretto and Bull, 1996).

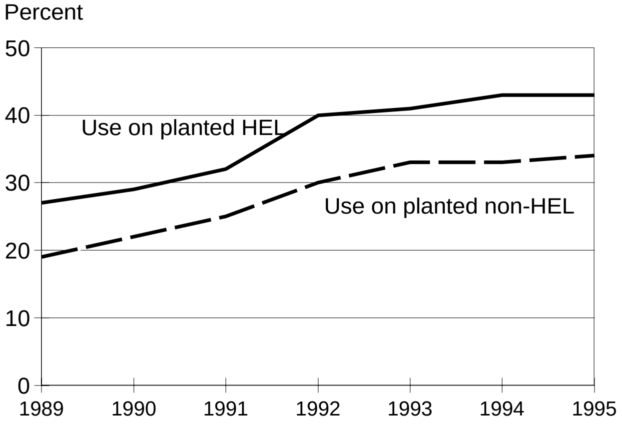
Policies and Programs Affecting CRM Adoption

The 1985 Food Security Act gave farmers an additional incentive to adopt CRM when it instituted the Conservation Compliance program to protect highly erodible land (HEL) by controlling erosion. Under the program, farmers who produce crops on HEL and fail to implement an approved conservation plan forfeit eligibility for most USDA farm program benefits (see chapter 6.4, *Conservation Compliance*). Crop residue management (including conservation tillage) is a key component in the conservation plans for around 75 percent of the 91 million acres of cultivated HEL subject to compliance. The 1990 Food, Agriculture, Conservation, and Trade Act further strengthened the Federal role of protecting soil and water resources. Besides increasing penalties for noncompliance, the Act established other programs that offer incentives to adopt practices such as CRM to improve water quality or control erosion (see chapter 6.1, *Conservation and Environmental Programs Overview).*

In 1991, USDA developed the Crop Residue Management Action Plan to assist producers with highly erodible cropland in implementing conservation systems that met the requirements of their approved conservation plans by the 1995 deadline. The plan increased the timely delivery of information, provided technical assistance to help land users install conservation systems, helped producers better understand the conservation provisions of farm legislation, and assisted them in maintaining their conservation plans and thus their eligibility for USDA program benefits. Crop Residue Management (CRM) alliances were established at the National, State, and local levels. The 20 State alliances, some of which remain active, included USDA agencies, agricultural supply industries, farm media, grower associations, commodity groups, conservation and environmental organizations, universities, and others interested in promoting the conservation of soil and water resources. USDA continues to provide assistance to farmers to meet conservation compliance requirements.

Adoption of conservation tillage practices, especially no-till, has been greater on HEL than on non-HEL (fig. 4.2.6). In 1995, conservation tillage was used on 43 percent of HEL acreage planted to major field crops in the primary producing States, compared with 34 percent for non-HEL. However, the rate of

Figure 4.2.6--Use of conservation tillage on HEL and non-HEL, major crops and growing States, 1989-95



See "Cropping Pracitces Survey" in the appendix for crops and States included.

Source: USDA, ERS, Cropping Practices Survey data.

Weed Control and Tillage

Crop yields can be significantly affected by weed populations. Traditional tools for controlling weeds have included crop rotations, crop or cover crop competition, and row crop cultivation and they play an important role in combination with modern pesticides to achieve effective pest control. These tools combined with scouting comprise the core of what has become known as integrated pest management (IPM). IPM is a systematic way of controlling pests (weeds, insects, and diseases) using a variety of techniques. The results from an effective IPM program often include higher profits due to savings from reduced pesticide applications and improved protection of the environment (CTIC, 1996).

Weed control problems vary among tillage systems because the nature of the weed population changes. An understanding of the response of weed species to tillage systems is essential in designing effective weed management programs (Martin, 1995). Actively tilling the soil before planting (and cultivating during the growing season for row crops) helps provide weed control in conjunction with herbicides. However, tillage also brings up dormant weed seeds and prepares a seedbed not only for the crop, but for weed seeds as well (Monson and Wollenhaupt, 1995). Tillage can also expand the perennial weed problem of some species by spreading their rhizomes and tubers (Kinsella, 1993). A challenge with no-till in some areas involves a gradual shift from annual weeds to several hard-to-control perennial weeds, including woody species and volunteer trees after 7-10 years (CTIC, 1996).

Mechanical cultivation for weed control is only feasible on the share of the cropland acreage planted with a row planter. The reported Cropping Practices Survey incidence of mechanical cultivation was fairly consistent across tillage systems except for higher use with ridge-till and considerably lower (one-third to one-half of the share of acres treated for other tillage systems) use with no-till. Ridge-till systems normally use mechanical cultivations during the season to rebuild and maintain the ridges in addition to controlling weeds.

Crop rotation can be an important tool for weed control because certain weeds are easier or more economical to control in one crop than another. For example, perennial grasses that are difficult to control in corn can be managed effectively in broadleaf crops such as cotton and soybeans (CTIC, 1996). Conversely, some broadleaf weeds are much easier to control in corn than in soybeans. A competitive crop that can achieve early shading of weeds can greatly improve weed control. The success of this system depends on obtaining a quick-closing crop canopy to shade emerging weeds and good stand establishment since skips allow some weeds to escape. Cover crops can accomplish this goal by reducing the amount of sunlight that reaches emerging weed seedlings (CTIC, 1996). In addition, crop rotations can often reduce the area needing treatment with pesticides and also decrease reliance on annual applications of the same pesticide; the latter pattern can increase pest resistance and reduce pesticide effectiveness.

Herbicide effectiveness depends on spraying at the right stage of growth and of plant stress, and under favorable weather conditions. Recommendations on the type and combination of herbicides and method of application for efficient weed control vary among tillage systems. The effective use of post-emergence herbicides most commonly employed in high residue situations requires careful and regular scouting and better knowledge of weed identification to facilitate appropriate herbicide selection. Herbicide application rates for ridge tillage were consistently lower than for other systems due to more prevalent banding, which uses smaller amounts of chemicals and more mechanical cultivation. Because no-till employs limited (or no) mechanical tillage, proper application of herbicides is essential for effective weed control. In addition, during the transition to higher residue systems, farmers often tend to increase slightly the amount of herbicide used as a risk aversion measure. The reported Cropping Practices Survey increase by no-till users in herbicide application (by weight) is due in part to the inclusion of an additional "burndown" herbicide treatment prior to planting as a substitute for mechanical weed control. However, successful no-till users find that herbicide costs generally decrease and become competitive with conventional tillage systems in 3-5 years (CTIC, 1996). Also, different management skills are required to control weeds with no-till or other high-residue tillage systems than with intensive tillage systems (CTIC, 1996). Crop residue management systems do not necessarily increase agricultural chemical requirements or application costs. The trend toward precision farming means that increasingly agricultural chemicals, including fertilizers and pesticides, will be carefully managed in a manner tailored to the site-specific conditions and the problems to be corrected. Improved input management is becoming necessary to ensure economic viability, maintain long-term productivity, and protect environmental quality.

increase in the use of conservation tillage on non-HEL was similar to that on HEL, suggesting that all producers are motivated by the potential of conservation tillage systems to reduce costs, improve efficiency, and/or increase soil productivity. Also, once a producer implements conservation tillage on HEL to stay in compliance, using the same equipment and techniques on his non-HEL makes good economic sense. The use of conservation tillage has leveled off in several regions since 1993 due in part to unusual weather patterns—primarily heavy rainfall—and cool planting conditions unfavorable for conservation tillage.

In passing the Federal Agriculture Improvement and Reform Act of 1996, Congress reaffirmed its preference for dealing with agricultural resource problems using voluntary approaches. The Act continued the Conservation Compliance Program and gave farmers greater flexibility in meeting requirements. The Act also established the Environmental Quality Incentives Program (EQIP) to replace previous financial and technical assistance programs and to better target assistance to areas most needing actions to improve or preserve environmental quality. While half of EQIP funding is to be directed to environmental practices relating to livestock production, the other half will be for other conservation improvements, which could include incentives (financial and technical assistance) for implementation of improved crop residue management. Directing the program toward management practices would favor crop residue management. Crop residue management, including conservation tillage, is a particularly cost-effective method of erosion control (requiring fewer resources than intensive structural measures such as terraces) that can be implemented in a timely manner to meet conservation requirements. The cost-savings from reduced fuel, labor, machinery, and time requirements, while usually maintaining or increasing crop yields, make greater adoption of CRM likely. (For more information on programs, see chapter 6.1, *Conservation and Environmental Programs Overview*.)

Barriers to CRM Adoption

Given the conservation and potential economic advantages of conservation tillage systems, and the promotion that has occurred, why aren't the systems used on more than 35 percent overall of U.S. cropland? First, adoption is the final step in a process that begins with becoming aware, moves to gaining information, then to trial, and finally to adoption. A number of farmers are in the reduced tillage transition stage between conventional intensive tillage and conservation tillage, or who are currently trying conservation tillage on part of their land, and will likely make further change. Second, there are particular soils and climatic or cropping situations where conservation tillage systems have not yet demonstrated that they can consistently produce good economic results. In these areas, most farmers are waiting for the development of improved systems. Further limiting factors include the additional management skill requirements and economic risk involved in changing systems, attitudes and perceptions against new practices, and, in some cases, institutional constraints.

Some farmers' attitudes against adoption of new technologies, including conservation tillage, derive from a reluctance to change from methods of production that have proven to be successful in terms of their own experience. The superiority of new techniques have to be demonstrated to a sufficient extent to offset exposure to the risks inherent in making a change from traditional methods. The perceived risks are critical because unusual weather or pest problems may be accepted as a normal occurrence with traditional methods but may be blamed on the new tillage system if they occur during the transition period. Consequently, the new technique may be unfairly discredited in the area for a long time if initial attempts result in failure.

Cultural and institutional factors can also constrain adoption. Some farmers or even whole communities demonstrate strong preferences for clean tilled fields as a sign of "good" management. The banker and/or landlord may be reluctant to permit a change in the way the land is farmed especially if they perceive more potential risk to crop yields and net returns during the transition.

Farmers are aware that a series of challenges exist with higher residue levels. These may include different (but not necessarily more serious) disease, insect, or weed problems; difficulties with more residue on the surface in proper seed, fertilizer, and pesticide placement; and, under certain conditions, particularly cool wet seasons, lower corn yields (CTIC, 1996). In addition, the land must be properly prepared for no-till (previous compaction and fertility problems need to be corrected first), and the transition period (2-4 years) can be very difficult as the farmer wrestles with learning how to adapt the new tillage system to his unique situation, especially if unusual weather or pest problems arise during the transition, because long-term benefits such as improved soil quality may take 4-7 years to be realized. However, in many situations, innovative farmers have found solutions to most of these problems or through experience have learned how to reduce their impact to tolerable levels until more acceptable solutions can be devised.

Farmers often face significant tradeoffs when choosing the most appropriate tillage system for their conditions. Higher residue systems generally allow less opportunity to correct mistakes or adjust to changed circumstances once the season is underway. Conservation tillage practices, with their higher levels of crop residue, usually require more attention to proper timing and placement of nutrients and pesticides, and in carrying out tillage operations. Nutrient management can become more complex with crop residue management because of higher residue levels and reduced options with regard to method and timing of nutrient applications. No-till in particular can complicate manure application and may also contribute to nutrient stratification within the soil profile from repeated surface applications without any mechanical incorporation. In those cases where nutrients cannot be utilized effectively by plant roots that are deeper in the soil profile, the problem can ususally be avoided by correcting prevalent nutrient deficiencies prior to the switch to no-till. With higher residue levels, however, evaporation is reduced and more water is maintained near the surface, which favors the growth of feeder roots near the surface where the nutrients are concentrated (Monson and Wollenhaupt, 1995). But in some instances, increased application of specific nutrients may be necessary and specialized equipment required for proper fertilizer placement, thereby contributing to higher costs.

Effects of CRM on Groundwater Quality

Enhanced infiltration of water under crop residue management raises concerns about whether there are greater adverse effects on groundwater than with conventional clean tillage. The issue continues to be analyzed; the difficulty of tracking a pesticide once it has been applied further complicates attempts to find an answer. While conservation tillage systems can change weed and insect problems and the kinds of herbicides and insecticides used, total use of pesticides does not change greatly when farmers convert to conservation tillage (tables 4.2.3-4.2.5) (Fawcett, 1987; Fawcett and others, 1994; Hanthorn and Duffy, 1983). Analyses of pesticide quantities by tillage system generally conclude that appropriate conservation tillage systems are no more likely to degrade water quality through chemical contamination than other tillage systems, and do not increase the risk of undesirable impacts from pesticides on human health and aquatic life (Baker, 1980; Baker, 1987; Baker and others, 1987; Baker and Laflen, 1979; Edwards and others, 1993; Fawcett and others, 1994; Melvin, 1995; Wagenet, 1987). For a specific site, the effects depend on a complex set of factors besides the infiltration rate, including properties of the chemicals applied, quantities applied, timing of application, method of application, and a variety of site specific factors (climatic, hydrologic, geologic, and topographic) (Onstad and Voorhees, 1987; Wagenet, 1987). Also, one has to consider what the cropping pattern and chemical use would be in the absence of CRM. In any situation, some of the factors may contribute to less effect and others to greater effect, with detailed analysis required to determine the net result. Some observations on these factors follow.

The potential for higher infiltration with conservation tillage creates an opportunity for groundwater degradation in some circumstances, such as for highly permeable sandy soils over shallow groundwater aquifers (Baker, 1987; CTIC, 1996; Wauchope, 1987). However, increased infiltration also normally dilutes the concentration of contaminants in the percolate to ground water (Bengtson and others, 1989; USDA, ERS, 1993).

The fate of applied chemicals is particularly dependent on the respective properties of the active ingredients, such as their adsorption, persistence, solubility, and volatility (Dick and Daniel, 1987; Fawcett, 1987; Melvin, 1995; Wauchope and others, 1992). Chemicals with high water solubility and low adsorption characteristics are highly mobile and possess the potential for loss through surface runoff or subsurface drainage (leachate) (Moldenhauer and others, 1995; USDA, ERS, 1993).

Pesticides that are strongly adsorbed to soil, sediment particles, or organic matter are protected from chemical or biological degradation and volatilization while adsorbed to these materials. Pesticides that are tightly held will not readily leach to ground water and will be found in surface-water runoff only under erosive conditions where the particles to which they are attached are washed off the fields. The soil adsorption property is a major factor affecting the pollution potential of a particular pesticide (Melvin, 1995; Wauchope and others, 1992; Weber and Warren, 1993).

The behavior of chemical compounds in the environment is also influenced by the application method. For example, whether a pesticide is applied to foliage or the soil or is incorporated into the soil makes a big difference in how easily the application deposits can be dislodged by rain, and thus be leached into the soil or transported in surface runoff. Soil incorporation physically lowers the susceptibility of a pesticide to volatilization and thereby increases its persistence (Wauchope and others, 1992).

Early pre-plant (EPP) herbicides are applied several weeks or months prior to crop planting. Their advantages include prevention of weed establishment, elimination of the need for burndown treatments at planting, reduction in the potential for herbicide carryover from one crop season to the next, and the spreading out of labor related to planting. However, there are disadvantages to EPP herbicides particularly on sloping or highly erodible cropland. Occasional heavy rains on unprotected sloping fields can cause soil erosion and high rates of surface runoff even with no-till systems, and chemicals (attached to soil particles or dissolved in runoff water) could enter waterways. Use of EPP herbicides should be avoided on sandy soils or other soil types with high leaching potential (CTIC, 1996). Pre-plant/pre-emergence herbicides depend on rainfall to trigger the active ingredients soon after application. Once in the soil, they must be mobile and persistent for a sufficient period of time to make contact with and destroy weed seedlings throughout the expected weed germination period. These enhanced mobility and persistence properties also facilitate the migration of such chemicals in the environment through surface-water runoff or percolation to ground water.

Burndown herbicides, more important in no-till systems, are nonselective and are used before or just after planting but prior to crop emergence. Post-emergence herbicides are successful in controlling problem weeds or escapes well into the growing season without damaging the crop or reducing yield potential and are generally unaffected by soil type or amount of crop residue on the surface. However, post-emergent application does depend on proper timing and correct identification of the target weeds. Post-emergence and burndown herbicides frequently have short or no residual soil effects (CTIC, 1996). They are generally less mobile and less persistent than pre-emergence herbicides and, therefore, less likely to migrate from their target. Pesticides applied to plant foliage, for instance, leave pesticide deposits that are highly vulnerable to photolysis and other degradation processes that reduce persistence and the potential for water pollution (Wauchope and others, 1992). For example, glyphosate and paraquat, although highly soluble, are strongly adsorbed to the targeted material or the soil and rapidly converted to relatively harmless degradation products that reduce their potential for contaminating ground water (Melvin, 1995; Moldenhauer and others, 1995).

The difference in chemical properties between the different classes of herbicides is important when considering the environmental impacts of herbicide use between tillage systems. Tillage systems that employ herbicides with lower mobility and shorter persistence are preferable from a water-quality standpoint to tillage systems that require herbicides with greater mobility and longer persistence (Melvin, 1995; Wauchope and others, 1992).

The inherent toxicity of the active ingredients and their degradation, the impact of these products on nontarget species, and their mobility and persistence in soil and water determine their relative impact on the environment. In addition, a specific active ingredient can be converted by environmental processes including hydrolysis, photolysis, and other processes into an important degradation product with different chemical properties (Wauchope and others, 1992). Tillage systems employing newer pesticides that are highly toxic to targeted species but are used at much lower rates may be more environmentally desirable. For a given chemical, the amount of active ingredient being dissipated into the environment is generally proportionate to the amount applied; as a result, lower application rates translate into reduced exposure of nontarget species to the side effects of these chemicals (Wauchope and others, 1992).

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Recent ERS Reports on Crop Residue Management

"Conservation Tillage Gaining Ground," AO-232, August 1996 (Carmen Sandretto and Len Bull). This special article discusses recent trends in conservation tillage practice adoption and describes some of the benefits and limitations associated with their use on major field crops. Conservation tillage practices such as no-till, ridge-till, and mulch-till were expected to be used on a record-high 103 million acres in 1996 (more than one-third of U.S. planted cropland), with most of the growth due to rapid expansion in the adoption of no-till which nearly tripled between 1989 and 1995 to almost 41 million acres. Expanded use of no-till has been greater for row crops such as corn and soybeans than for small grains or sorghum.

Crop Residue Management and Tillage System Trends, SB-930, August 1996 (Len Bull and Carmen Sandretto). Trends in national and regional use of crop residue management show that conservation tillage use expanded from 72 million acres in 1989 to more than 99 million acres in 1994. Tillage systems use on major field crops is presented for 1988-94 and by surveyed States for 1994.

Soil Erosion and Conservation in the United States: An Overview, AIB-718, September 1995 (Richard Magleby, Carmen Sandretto, William Crosswhite, and C. Tim Osborn). This report provides background information on soil use, erosion, and conservation policies and programs; summarizes assessments of economic and environmental effects of erosion; and discusses policies and programs as well as options for their improvement.

"Analysis of Pesticide Use by Tillage System in 1990, 1991, and 1992 Corn and Soybeans," AR-32, October 1993 (Len Bull, Herman Delvo, Carmen Sandretto, and Bill Lindamood). This special article examines the relationship between pesticide use and tillage systems in the production of corn and soybeans in 1990, 1991, and 1992. Little difference between tillage systems was observed in the percentage of acres treated or in the number of herbicide treatments. Average pounds of herbicide active ingredients applied did not exhibit a consistent pattern across tillage systems over the three year period. Among tillage systems, about 40-50 percent of the herbicide acre-treatments were combination mixes of more than one active ingredient, but no-till was the exception with about 50-60 percent being combination mixes. Corn insecticide applications were not significantly different between tillage systems, although no-till acreage received lower application amounts for each year.

"Water Quality Effects of Crop Residue Management," AR-30, May 1993 (Carmen Sandretto). This special supplement points out that crop residue management in combination with other appropriate management strategies and the proper selection and use of chemicals can play a crucial role in protecting water quality. The movement of agricultural chemicals from the point of application to ground or surface waters depends on a complex set of interactions between a variety of site specific factors ranging from the climate and the hydrologic, geologic, and topographic characteristics of the land surface, and the chemical carriers—sediment, surface runoff, and subsurface drainage water—and the respective properties of the active ingredients of the applied chemicals, such as their adsorption, persistence, solubility, and volatility characteristics.

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4.3 Cropping Management

Rotating crops can help maintain soil fertility and reduce the need for chemical fertilizers and pesticides. Most corn and soybeans are grown in rotation with each other or other row crops. The most predominant wheat rotation is wheat-fallow-wheat, while monoculture is the most common practice in cotton. The primary factor determining a farmer's choice of cropping pattern is the rate of return; other contributing factors include agroclimatic conditions, farm programs, conservation programs, and environmental regulations. Crop rotations, generally. will prevail over monoculture only if more profitable.

Contents

Rotating crops to help maintain soil fertility, reduce soil erosion, and control insects and diseases (by disrupting the life cycle of insect pests, weeds, and plant pathogens) was much more common before the mid-1950s, when farmers increased their reliance on insecticides, herbicides, and fungicides, and commercial fertilizers as a means of sustaining or increasing yields. More recently, public concerns about the hazards of these chemicals in the food chain and in ground and surface water have prompted policy makers, universities, and other private sector decision makers to examine ways to reduce the use of these chemicals in agricultural production. Consequently, farmers are increasingly considering production alternatives, including crop rotation, to reduce adverse environmental consequences.

Farmers choose between crop rotation (planting different crops successively in the same field) and monoculture (or continuous cropping) based on agro-climatic and economic factors. This choice, in turn, frequently affects the use of fertilizers and pesticides. The Cropping Practices Survey, which collects a 3-year cropping history, indicates various cropping patterns and how they affect input use in the production of corn, soybeans, cotton, and wheat—the four major commercial crops (see box, "Cropping Pattern Definitions").

Environmental Benefits of Crop Rotations

The potential benefits of crop rotation include improved fertility by including nitrogen fixing legumes in crop rotation; reduced incidence of plant diseases, insects, and weeds; reduced loss of soil, nutrients, and moisture; increased water-holding capacity of the soil through increased organic matter; and reduced water pollution often associated with runoff and leaching. However, short-term benefits accruing to the farmer may not be sufficient to prevent a reduction in earnings from substituting one crop with another, unless the new crop can by used by onfarm livestock.

Crop rotations improve soil conditions so that in most cases yields of grain crops will increase beyond those achieved with continuous cropping (Heichel, 1987; Power, 1987). Corn following wheat, which is not a

Cropping Pattern Definitions

The following definitions were applied to 3-year crop sequence data reported in the Cropping Practices Survey to represent a cropping pattern for each sample field. The data were limited to the current year's crop plus the crops planted the previous 2 years on the sample field.

Monoculture or continuous same crop—A crop sequence where the same crop is planted for 3 consecutive years. Small grains (wheat, oats, barley, flax, rye, etc.) or other close-grown crops may be planted in the fall as a cover crop. The rotation excludes soybeans double-cropped with winter wheat.

Continuous row crops—A crop sequence, excluding continuous same crop, where only row crops (corn, sorghum, soybeans, cotton, peanuts, vegetables, etc.) are planted for 3 consecutive years. Small grains or close-grown crops may be planted in the fall as a cover crop.

Mix of row crops and small grains—A crop sequence where some combination of row crops and small grains are planted over the 3-year period. The rotation excludes soybeans double-cropped with winter wheat.

Hay, pasture, or other use in rotation—A crop sequence that includes hay, pasture, or other use in 1or more previous years. The rotation excludes any of the above rotations and any area that was idle or fallow in one of the previous years.

Idle or fallow in rotation—A crop sequence that includes idle, diverted, or fallowed land in 1 or more of the previous years.

Double-cropped soybeans—A crop sequence, limited to soybean acreage, where winter wheat was planted the previous fall.

legume, produces a greater yield than continuous corn when the same amount of fertilizer is applied (Power, 1987). Yields following legumes are often 10 to 20 percent higher than continuous grain regardless of the amount of fertilizer applied (National Research Council, 1989).

Crop rotations can also control insects, diseases, and weeds, particularly those pests that attack plant roots. Crop rotations aid in insect management by replacing a susceptible crop with a non-host crop. Rotating corn with soybeans may reduce soil population of corn rootworm larvae and thereby reduce the need for insecticide treatment. In the southern United States, when peanuts are rotated with cotton and corn, the nematode population drops. If cotton is rotated with corn or grown continuously, then the sting nematode can build up to devastating levels in a few years.

Crop rotations can also help control soil erosion. Closely sown field grain crops such as wheat, barley, and oats, as well as most hay and forage crops, provide additional vegetative cover to reduce soil erosion. In addition, these crops also compete with broadleaf weeds and may help control the weed infestation in subsequent crops since they are usually harvested before weeds reach maturity and produce seed.

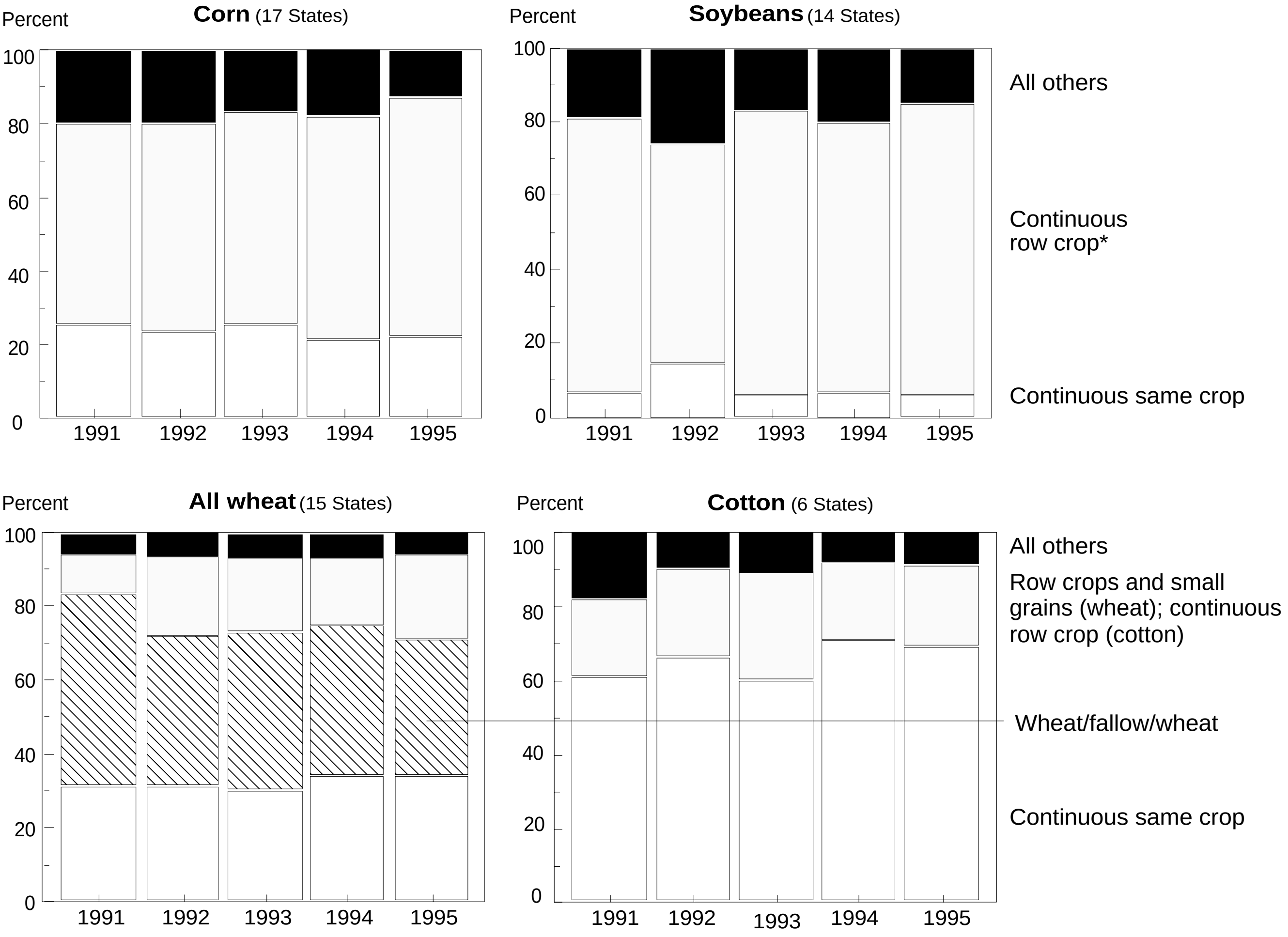
Finally, all rotations promote diversification and can provide an economic buffer against price fluctuations for crops and production inputs. Diversification also helps reduce the vagaries of weather and disease and pest infestations.

Cropping Patterns on Land Producing Major Crops

Corn. Cropping Practices Survey data (see appendix for a description of the survey) indicate that for most areas of the United States, farmers varied the crops planted from year to year. In the 17 major corn growing States, about 63 percent of the corn acreage in 1995 was in rotation with soybeans or other row crops (table 4.3.1, fig. 4.3.1). Twenty-one percent was in continuous corn. Only 9 percent of corn acreage was in rotation with small grains, hay, or pasture and the remaining 7 percent was idle for at least 1 of the 2 preceding years. Over 1991-95, corn monoculturing appears to have declined slightly, while continuous row cropping has slowly but steadily increased (fig. 4.3.1).

Soybeans. Nearly three-fourths of soybean acreage in 14 major producing States in 1995 was reported in rotation with corn or other row crops (fig. 4.3.1, table 4.3.1). Continuous soybeans (monoculture) occurred on only 10 percent of the acreage. Farmers in the

Figure 4.3.1--Trends in major cropping patterns, 1991-95



* Corn mostly in rotation with soybeans.
Source: USDA, ERS, Cropping Practices Survey data.
For States included, see "Cropping Practices Survey" in the appendix.

Northern States mostly rotated soybeans with corn, whereas Southern farmers tended to plant continuous soybeans. Over 1991-95, the rotation of soybeans with other row crops increased, while the proportion in continuous soybeans remained low (fig. 4.3.1).

Cotton. In 1995, 68 percent of the cotton acreage in the 6 major cotton producing States followed a continuous cotton pattern (fig. 4.3.1, table 4.3.1). Continuous row crops accounted for another 21 percent. Over 1991-95 period, cotton monoculturing increased.

Wheat. The two predominant cropping patterns in the major wheat growing States were continuous wheat (34 percent of total wheat acreage) and wheat-fallow-wheat (37 percent) (fig. 4.3.1, table 4.3.1). Much of the wheat in the United States is grown in the Great Plains, where moisture is limited. Farmers in these areas prefer the moisture-conserving wheat-fallow-wheat rotation. However, wheat with row crops is mostly grown in the more humid regions such as Illinois, Missouri, Ohio, and Minnesota. The rotation of wheat with row crops and other small grains (23 percent in 1995) may be increasing, while a wheat-fallow-wheat pattern may be declining (fig. 4.3.1). Also, the share of wheat acreage in continuous wheat was up slightly in 1994 and 1995 compared with 1991-93.

Rotations and Chemical Use

Herbicide use. Most acres in corn, cotton, and soybeans received one or more herbicide treatments, regardless of the cropping pattern (table 4.3.1). Some differences existed among patterns in the annual pounds of active ingredient applied per treated acres but these have not been consistent from year to year

Table 4.3.1—Cropping patterns and associated chemical use in major producing States, 1995[1]

Crop/Item	3-year crop sequence[2]							
	Continuous			Combination row crops and small grains	Idle or fallow	Hay, pasture or other crops	Double-cropped w/wheat or soybeans	Total
	Same crop	Row crops	Small grains					
Corn: (17 States)								
Planted acres (1,000 ac.)	13,581	40,050	n/a	1,770	4,480	4,224	n/a	64,105
Planted acres treated with:				*Percent of planted acres*				
Nitrogen	96.7	98.2	n/a	90.2	98.1	95.2	n/a	97.4
Phosphate	76.6	82.3	n/a	65.5	77.9	86.6	n/a	80.6
Potash	55.3	75.4	n/a	36.9	61.6	82.6	n/a	69.6
Herbicides	95.8	98.2	n/a	93.7	94.2	93.0	n/a	97.0
Insecticides	58.7	18.9	n/a	4.2	24.7	22.4	n/a	27.5
Average application rates for:				*Pounds a.i. per treated acre*				
Nitrogen	138	136	n/a	85	120	82	n/a	130
Phosphate	43	63	n/a	37	52	44	n/a	56
Potash	63	85	n/a	43	74	60	n/a	78
Herbicides	2.54	2.81	n/a	2.14	2.65	2.50	n/a	2.71
Insecticides	0.80	0.67	n/a	1.03	0.75	0.97	n/a	0.75
Soybeans: (14 States)								
Planted acres (1,000 ac.)	5,088	37,932	n/a	2,293	2,311	763	3,454	51,840
Planted acres treated with:				*Percent of planted acres*				
Nitrogen	18.0	15.3	n/a	23.6	10.7	19.3	29.9	17.0
Phosphate	27.4	19.1	n/a	36.5	21.4	33.8	31.5	22.0
Potash	30.2	23.0	n/a	35.4	23.7	33.8	36.5	25.3
Herbicides	93.7	99.0	n/a	91.4	95.1	90.2	92.9	97.5
Insecticides	7.8	1.0	n/a	1.3	0.4	id	4.1	1.8
Average application rates for:				*Pounds a.i. per treated acre*				
Nitrogen	32	27	n/a	26	15	35	42	29
Phosphate	44	57	n/a	49	38	56	56	54
Potash	71	91	n/a	55	73	85	79	85
Herbicides	1.28	1.07	n/a	1.42	1.33	0.66	1.22	1.12
Insecticides	0.56	0.39	n/a	0.64	0.58	id	0.57	0.49
Cotton: (6 States)								
Planted acres (1,000 ac.)	7,938	2,453	n/a	205	781	274	n/a	11,650
Planted acres treated with:				*Percent of planted acres*				
Nitrogen	85.3	93.0	n/a	95.1	79.6	87.6	n/a	86.8
Phosphate	52.6	72.5	n/a	69.6	40.4	55.3	n/a	56.3
Potash	44.0	35.1	n/a	44.6	20.6	34.0	n/a	40.3
Herbicides	98.5	95.8	n/a	83.4	95.7	100.0	n/a	97.5
Insecticides	73.2	81.7	n/a	84.4	81.0	92.3	n/a	76.2
Average application rates for:				*Pounds a.i. per treated acre*				
Nitrogen	93	91	n/a	137	123	148	n/a	96
Phosphate	40	47	n/a	46	48	59	n/a	43
Potash	53	47	n/a	57	31	40	n/a	51
Herbicides	2.16	1.78	n/a	2.17	1.38	2.16	n/a	2.03
Insecticides	2.36	2.28	n/a	3.18	2.27	2.66	n/a	2.36
All wheat: (15 States)								
Planted acres (1,000 ac.)	17,982	n/a	1,949	11,934	19,423	1,262	414	52,965
Planted acres treated with:				*Percent of planted acres*				
Nitrogen	87.8	n/a	95.8	96.0	80.9	72.3	86.1	87.0
Phosphate	58.2	n/a	92.5	81.8	52.6	57.6	56.7	62.7
Potash	9.8	n/a	22.7	43.7	8.6	13.3	36.3	17.7
Herbicides	63.1	n/a	95.3	67.4	74.4	83.6	45.1	69.7
Insecticides	8.8	n/a	1.7	0.8	1.2	id	id	3.7
Average application rates for:				*Pounds a.i. per treated acre*				
Nitrogen	62	n/a	73	79	59	57	74	64
Phosphate	30	n/a	29	44	27	36	49	33
Potash	21	n/a	12	50	25	45	60	38
Herbicides	0.29	n/a	0.67	0.47	0.44	0.49	0.10	0.41
Insecticides	0.36	n/a	0.50	0.30	0.38	id	id	0.36

Id = Insufficient data. n/a = Not applicable. [1] For States included, see "Cropping Practices Survey" in the appendix. [2] See box, "Cropping Pattern Definitions." Source: USDA, ERS, Cropping Practices Survey data.

and may reflect regional and weather variations. Continuous wheat showed the lowest percentage of wheat acres treated with herbicides, but this may be due to the agroclimatic conditions in the region where this pattern predominates.

Insecticide use. Insecticide use on continuous corn occurred much more frequently than on corn in rotations (table 4.3.1). Higher use of insecticides on continuous corn is needed to reduce the build up of insects, especially corn rootworm, which monoculture tends to encourage. Alternating crops with corn reduces the need for insecticide treatment because rootworms and other populations are not allowed to build up. Three-fourth of cotton acres were treated with insecticide, with little difference among patterns in average amount applied. Soybeans usually are not treated with insecticide. While only a small part of wheat acreage was treated with insecticides, the proportion of continuous wheat treated was higher than that for wheat in various rotations.

Fertilizer use. Most corn, cotton, and wheat acres received nitrogen fertilizer in 1995, with smaller proportions receiving phosphate and potash (table 4.3.1). Cropping patterns generally did not influence average annual pounds applied except nitrogen use was higher for continuous corn than for some rotations, and lower for continuous cotton than for some rotations.

Factors Affecting Cropping Patterns

The primary factor determining a farmer's choice of cropping pattern is the rate of return; other contributing factors include agroclimatic conditions, farm programs, conservation programs, and environmental regulations. Crop rotations, generally, will prevail over monoculture only if more profitable as in Iowa, where corn-soybeans-corn was shown to yield $40 per acre more than continuous corn (Duffy, 1996).

Climate, rainfall, environmental, and economic conditions divide the United States into very distinct agroclimatic regions, with each region's conditions determining its needs and ability to rotate crops. For example, the level and the variability of rainfall in a given area determine the usefulness of legumes in a rotation. Alfalfa and other deep-rooted legumes can deplete the subsoil moisture to a greater depth than corn. As a result, in arid and semi-arid regions and in subhumid and humid regions during drought, the inclusion of these legumes in a rotation may reduce the yields of the following corn or other crops. Under irrigated conditions or in areas of abundant rainfall, however, legumes in rotation with cash grains will boost yield and reduce the need for fertilizer by providing for some or all of the nitrogen needed by corn or small grains (National Research Council, 1989).

Federal policies often unintentionally discourage the adoption of crop rotations. For example, commodity programs that restricted base acreage to one or two crops encouraged monoculture. To reduce this unintended effect, the 1990 Farm Act eliminated deficiency payments on 15 percent of participating crop base acres known as Normal Flex Acreage (NFA), regardless of the crops planted on them (with a few fruit and vegetable exceptions). As a result, many farmers flexed out of monoculture or idled the marginal acreage. The extent of flexing out varied by type of crop base, depending on expected relative market return. For example, oats appeared to be the least profitable program crop during 1991-94 as almost half of its NFA was flexed to another crop. The 1996 Farm Act allows 100 percent flexing (again with a few fruit and vegetable exceptions).

Under the 1985 and subsequent farm acts, highly erodible land (HEL) used for crops requires a conservation plan to qualify for USDA farm program benefits (see chapter 6.4, *Conservation Compliance,* for more detail). Planting crops in rotation can reduce erosion and is a part of many conservation plans for HEL. Indeed, more HEL in corn in 1995 was in rotation (18 percent) than was non-HEL (12 percent) (table 4.3.2). Also more winter, spring, and durum wheat (50, 64, and 46 percent respectively) on HEL was in a fallow or idle rotation than non-HEL (34, 20, and 44 percent).

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Table 4.3.2—Cropping patterns on highly and non-highly erodible land in major producing States, 1995

Category	Corn (17 States	Soybeans (14 States)	Cotton (16 States)	Winter wheat (11 States)	Spring wheat (4 States)	Durum wheat (ND)	Total
Planted acres (1,000)[1]	64,105	51,840	11,650	34,265	15,750	2,950	180,560
Erodibility:				*Percent of planted acres*			
Highly erodible land (HEL)	18	15	20	34	26	24	21
Land not highly erodible	78	77	70	63	71	75	74
Land not designated	4	8	10	3	3	2	5
Three-year crop sequence on HEL:				*Percent of HEL planted acres*			
Continuous same crop	25	6	84	40	20	22	29
Continuous row crops	58	78	10	n/a	n/a	n/a	34
Continuous small grains	n/a	n/a	n/a	id	2	15	
Row crop and small grains[2]	3	9	1	10	14	15	8
Idle or fallow in rotation	11	7	4	50	64	46	28
Hay or other crops in rotation	4	id	id	id	id	id	1
Three-year crop sequence on non-HEL:				*Percent of non-HEL planted acres*			
Continuous same crop	22	10	67	45	15	23	24
Continuous row crops	67	74	24	n/a	n/a	n/a	53
Continuous small grains	n/a	n/a	n/a	id	12	12	1
Row crop and small grains[2]	3	11	2	20	52	20	10
Idle or fallow in rotation	7	4	7	34	20	44	12

n/a = not applicable. Id = insufficient data. Percentages may not add to 100 due to rounding.

[1] For the States included, see "Cropping Practices Survey" in the appendix. [2] Includes double-cropped with wheat or soybeans.

Source: USDA, ERS, Cropping Practices Survey data.

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4.4. Pest Management

Insects, disease, and weeds cause significant yield and quality losses to U.S. crops, and farmers currently rely on pesticides to combat this damage. However, many scientists now recommend greater use of biological and cultural pest management methods, and biological products, such as Bacillus thuringiensis, have recently captured a small share of the pest control market. Government programs to encourage the development and use of biological and cultural methods include areawide pest management, integrated pest management (IPM), national organic standards development, and regulatory streamlining for biologicals.

Contents

For nearly four decades, the majority of U.S. farmers have relied on synthetic pesticides as their primary method for managing most crop pests in most commodities. Farmers adopted synthetic pesticides quickly after their commercial introduction in the 1940's because they were inexpensive, effective, and easy to apply (MacIntyre, 1987). Biological and cultural control methods such as Bt applications and trap cropping, which use living organisms and strategic cropping to combat pest damage, are not as widely used (see glossary for definitions of terms and methods).

During the early 1990's, USDA's Economic Research Service (ERS), using a producer probability survey representing over 60 percent of U.S. crop production, began compiling a baseline on the uses of various chemical, cultural, and biological practices to control pests. According to these data, pesticides are used on the majority of crop acreage of most major commodities. Most growers also used scouting, economic thresholds, and other pesticide-efficiency techniques, but less than half reported the use of cultural and biological techniques. (For information on pesticide quantitities and active ingredients, see chapter 3.2, *Pesticides*.)

The National Research Council recently concluded that pest resistance and other problems created by pesticide use had created an "urgent need for an alternative approach to pest management that can complement and partially replace current chemically based pest-management practices" (National Academy of Sciences, 1985). Various government programs and activities are being initiated to encourage increased use of integrated pest management (IPM) and other strategies to reduce pesticide use and risks, and to promote research and implementation of biological and cultural controls (Jacobsen, 1996; Browner, 1993).

Why Manage Pests?

Approximately 600 species of insects, 1,800 plant species, and numerous species of fungi and nematodes are considered serious pests in agriculture (Klassen and Schwartz, 1991). If these pests were not managed, crop yields and quality would fall substantially, likely increasing production costs and food and fiber prices. In addition, producers with greater pest problems would become less competitive.

Cultural and biological techniques were the primary methods used to manage pests in agriculture for thousands of years. U.S. farmers began shifting to chemical methods upon the successful use of a natural arsenic compound to control Colorado potato beetles in 1867 (National Academy of Sciences, 1995) and the inception of USDA's chemical research program in 1881 (Klassen and Schwartz, 1991).

The increases in crop yields throughout this century have been partly credited to pesticide technology; the majority of U.S. crop acreage is now treated with pesticides. The benefits of pesticides, the value of production that would be lost if alternatives were less effective, and the additional pest management costs if alternatives were more expensive have been shown in numerous studies (Osteen, 1987). The costs of pesticide use to human health and the environment have been much more difficult to quantify. A preliminary Cornell study estimates that the costs from human pesticide poisonings, reduction of fish and wildlife populations, livestock losses, honey bee losses, destruction of beneficial insects, pesticide resistance, and other pesticide effects are $8 billion annually in the U.S. (Pimentel and others, 1992). An alternative method that is more expensive or less effective than pesticides might be economically justified when weighed against the indirect costs of pesticides (see box, "Why Reduce Reliance on Pesticides?").

Pest Management Systems and Practices

USDA cropping practices and chemical use surveys between 1990 and 1995 provide information about chemical, cultural, and biological pest management systems for five major field crops (corn, soybeans, wheat, cotton, and potatoes) and selected fruits and vegetables. About 60 percent of U.S. cropland planted to crops was represented in these annual surveys.

Pesticide-Based Management

Pesticides are applied annually to the majority of U.S. crop acreage. One or more pesticides are used to control weeds and other pests of major field crops, corn, soybeans, wheat, cotton, and potatoes (table 4.4.1), as well as most fruit and vegetable crops (table 4.4.2).

Corn. The largest crop in the United States is corn, and it exceeds any other crop in the number of acres treated with pesticides (table 4.4.1). At least some herbicide was applied to 98 percent of the corn area in the 10 surveyed States in 1995, up from 95 percent in 1990. While the total amount of herbicide applied per acre fell slightly, the number of herbicide treatments and number of different ingredients applied per acre increased. The use of more frequent treatments and additional ingredients reflects an increase in the number of treatments later in the growing season and the grower's need for more broad-spectrum weed control. Treatments applied later in the growing season are less likely to run off or leach and are more likely to be post-emergence herbicides, which are often less persistent in the environment. The amount of herbicide applied per acre has fallen with the increased use of low-rate sulfonylurea herbicides and with reduced-rate applications of atrazine and other older herbicides.

Less than one-fourth of the corn acreage received insecticides in 1995, and corn rootworm was the most frequently treated insect. Insecticide applied to the soil before or during planting kills hatching rootworm larvae and is a common control method, especially when corn is planted every year. Corn acreage treated with insecticides in 1995 was down 6 percentage points from 1990. This decline may be due to closer monitoring of insect and mite populations in the previous crop to decide if preventive treatments are needed.

Soybeans. Herbicides account for virtually all the pesticides used on the soybean crop. In the late 1980's, sulfonylurea and imidazolinone herbicides, which could be applied at less than an ounce per acre, began to replace older products commonly applied at 1 to 2 pounds per acre. They are now among the most commonly used soybean herbicides and have caused total herbicide use to drop. However, the number of acres treated and number of treatments per acre have increased, partly due to the growth in no-till soybean systems, which often replace tillage prior to planting with a preplant "burndown" herbicide to kill existing vegetation. The area treated with herbicides after planting increased from 52 percent to 74 percent from 1990 to 1995, while treatments before planting dropped only a few percentage points.

Wheat. Wheat is one of the largest field crops in the United States, in terms of acreage, and is the least pesticide-intensive. Wheat accounted for 29 percent of the surveyed acreage in 1994, but received only 4 percent of the pesticides. Herbicides were applied on about half of the winter wheat, the largest wheat crop, in 1995, up from only 34 percent in 1990. Winter wheat grows through the fall and winter, and many weeds germinating in the spring cannot compete with the established wheat. In contrast, spring wheat seedlings compete directly with weed seedlings in the spring, and nearly all of these crops receive herbicide treatments.

Why Reduce Reliance on Pesticides?

Concern about the side effects of synthetic pesticides began emerging in scientific and agricultural communities in the late 1940's, after problems with insect resistance to DDT. The public became concerned about the unintentional effects of pesticide use after Rachel Carson's book on bioaccumulation and other potential hazards was published in the 1960's. Many unintentional effects of pesticide exposure on nontarget species have been reported since then, including acute pesticide poisonings of humans (especially during occupational exposure) and damage to fish and wildlife, including species that are beneficial in agricultural ecosystems. Since the 1960's, some pesticides have been banned, others restricted in use, and others' formulations changed to lessen undesirable effects.

Human Health Impacts. The American Association of Poison Control Centers estimates that approximately 67,000 nonfatal acute pesticide poisonings occur annually in the United States (Litovitz and others, 1990). However, the extent of chronic health illness resulting from pesticide exposure is much less documented. Epidemiological studies of cancer suggest that farmers in many countries, including the United States, have higher rates than the general population for Hodgkin's disease, leukemia, multiple myeloma, non-Hodgkin's lymphoma, and cancers of the lip, stomach, prostate, skin, brain, and connective tissue (Alavanja and others, 1996). Emerging case reports and experimental studies suggest that noncancer illnesses of the nervous, renal, respiratory, reproductive, and endocrine systems may be influenced by pesticide exposure. Case studies, for example, indicate that pesticide exposure is a risk factor for several neurodegenerative diseases, including Parkinson's disease and amyotrophic lateral sclerosis, also known as Lou Gehrig's disease (Alavanja and others, 1993). A comprehensive Federal research project on the impacts of occupational pesticide exposure on rates of cancer, neurodegenerative disease, and other illnesses was begun about 4 years ago in North Carolina and Iowa; about 49,000 farmers who apply pesticides and 20,000 of their spouses, along with 7,000 commercial pesticide applicators, are expected to participate in the study (Alavanja and others, 1996).

Direct exposure to pesticides by those who handle and work around these materials is believed to pose the greatest risk of human harm, but indirect exposure through trace residues in food and water is also a source of concern (EPA, 1987). The effects of these pesticide residues on infants and children and other vulnerable groups have recently been addressed with a new legislative mandate in the Food Quality Protection Act of 1996 (see box, "Pesticide Tolerance and Dietary Risks" in chapter 3.2, *Pesticides*).

Environmental Quality. Documented environmental impacts of pesticides include: poisonings of commercial honeybees and wild pollinators of fruits and vegetables; destruction of natural enemies of pests in natural and agricultural ecosystems; ground- and surface-water contamination by pesticide residues with destruction of fish and other aquatic organisms, birds, mammals, invertebrates, and microorganisms; as well as population shifts among plants and animals within ecosystems toward more tolerant species.

Most insecticides used in agriculture are toxic to honeybees and wild bees, and costs related to pesticide damages include honeybee colony losses, honey and wax losses, loss of potential honey production, honeybee rental fees to substitute for pollination previously performed by wild pollinators, and crop failure because of lack of pollination (Pimentel and others, 1992). Approximately one-third of annual agricultural production in the United States is derived from insect-pollinated plants (Buchman and Nabhan, 1996), and flowering plants in natural ecosystems may not thrive because of fewer pollinators.

The destruction of the natural enemies of crop pests has led to outbreak levels of primary and secondary crop pests for some commodities, and pest management costs have increased when additional pesticide applications have been needed for these larger or additional pest populations. Measurable costs related to pesticide residues in surface- and groundwater include residue monitoring and contamination cleanup costs and costs of damage to fish in commercial fisheries. Birdwatching, fishing, hunting and other recreational activities have been affected by aquatic and terrestrial wildlife losses due to pesticide poisonings. An emerging issue is the environmental impacts of invertebrate and microorganism destruction because of the essential role they play in healthy ecosystems.

Pesticide Resistance. After repeated exposure to pesticides, insect, weed, and other pest populations in agricultural cropping systems may develop resistance to pesticides through a variety of mechanisms. The newer safety requirements for pesticide registration along with the increasing pace of pest resistance has raised doubts about the ability of chemical companies to keep up with the need for replacement pesticides. In the United States, over 183 insect and arachnid pests are resistant to 1 or more insecticides, and 18 weed species are resistant to herbicides (U.S. Congress, 1995). Cross-resistance to multiple families of pesticides, along with the need for higher doses and new pesticide formulations, is a growing concern among entomologists, weed ecologists, and other pest management specialists.

Emerging issues include the impact of endocrine-system disrupting pesticides on human health and wildlife, including potential reproductive effects and effects on child growth and development (EPA, 1997), and the impacts of exposure to pesticides, particularly the potential for synergistic impacts (Arnold and others, 1996).

Table 4.4.1—Pest management practices on major field crops in major producing States, 1990-95

Crop	Units	1990	1991	1992	1993	1994	1995
Corn (10 States):[1]							
Planted area	1,000 ac.	58,800	60,350	62,850	57,350	62,500	55,850
Area receiving herbicides	Percent	95	96	97	98	98	98
Before or at plant only	Percent	39	38	33	35	29	30
After plant only	Percent	29	34	36	37	38	38
Both	Percent	26	23	27	26	32	29
Avg. number of treatments/acre	Number	1.4	1.4	1.4	1.4	1.5	1.5
Avg. number of ingredients/acre	Number	2.2	2.1	2.3	2.3	2.5	2.4
Avg. amount applied	Lbs./ac.	3.24	2.97	2.98	2.94	2.79	2.76
Amount banded	Percent	7	7	9	8	8	6
Area receiving insecticides	Percent	32	30	29	28	27	26
Before or at plant only	Percent	26	23	23	22	19	18
After plant only	Percent	4	6	5	5	7	7
Both	Percent	2	2	1	1	1	1
Avg. number of treatments/acre	Number	1.1	1.1	1.1	1.1	1.1	1.1
Avg. number of ingredients/acre	Number	1.1	1.1	1.1	1.0	1.1	1.1
Avg. amount applied	Lbs./ac.	1.18	1.04	0.95	0.90	0.83	0.75
Area scouted for pests	Percent	na	na	na	65	77	na
Operator or family member	Percent	na	na	na	na	64	na
Chemical dealer	Percent	na	na	na	na	5	na
Commercial service	Percent	na	na	na	na	62	na
Other	Percent	na	na	na	na		na
Area under crop rotation	Percent	76	75	77	75	74	80
Area with cultivations for weed control	Percent	70	68	72	53	63	66
Soybeans (8 States):[1]							
Planted area	1,000 ac.	39,500	42,050	41,350	42,500	43,750	45,150
Area receiving herbicides	Percent	96	97	98	98	98	98
Before or at plant only	Percent	44	39	36	28	28	23
After plant only	Percent	20	26	28	30	29	32
Both	Percent	32	32	34	35	42	42
Avg. number of treatments/acre	Number	1.5	1.5	1.6	1.6	1.7	1.7
Avg. number of ingredients/acre	Number	2.3	2.3	2.4	2.5	2.7	2.7
Avg. amount applied	Lbs./ac.	1.39	1.27	1.14	1.11	1.14	1.09
Amount banded	Percent	6	5	5	5	4	4
Area with scouting for pests	Percent	na	na	na	70	76	na
Operator or family member	Percent	na	na	na	na	68	na
Chemical dealer	Percent	na	na	na	na	5	na
Commercial service	Percent	na	na	na	na	2	na
Other	Percent	na	na	na	na	1	na
Area under crop rotation	Percent	na	na	na	na	93	90
Area with crop cultivations for weed control	Percent	67	61	54	38	44	41
Winter wheat (11 States):[1]							
Planted area	1,000 ac.	38,900	31,000	33,990	35,500	32,930	32,670
Area receiving herbicides	Percent	34	26	31	40	46	54
Before or at plant only	Percent	3	3	1.5	3	4	4
After plant only	Percent	30	23	29	36	40	48
Both	Percent	1	1	0.5	1	1	2
Avg. number of treatments/acre	Number	1.1	1.1	1.1	1.1	1.1	1.1
Avg. number of ingredients/acre	Number	1.5	1.5	1.6	1.8	1.8	1.8
Avg. amount applied	Lbs./ac.	0.28	0.27	0.28	0.30	0.33	.25
Area with scouting for pests	Percent	na	na	na	na	na	80
Area under crop rotation	Percent	na	na	na	na	61	57
Spring wheat (4 States):[1]							
Planted area	1,000 ac.	15,800	13,500	17,350	16,950	17,250	15,750
Area receiving herbicide	Percent	91	92	88	96	95	95
Before plant only	Percent	1	3	6	4	4	2
After plant only	Percent	82	83	77	83	79	86
Both	Percent	8	7	5	9	11	7
Avg. number of treatments/acre	Number	1.2	1.2	1.2	1.2	1.2	1.2
Avg. number of ingredients/acre	Number	1.8	2.0	2.1	2.2	2.3	2.4

Continued--

Table 4.4.1—Pest management practices on major field crops in major producing States, 1990-95 (cont.)

Crop	Units	1990	1991	1992	1993	1994	1995
Spring wheat (cont.)							
Avg. amount applied	Lbs./ac.	0.52	0.47	0.49	0.49	0.52	0.54
Area with scouting for pests	Percent	na	na	na	na	na	82
Area under crop rotation	Percent	na	na	na	na	100	84
Cotton (6 States):[1]							
Planted area	1,000 ac.	9,730	10,860	10,200	10,360	10,023	11,650
Area receiving herbicides	Percent	95	92	91	92	94	98
Before or at plant only	percent	58	52	49	45	41	46
After plant only	Percent	6	5	9	10	6	7
Both	Percent	31	35	33	38	46	45
Avg. number of treatments/acre	Number	2.1	2.3	2.5	2.5	2.6	2.7
Avg. number of ingredients/acre	Number	2.3	2.5	2.7	2.7	2.7	2.8
Avg. amount applied	Lbs./ac.	1.79	2.01	2.11	2.01	2.23	2.03
Amount banded	Percent	33	35	33	31	27	28
Area receiving insecticides	Percent	na	66	65	65	71	76
Avg. number of treatments/acre	Number	na	3.1	4.5	4.9	5.7	6.2
Avg. number of ingredients/acre	Number	na	2.3	3.2	3.4	3.5	3.8
Avg. amount applied	Lbs./ac.	na	1.13	1.83	2.06	2.48	2.36
Area receiving other pesticides	Percent	na	56	47	64	67	57
Avg. number of treatments/acre	Number	na	1.8	1.6	1.6	1.7	2.1
Avg. number of ingredients/acre	Number	na	2.0	2.0	1.9	2.0	2.1
Avg. amount applied	Lbs./ac.	na	1.63	2.34	1.79	1.72	2.40
Area with scouting for pests	Percent	na	na	na	na	88	na
Operator or family member	Percent	na	na	na	na	30	na
Chemical dealer	Percent	na	na	na	na	10	na
Commercial service	Percent	na	na	na	na	40	na
Other	Percent	na	na	na	na	8	na
Area under crop rotation	Percent	na	na	na	na	31	32
Area with cultivations for weed control	Percent	97	94	92	96	98	98
Area with pheromones used to monitor pests	Percent	na	na	na	na	19	25
Area with pheromomes used to control pests	Percent	na	na	na	na	9	na
Area treated with purchased beneficial insects	Percent	na	na	na	na	2	1
Fall potatoes (11 States):[1]							
Planted area	1,000 ac.	1,087	1,123	1,064	1,114	1,140	1,147
Area receiving herbicides	Percent	81	81	82	82	84	86
Before or at plant only	Percent	16	13	14	14	16	10
After plant only	Percent	60	61	63	62	58	72
Both	Percent	6	7	5	7	10	5
Avg. number of treatments/acre	Number	1.3	1.4	1.3	1.3	1.4	1.4
Avg. number of ingredients/acre	Number	1.6	1.7	1.7	1.7	1.8	1.9
Avg. amount applied	Lbs./ac.	2.15	2.29	1.94	2.06	2.42	2.40
Amount banded	Percent	3	4	2	1	2	1
Area receiving insecticides	Percent	89	92	90	88	88	88
Before or at plant only	Percent	18	13	14	14	16	16
After plant only	Percent	52	58	60	59	59	53
Both	Percent	19	21	17	16	13	19
Avg. number of treatments/acre	Number	2.0	2.2	2.3	2.2	2.7	2.5
Avg. number of ingredients/acre	Number	1.8	1.9	2.0	2.0	2.1	1.9
Avg. amount applied	Lbs./ac.	3.15	2.81	2.89	2.90	3.49	2.55
Area receiving fungicides	Percent	69	69	72	76	80	85
Avg. number of treatments/acre	Number	2.7	2.7	3.1	3.4	4.2	6.1
Avg. number of ingredients/acre	Number	1.4	1.5	1.9	2.1	3.2	2.7
Avg. amount applied	Lbs./ac.	3.17	3.42	3.93	4.22	5.61	6.75
Area receiving other pesticides	Percent	34.6	44.9	43.1	52.9	59.9	57.1
Avg. number of treatments/acre	Number	1.3	1.3	1.4	1.3	1.4	1.6
Avg. number of ingredients/acre	Number	1.1	1.2	1.3	1.2	1.2	1.3
Avg. amount applied	Lbs./ac.	73.38	71.24	84.43	74.56	94.36	92.74
Area with scouting for pests	Percent	na	na	na	85	na	na
Area under crop rotation	Percent	97	97	97	97	96	98
Area with cultivations for weed control	Percent	91	95	93	93	93	94
Area treated with purchased beneficial insects	Percent	na	na	na	na	na	na

na = not available. [1] For States included, see "Cropping Practices Survey" in the appendix. Source: USDA, ERS, Cropping Practices Survey data.

Table 4.4.2—Fruit and vegetable acreage treated with pesticides, major producing States, 1992/93 and 1994/95

	Planted acres[1]	States surveyed[2]	Area receiving application						Total application 1994/95		
			1992/1993			1994/1995			1994/1995		
			Herbicide	Insecticide	Fungicide	Herbicide	Insecticide	Fungicide	Herbicide	Insecticide	Fungicide
	1,000 ac.	*No.*	*Percent of acres*						*1,000 lbs.*		
Fruit:											
Grapes, all types	796	6	64	66	93	74	67	90	1,193	3,970	32,551
Oranges	760	2	94	90	57	97	94	69	3,466	40,263	1,962
Apples, bearing	345	9	43	99	88	63	98	93	567	10,733	4,624
Grapefruit	147	2	93	93	85	92	89	86	618	9,185	1.420
Peaches, bearing	144	8	49	99	98	66	97	97	182	2,023	5,029
Prunes	94	1	40	93	84	46	73	84	64	842	398
Avocados	73	1	50	12	10	24	9	1	35	14	8
Pears	68	4	44	98	92	65	96	90	96	3,310	1,388
Cherries, sweet	47	4	45	94	87	61	92	93	56	777	655
Lemons	48	1	71	88	14	83	73	64	141	1,280	106
Cherries, tart	47	4	49	98	99	67	94	98	45	93	930
Plums	44	1	70	89	79	48	75	71	36	562	303
Olives	38	1	67	27	33	54	14	30	58	108	59
Nectarines	36	1	84	98	95	82	97	96	84	98	95
Blueberries	30	4	75	91	81	73	86	87	50	127	222
Vegetables:											
Sweet corn, proc.	503	7	92	75	19	94	66	9	1,623	254	59
Tomatoes, proc.	323	1	90	81	92	76	71	86	442	219	9,817
Greenpeas, proc.	203	6	91	49	1	93	50	*	251	42	4
Lettuce, head	191	5	68	97	76	60	100	77	127	631	524
Snap beans, proc.	173	9	95	68	55	91	58	41	449	139	65
Watermelon	166	6	37	53	71	41	45	64	68	136	681
Sweet corn, fresh	164	12	75	84	41	79	81	36	328	627	203
Onion	128	9	86	79	83	88	76	89	760	174	887
Broccoli	111	4	58	95	31	67	96	36	242	287	48
Tomatoes, fresh	104	8	75	95	86	52	94	91	114	710	3,417
Carrots	101	9	67	37	79	72	34	71	117	58	483
Cantaloupe	98	5	44	78	73	41	82	41	42	103	636
Cucumbers, proc.	83	9	74	34	32	77	48	30	95	41	49
Asparagus	81	5	86	64	28	91	70	23	205	100	59
Snapbeans, fresh	71	7	52	77	62	60	79	63	62	120	504

*Applied on less than 1 percent of the acres.

[1] Fruit producers were surveyed in 1993 and 1995; vegetable producers were surveyed in 1992 and 1994. Planted acreage in the major producing States surveyed is for 1994 for vegetables and 1995 for fruit.

[2] The survey was conducted in major producing States during both survey periods; the set of minor producing States that were surveyed was modified slightly between survey years for about one-third of the commodities. For States included, see "Chemical Use Survey" in the appendix.

Source: USDA, ERS and NASS, Chemical Use Survey data.

Insecticide use fluctuates with cycles of pest infestation, but is generally well under 10 percent of wheat area. Large populations of Russian wheat aphid and other insect pests in 1994 caused winter wheat farmers to treat nearly 10 percent of their acreage with insecticides (Padgitt, 1996). Because disease-resistant varieties are used to combat many wheat diseases, fungicides are normally applied to less than 5 percent of the wheat acres.

Cotton. Cotton is one of the most pesticide-intensive field crops grown in the United States. In 1995, 98 percent of cotton acreage received herbicides, 76 percent received insecticides, and 57 percent received other types of pesticides. Herbicides and insecticides account for about 76 percent of the pesticide applied to cotton, while plant growth regulators, defoliants, and other pesticides used to aid harvesting account for most of the remainder. Cotton diseases treated with a fungicide account for only 1 percent of all pesticides used on cotton.

Insect infestation on cotton is much greater than it is for corn, soybeans, or wheat, partly due to its longer growing season and the winter survival rates of insect eggs and larvae in warmer climates where it is grown. Although boll weevil eradication programs have been successful in several Southern States, tobacco budworms, cotton boll worms, thrips, and the boll weevil prevail in other States and require frequent treatments. About two-thirds of the cotton acres are treated for insect pests, often with repetitive treatments. Significant increases in insecticide use have occurred annually during the 1990’s. The average quantity of insecticides applied per acre more than doubled between 1991 and 1994, while the average number of treatments increased from 3.1 to 5.7 and the number of different insecticide products increased from 2.3 to 3.5. In Louisiana and Mississippi, 10 or more insecticide treatments are applied during the growing season.

For weed control, most cotton is treated with a combination of pre-emergence and post-emergence herbicides. Unlike corn, soybeans, and wheat, no new low-rate herbicides have become available for cotton, and producers continue to rely on herbicides registered during the 1950’s and 1960’s.

Potatoes. Potatoes are among the most pesticide-intensive crops for all types of pesticides. Herbicides, insecticides, and fungicides are each used to treat 85 percent or more of potato acreage, and recently over half of the acres have also been treated with a soil fumigant, growth regulator, defoliant, or harvest aid. While the share of potato acres receiving any pesticide type did not change much between 1990 and 1995, the intensity of treatments did increase for all pesticide types. Fungicides, which are used to treat early and late blight and other diseases, accounted for the largest increase in pesticide treatments. The average number of fungicide treatments per acre and the application rate both doubled between 1990 and 1994. Soil fumigants and defoliants account for the largest total quantity of pesticides used on potatoes, but are applied to the smallest area.

Other Vegetables and Fruits. Orchards, vineyards, and vegetable farms generally have much higher net returns per acre than farms that specialize in field crop production, and fruit and vegetable growers have found it profitable to use insecticides and fungicides. Between 90 and 98 percent of the acreage of the 5 largest fruit crops--grapes, oranges, apples, grapefruit, and peaches--received at least one treatment with an herbicide, insecticide, or fungicide in 1995, and the majority of acres were treated with all three types (table 4.4.2). Herbicides, insecticides, and fungicides were used to treat 97, 94, and 69 percent of the U.S. orange acreage in 1995, for example, and 63, 98, and 93 percent of the apple acreage. For most fruit crops, the volume of insecticides and fungicides used is generally higher than the volume of herbicides used.

Among other vegetables, herbicides and insecticides were used on 94 and 66 percent of processing sweet corn, the largest vegetable crop, in 1994. Herbicides and fungicides were used on 76 and 86 percent of the second largest crop, tomatoes grown for processing. Pesticide surveys from the 1960’s and 1970’s also showed the majority of fruit and vegetable acreage receiving pesticides (Osteen and Szmedra, 1989).

Consumer expectations of cosmetically perfect fruits and vegetables, with no blemishes from insects or disease, fuels insecticide and fungicide use. And fresh-market vegetable acreage often receives more pesticides than the processing market crop. For example, a larger share of the fresh-market sweet corn and tomato acreage received fungicide and insecticide treatments than sweet corn and tomatoes grown for processing (table 4.2.2).

Regional differences in rainfall, humidity, soil types, and other growing conditions help determine the severity of pest problems and the intensity of pesticide use. Insecticide applications on grapes in 1994/95 ranged from 17 percent of the crop area in Washington to 96 percent in Michigan (table 4.4.3). Processing sweet corn receiving insecticides ranged from 41 percent in Washington to 82 percent in Illinois.

Pest problems, and the available alternatives for managing pests, vary over time as well as by crop and region. For the top three fruit crops—grapes, oranges, and apples—total area treated with pesticides increased or stayed about the same between 1992/93 and 1994/95 (table 4.4.3). However, insecticide and fungicide applications to total acreage of the two top vegetable crops—processing sweet corn and tomatoes—dropped. While insect and disease pressure may have been lighter during the second survey, the availability of alternatives may have also

Table 4.4.3—Pesticide application on selected fruit and vegetable crops, by major producing State, 1992/93 and 1994/95

		Area receiving applications					
		1992/1993			1994/1995		
Crop and State	Planted acres[1]	Herbicide	Insecticide	Fungicide	Herbicide	Insecticide	Fungicide
	1000 ac.	*Percent of acres*					
Fruit:							
Grapes, all types	796	64	66	93	74	67	90
California	701	62	67	94	73	68	92
Washington	34	72	39	52	77	17	35
New York	33	81	64	99	85	78	94
Michigan	12	90	97	100	93	96	100
Pennsylvania	11	72	59	52	99	93	99
Oregon	5	52	3	99	70	18	95
Oranges	760	94	90	57	97	94	69
Florida	563	98	96	69	98	96	77
California	197	94	90	57	92	86	46
Apples, bearing	345	43	99	88	63	98	93
Washington	153	45	100	85	66	99	88
New York	58	33	100	100	63	99	99
Michigan	54	54	99	100	68	100	100
California	40	46	92	71	48	86	88
Pennsylvania	22	34	100	100	66	98	98
Oregon	9	66	98	98	73	99	96
South Carolina	4	18	100	100	84	99	99
Vegetables:							
Sweet corn, proc.	503	92	75	19	94	66	9
Wisconsin	161	92	68	11	95	62	3
Minnesota	143	94	81	40	95	80	20
Washington	75	87	85	*	86	41	*
Oregon	49	90	60	*	98	63	*
Illinois	37	98	99	50	97	82	20
New York	33	92	60	**	98	66	3
Michigan	7	93	93	*	88	77	*
Tomatoes, proc.	323	90	81	92	76	71	86
California	318	90	81	92	76	71	86
Michigan	5	90	82	99	85	88	100

*Applied on less than 0.5 percent of the acres.

**Insufficient reports to publish percent of area receiving.

[1] Fruit producers were surveyed in 1993 and 1995, vegetable producers in 1992 and 1994; planted acreage in the listed State is for 1994-95.

played a role. A large U.S. food processor, for example, sought in the early 1990's to reduce the amount and frequency of pesticide use among its growers, and has been encouraging the use of Bt, parasitic wasps, mating-disrupting pheromones, disease-forecasting systems, and other biological and pesticide-reducing technologies (Orzalli, Curtis, and Bolkan, 1996).

Pesticide-Efficiency Tools

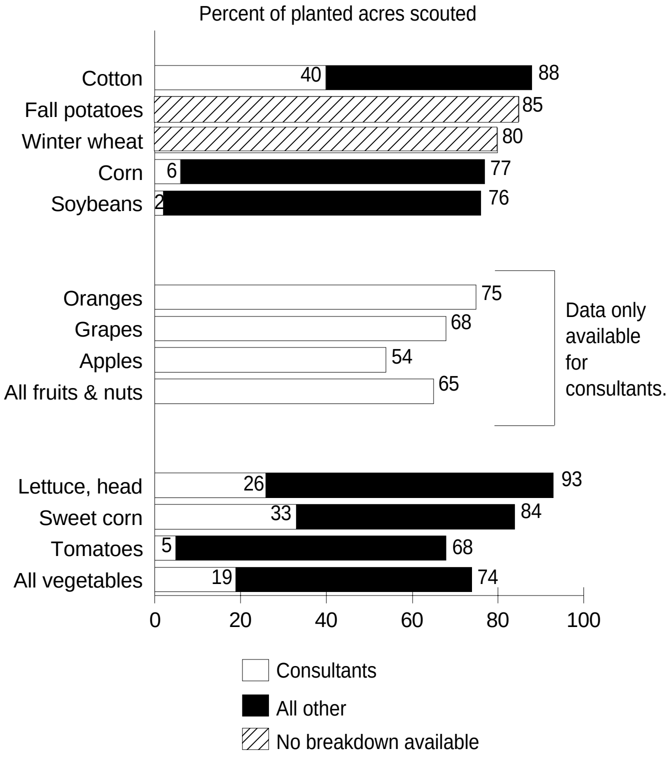
Entomologists have developed pest scouting, economic thresholds, and other tools to help producers determine when to make pesticide applications, which pesticides to use, and how much to use, and "expert systems" have integrated these tools into decision management software. Several new chemical-efficiency technologies—including precision farming and herbicide-tolerant crops—are just now being developed and commercialized. While these tools generally rely on pesticides, they may lower risks through lower rates, less toxic materials, or fewer applications.

Scouting and Economic Thresholds. Entomologists have been developing scouting techniques to monitor the populations of major insect and other arthropod pests for several decades. Field trials were conducted to determine the crop-damage functions associated with these pests in order to set economic thresholds--pest population levels above which economic damage to the crop would occur without pesticide application. These scouting techniques and thresholds were designed to replace routine, calendar-based insecticide applications.

While scouting techniques and thresholds have been developed for most major insect pests in agriculture, weed scientists and ecologists have only recently begun exploring whether economic thresholds are applicable for weed management (Coble and Mortensen, 1992). Economic thresholds are rarely used for plant pathogens since infections generally spread too quickly to use fungicides after the disease is detected. However, disease prediction models that result in disease advisories for some major fruit and field crops have been developed and commercialized.

Scouting and threshold use is widespread in specialty crop production (Vandeman and others, 1994). Nearly two-thirds of the U.S. fruit and nut acreage and nearly three-quarters of the vegetable acres in the surveyed States were scouted for insects, mostly by chemical dealers, crop consultants, and other professionals (table 4.4.4, fig. 4.4.1). Growers reported using thresholds as the basis for making pesticide treatment decisions on virtually all of these scouted acres (Vandeman and others, 1994). Potato growers reported that 85 percent of their acreage was scouted in 1993 (table 4.4.1), and thresholds were used in making nearly three-quarters of their insecticide application decisions. Growers of two-thirds to three-fourths of corn and soybeans reported scouting, mostly by themselves or a family member. Most of these growers reported using thresholds as well (Vandeman and others, 1994). Nearly 90 percent of the cotton acreage was scouted, including commercial scouting service on 40 percent of this acreage (table 4.4.1, fig. 4.4.1). Insect pests cause large economic losses in cotton production, and entomologists have been developing thresholds for these pests for several decades.

Figure 4.4.1--Use of scouting for pests, selected crops in major producing States, 1990's



Source: USDA, ERS, Cropping Practices and Chemical Use Surveys.

Application Tools. Producers use a variety of pesticide application techniques to make applications more efficient. For example, most farmers broadcast pesticides across the field, but an alternative technique--banding applications--can lower herbicide application rates substantially (Lin and others, 1995). However, mechanical cultivation to control weeds between rows is often required, and growers have not increased their use of banding during the 1990’s. About 14 percent of the U.S. corn area in surveyed States treated with herbicides in 1994 was banded, and about 6 percent of soybeans were banded. Other examples of efficiency tools include drip pans for spray equipment to catch "overspray," and the use of dwarf fruit trees, which require less pesticide spray material than full-size trees.

Expert Systems. “Expert systems” integrate information on pest density, economic thresholds, application methods, and other elements of pesticide use into a computer software package that helps the farmer determine when to make pesticide applications, which pesticides to use, and how much to use. For example, a threshold-based model for corn and soybeans (NebraskaHERB) determines whether it is cost-effective to manage weeds in a

Table 4.4.4—Use of selected biological and cultural pest management practices on fruit, vegetable, and nut crops, major producing States, 1990's

Crop		Scouting					Biological methods[2]				Cultural methods[2]		
	In surveyed States[1]	Consultants	Grower/ family member	Chemical dealer	Other	Total	Beneficial insects	Habitat provision	Pheromone traps[3]	Resistant varieties	Water management	Field sanitation	Adjust planting dates
	1,000 ac. planted	*Percent of acres*											
Fruit:													
Grapes, all	730	68	na	na	na	na	18	na	14	31	41	64	na
Oranges	613	75	na	na	na	na	22	na	28	21	27	48	na
Apples	381	54	na	na	na	na	2	na	66	16	22	73	na
All fruits & nuts	3,251	65	na	na	na	na	19	na	37	22	31	60	na
Vegetables:[4]													
Sweet corn	640	33	22	2	27	84	*	na	17	na	7	na	8
Tomatoes	357	5	15	47	1	68	5	na	6	na	21	na	47
Lettuce, head	259	32	26	26	9	93	3	na	1	na	4	na	26
All vegetables	2,914	21	19	19	15	74	3	na	7	na	11	na	15
	No. growers surveyed	*Percent of surveyed growers*											
Certified organic vegetables:													
Sweet corn	64	**	91	0	3	94	46	67	na	80	33	na	56
Tomatoes	55	**	94	0	1	95	48	57	na	71	46	na	41
Lettuce, head	33	**	97	0	3	100	60	60	na	73	80	na	50
All vegetables	303	**	91	0	6	97	46	58	na	75	44	na	54

* Used on less than 0.5 percent. **Included in other. na = not available.

[1] Data is from the 1991 USDA Chemical Use Survey for fruits and nuts, the 1992 Survey for vegetables, and the 1994 Survey for certified organic vegetables. For major producing States surveyed, see "Chemical Use Survey" in the appendix.

[2] Use for any type of pest in 1991 and 1992, and for three specific types (insects, disease, or weeds) in 1994 (highest use for a specific type is shown).

[3] Reported for all uses (pest control and monitoring) in 1991 and 1994, and for control only in 1992.

[4] Includes fresh and processing crops.

Source: USDA, ERS and NASS, Chemical Use Survey data.

field, and identifies whether broadcast or band-applied herbicides or cultivation is the most cost-effective treatment. The Nebraska Extension Service reports use in Nebraska is small but growing (USDA, 1994). The use of "expert systems" (decision support) software is still well under 1 percent in U.S. corn and soybean production according to recent ERS surveys (Padgitt, 1996). Several university expert systems, which forecast diseases in some major fruit and vegetable crops, have recently become available commercially through IPM product suppliers, including the "Penn State Apple Orchard Consultant" and the University of Wisconsin's WISDOM software.

Precision Farming. Precision farming is an emerging technology that may allow a more efficient application of inputs by using tractor-mounted yield monitors, satellite images, GIS, and other developing information technologies to tailor inputs to the different conditions in each field. Soil leachability, pH, and other characteristics often vary, sometimes substantially, within the farm field, and better tailoring of inputs to site-specific field conditions can increase crop yields. Most precision farming has addressed nutrient management, but research on pest management using this technology is emerging. Recent industry surveys indicate that only a small number of corn growers are experimenting with precision farming. The yield monitors and equipment necessary for many other crops, especially vegetable crops, have not been developed yet.

The potential for this technology to increase yields or to reduce pesticide use is being examined by USDA, the chemical industry, and other organizations. The few existing studies on the potential of precision farming to provide environmental benefits have been inconclusive about its effect on pesticide use.

Bioengineered Herbicide Tolerance. Seed and chemical companies have expanded research and development on plant biotechnology because of the increasing costs to develop chemical pesticides that meet human health and environmental regulations and are sufficiently toxic to kill target pests (Ollinger and Fernandez-Cornejo, 1995). Compared with traditional genetic plant breeding, plant biotechnology reduces the time required to identify desirable traits. In addition, by inserting into the plant a gene that imparts some desirable properties, biotechnology allows a precise alteration of a plant's traits, facilitating the development of plant characteristics not possible through traditional plant breeding techniques. This technology allows researchers to target a single plant trait, which decreases the number of unintended characteristics that may occur with traditional breeding techniques. The development of genetically modified plants takes about 6 years and costs about $10 million, while a chemical pesticide takes an average of 11 years at a cost of $50-$70 million to develop (Ollinger and Fernandez-Cornejo, 1995).

A number of seed and chemical companies have been developing plant varieties with resistance to particular herbicides (table 4.4.5). Monsanto has developed a soybean variety that is not damaged by Monsanto's popular herbicide glyphosate (Roundup) and similar glyphosate-tolerant varieties are being developed for canola, cotton, corn, sugar beets, and rapeseed oil. This technology could provide growers with an incentive to use pesticides that are effective at lower rates than other pesticides.

Concerns about this technology include the possibility of accelerated weed resistance as well as the toxicity of the herbicide products that crop tolerance is developed for. Danish scientists recently reported that the genes for herbicide resistance in transgenic oilseed rape had moved to field mustard, a wild relative, and that this weed demonstrated herbicide resistance (Kling, 1996).

Biological Pest Management

According to a recent Office of Technology report, the market for biologically based pest controls is small but fast-growing. The market value of biologically based products—natural enemies, pheromones, and microbial pesticides—sold in the United States during the early 1990's was estimated at $95-$147 million, 1.3 to 2.4 percent of the total market for pest control products (U.S. Congress, 1995). At least 30 commercial firms or "insectaries" produce natural enemies. Even though the current market for biological products is growing and large pest control companies are beginning to participate, the market is still so small that biologicals are unlikely to replace pesticides in the foreseeable future unless major research and development activities are started (Ridgway and others, 1994).

Table 4.4.5—Bioengineered crop varieties approved for commercial production, 1994-96

Approval date[1]	Applicant	Crop
Herbicide-tolerant varieties:		
2/5/94	Calgene	Cotton
5/19/94	Monsanto	Soybean
6/22/95	AgrEvo	Corn
7/11/95	Monsanto	Cotton
12/19/95	Dekalb	Corn
1/26/96	Dupont	Cotton
7/31/96	AgrEvo	Soybean
Herbicide-tolerant varieties with other traits:		
2/22/96	Plant Genetic Systems	Corn[2]
(8/30/96)[3]	Monsanto	Corn[4]
Insect-resistant varieties:		
3/2/95	Monsanto	Potato
5/17/95	Ciba-Geigy	Corn
6/22/95	Monsanto	Cotton
8/22/95	Monsanto	Corn
1/18/96	Northrup-King	Corn
5/3/96	Monsanto	Potato
(8/14/96)[3]	Dekalb	Corn
Virus-resistant varieties:		
12/7/94	Upjohn	Squash
6/14/96	Asgrow	Squash
(2/20/96)[3]	Cornell University	Papaya

[1] Date the Animal Plant Health Inspection Service (APHIS) determined that these field-tested crop varieties had no potential for plant pest risk and need no longer be regulated.

[2] Includes a male sterility trait.

[3] Date APHIS received the petition for approval; non-regulated status is still pending.

[4] Includes an insect resistant trait.

Source: USDA, ERS, based on information provided by APHIS.

Biological pest management includes the use of pheromones, plant regulators, and microbial organisms such as *Bacillus thuringiensis* (Bt), as well as pest predators, parasites, and other beneficial organisms. EPA currently regulates biochemicals and microbial organisms and classifies them as "biorational pesticides." Another major biological tactic has been to breed crop varieties with "host plant resistance" to insects and disease.

Microbial Pesticides and Pheromones. Biorational pesticides, such as Bt and pheromones, have differed significantly from chemical pesticides in that they have generally managed rather than eliminated pests, have had a delayed impact, and have been more selective (Ollinger and Fernandez-Cornejo, 1995). For example, microbial pesticides have not been successful as herbicides because target weeds are replaced by other weeds not affected by the microbial pesticide.

Among the most successful microbials has been Bt, which kills insects by lethal infection. Growers have dramatically increased their use of Bt during the 1990's, especially under biointensive and resistance-management programs, because of its environmental safety, improved performance, cost competitiveness, selectivity, and activity on insects that are resistant to chemical pesticides. It is one of the most important insect management tools in certified organic production. Bt was used on more than 1 percent of the acreage of 12 fruit crops in 1995, up from 5 crops in 1991 (table 4.4.6). Between 12 and 23 percent of the apple, plum, nectarine and blackberry acreage received Bt applications in 1995, and it was applied on over half of the raspberry acreage. Among vegetable crops, the acreage treated with Bt increased for 13 of the 20 crops surveyed by USDA between 1992 and 1994, and was used on about half or more of the cabbage, celery, and eggplant acreage. Bt has been used on only a couple of field crops. Corn acreage treated with Bt was steady at 1 percent in 1994 and 1995, while treated cotton increased from 5 percent in 1992 to 9 percent in 1994 and 1995.

New Bt strains with activity on insects not previously found to be susceptible to Bt have been discovered in recent years. Current research is devoted to improving the delivery of Bt to pests and to increasing the residual activity and efficacy of Bt.

Pheromones are used to monitor populations of crop pests and to disrupt mating in organic systems and some IPM programs. Pheromones were used on 37 percent of fruit and nut crops acreage to monitor and control pests and on 7 percent of vegetable acreage to control pests (use for monitoring was not included in this survey) (table 4.4.4).

Table 4.4.6—Agricultural applications of *Bacillus thuringiensis* (Bt), selected crops in surveyed States, 1991-95

Crop[1]	1994/95 planted acres[2]	Area receiving application				
		1991	1992	1993	1994	1995
	1,000 acres	*Percent of acres*				
Field crops:						
Corn (17 States)	64,105	*	*	*	1	1
Cotton, upland	11,650	*	5	8	9	9
Fruit:						
Grapes	796	*	-	2	-	6
Oranges	760	2	-	7	-	3
Apples, bearing	345	3	-	13	-	12
Peaches	144	*	-	3	-	5
Prunes	94	*	-	*	-	9
Pears	68	*	-	1	-	2
Sweet cherries	47	*	-	8	-	9
Plums	44	*	-	*	-	14
Nectarines	36	*	-	10	-	22
Blueberries	30	11	-	8	-	5
Raspberries	11	49	-	45	-	52
Blackberries	4	18	-	*	-	23
Vegetables:						
Tomatoes, proc.	323	-	6	-	5	-
Lettuce, head	191	-	18	-	20	-
Sweet corn, fresh	164	-	3	-	3	-
Onion	128	-	*	-	1	-
Broccoli	111	-	7	-	14	-
Tomatoes, fresh	104	-	31	-	39	-
Cantaloupe	98	-	32	-	8	-
Snap beans, fresh	71	-	20	-	29	-
Cabbage, fresh	70	-	48	-	64	-
Bell peppers	61	-	35	-	37	-
Lettuce, other	60	-	39	-	22	-
Cauliflower	54	-	12	-	20	-
Cucumbers, fresh	51	-	19	-	22	-
Strawberries	46	-	24	-	33	-
Celery	36	-	51	-	61	-
Honey dew	26	-	28	-	10	-
Spinach	10	-	13	-	21	-
Eggplant	4	-	13	-	48	-

* Applied on less than 0.5 percent of the acres. - = Not a survey year for that commodity.

[1] Bt use was too small to report on soybeans, wheat and potatoes, and on other surveyed fruit and vegetable crops.

[2] Planted acres in the surveyed States.The survey accounted for between 79 and 90 percent of U.S. total planted corn acreage, between 70 and 78 percent of the total Upland cotton acreage, and over 70 percent of fruit and vegetable acreage. For major producting States included, see "Chemical Use Survey" in the appendix.

Source: USDA, ERS and NASS, Chemical Use Survey data.

Beneficial Organisms. Natural enemies of crop pests, or "beneficials," may be imported, conserved, or augmented. Many crop pests are not native to this country, and USDA issues permits for the natural enemies of these pests to be imported from their country of origin. Natural enemy importation and establishment, also called classical biological control, has been undertaken primarily in university, State, and Federal projects; 28 States operate biocontrol programs and most have cooperative efforts with USDA agencies (U.S. Congress, 1995). Some crop pests, such as the woolly apple aphid in the Pacific Northwest, have been largely controlled with this method.

Natural enemies may also be "conserved" by ensuring that their needs—for alternate hosts, adult food resources, overwintering habitats, a constant food supply, and other ecological requirements—are met, and by preventing damage from pesticide applications and other cropping practices (Landis and Orr, 1996). Over half of the certified organic vegetable growers in 1994 were providing habitat for beneficials (table 4.4.4).

"Augmentation" boosts the abundance of natural enemies (native and imported) through mass production and inundative or inoculative releases in the field (Landis and Orr, 1996). An inundative release—the most common augmentation method—can be timed for when the pest is most vulnerable and is used when the natural enemy is absent or when its response to the pest pressure is insufficient. An inoculative release may be made in the spring for a natural enemy that cannot overwinter in order to establish a population. Unlike the importation and conservation approaches, the augmentation method generally does not provide permanent suppression of pests. Beneficial insects were used on 3 and 19 percent of the surveyed vegetable and fruit acreage in the early 1990's, and by nearly 46 percent of the certified organic vegetable growers (table 4.4.4).

A small but increasing number of companies are supplying natural enemies of insects, weeds, and other pests to farmers. For greenhouse and agricultural crop production, most natural enemies being sold—such as beneficial insects, predatory mites, parasitic nematodes, and insect egg parasites—are used for managing pest mites, caterpillars, citrus weevils, and other insect and arthropod pests. However, a number of natural enemies—musk thistle defoliating weevils, for example—are being sold for managing weeds on rangeland and uncultivated pastures (Poritz, 1996).

The California Environmental Protection Agency has published a list of commercial suppliers of natural enemies in North America since 1979, and the number has increased steadily. In 1994, 132 companies were listed, mostly in the United States, offering over 120 different organisms for sale (Hunter, 1994).

Host Plant Resistance. Corn and soybean breeding for genetic resistance to insects, disease, and other pests has been the research and development focus of major seed companies for many decades (Edwards and Ford, 1992). U.S. soybean acreage, for example, receives virtually no fungicides because of the effectiveness of the disease-resistance soybean cultivars that have been developed.

The use of classical breeding programs is now being augmented with new plant breeding efforts using transgenic and other genetic engineering techniques. In March 1995, the EPA approved, for the first time, a limited registration of genetically engineered plant pesticides to Ciba and Mycogen Plant Sciences, and in August 1995, granted conditional approval for full commercial use of a transgenic pesticide to combat the European corn borer (EPA, 1995). This plant pesticide, Bt corn, is produced when the genetic information related to insecticidal properties is transferred from the Bt bacterium to the corn plant. This technology could reduce the need for conventional chemical insecticides in corn production. In 1995, 26 percent of U.S. corn acreage was treated with insecticides (table 4.4.1), and corn borer is one of the top insect pests targeted for treatment.

However, since these new corn varieties contain natural genes and genes produced from the soil bacteria Bt, many scientists are concerned that the new corn will hasten pest immunity to Bt. This is especially a concern for the growing number of producers who rely on the foliar-applied Bt, and has led the EPA to approve the new pesticides conditional on the monitoring for pest resistance and the development of a management plan in case the insects become resistant.

The techniques used for developing disease-resistant plants are similar to the immunization of humans by vaccines. Small amounts of plant viruses are inserted into the plants, which subsequently become immune to the diseases (Salquist, 1994). The plants are capable of passing this trait from generation to generation. For example, researchers have developed squash varieties that are naturally virus-resistant, thus preventing insect-borne viruses that can destroy up to 80 percent of the squash crop. A number of seed and chemical companies and one university have been field-testing insect- and virus-resistant plants, developed with these genetic engineering techniques, for several major field crops and vegetables (table 4.4.5).

While most classical breeding programs have focused on pests resistant to chemicals or treatments that were too expensive (Zalom and Fry, 1992b), consumer concern over pesticides in agricultural products has prompted biotechnology companies to enter the genetically engineered plant market. As agricultural biotechnology products attain commercial success, some private investment funding may shift from the smaller pharmaceutical markets toward agricultural crop protection (Niebling, 1995). On the other hand, consumer acceptance of the bioengineered Bt corn, Bt cotton, and other genetically engineered crops has not yet been demonstrated in major U.S. markets. A 1992 survey of U.S. consumer attitudes about food biotechnology, published by North Carolina State University, found that most consumers want information on labels about various food characteristics, including the use of biotechnology (Hoban and Kendall, 1993).

APHIS (Animal Plant Health Inspection Service) has approved or acknowledged 638 field trials for insect-resistant varieties since 1987 (24 percent of the total field trials approved or acknowledged), 286 field trials to test viral resistance (11 percent), and 94 field trials for fungal resistance (3.5 percent).

Cultural Pest Management

A number of production techniques and practices—including crop rotation, tillage, alterations in planting and harvesting dates, trap crops, sanitation procedures, irrigation techniques, fertilization, physical barriers, border sprays, cold air treatments, and habitat provision for natural enemies of crop pests—can be used for managing crop pests. Cultural controls work by preventing pest colonization of the crop, reducing pest populations, reducing crop injury, and enhancing the number of natural enemies in the cropping system (Ferro, 1966).

These ecosysem-based pest control techniques are knowledge-intensive, and widespread adoption by growers would require major new funding for basic and applied research (National Academy of Sciences). The National Research Council also suggests that the base of research necessary to develop and implement cultural pest management and other ecosystem-based pest management techniques is much greater than for synthetic chemical pesticides.

Crop rotation is one of the most important of the current cultural techniques. Eighty percent of U.S. corn acreage was in rotation with other crops in 1995, up slightly from 76 percent in 1990 (table 4.4.1). Over half of the corn was being grown in rotation with soybeans and about 15 percent with other row crops (see chapter 4.3, *Cropping Management*, for more detail on cropping patterns). Ninety percent of soybeans were grown in crop rotations in 1995. Corn producers rotating corn with other crops used insecticides less frequently than did those planting corn 2 years in succession (11 percent of acres versus 46 percent). Corn is often grown as a monocrop in heavy livestock areas and where climate limits the soybean harvest period (Edwards and Ford, 1992).

Crop rotation was much less prevalent for cotton, which has among the highest per-acre returns of U.S. field crops. Less than one-third of the cotton producers use this technique (table 4.4.1). Crop rotation in wheat varies with the type being grown; it was used on 77 percent of the spring crop but only 57 percent of the winter wheat crop in 1995. Crop rotation was used for virtually all of the potato acreage.

Cultivation for weed control is widely practiced for field crops, mostly in conjunction with herbicide use. Almost all of the potato and cotton acreage received cultivations in 1995, along with 66 percent of corn. For soybeans, cultivations dropped from 67 percent in 1990 to 41 percent in 1995 (table 4.4.1).

Field sanitation and water management (see glossary) are widely used on fruit and nut crops, with 60 percent and 31 percent of the acreage under these practices in the early 1990’s (table 4.4.4). For vegetable crops, planting dates were adjusted as a cultural control on 15 percent of the surveyed crop area. Water management was used by 44 percent of the certified organic vegetable producers, and over half were using adjusted planting dates to manage pests.

Research on new cultural techniques such as solarization—heating the soil to kill crop pests—continues to emerge. However, most cultural practices do not involve a marketable product, and research and development depends almost entirely on public sector funding (U.S. Congress, 1995). While cultural practices may be effective for controlling pests, reducing pesticide use, and lowering input costs, these techniques require a knowledgeable producer and growers may not be getting adequate information about them.

Pest Management Programs and Initiatives

Pest management systems in the future will emerge against the backdrop of continued consumer preference for fewer farm chemicals and scientific uncertainty about the ecological and health impacts of chemical use. In addition to State and Federal pesticide regulations, farmers' pest management choices will be influenced by the costs and risks of pesticides and alternatives, the market for green products, and other factors. USDA, EPA, and other government agencies have initiated a number of programs to encourage biological and cultural pest management, including biointensive IPM research and promotion, areawide pest management, regulatory streamlining for biologicals, and national organic standards development.

IPM Research and Promotion

On September 22, 1993, the EPA, USDA, and the Food and Drug Administration (FDA) presented joint testimony to Congress on a comprehensive interagency effort designed to reduce the pesticide risks associated with agriculture. The three goals of this effort are to (1) discourage the use of higher risk products, (2) provide incentives for the development and commercialization of safer products, and (3) encourage the use of alternative control methods which decrease the reliance on toxic and persistent chemicals (Browner and others, 1993). This joint testimony also expressed support for integrated pest management (with a goal of IPM programs on 75 percent of total U.S. crop acreage by the year 2000), ecosystem-based programs to reduce pesticide use, market-based incentives such as reduced-pesticide use food labels, and other efforts to help reduce pesticide risks.

State Extension Service IPM programs are overseen by designated IPM coordinators, mostly entomologists who focus on developing interdisciplinary pest management programs (Grey, 1995). Over half of U.S. farmers are using a minimum level of IPM—including scouting for insect pests and applying insecticides when economic thresholds are reached (Vandeman and others, 1994)—as opposed to the conventional pesticide application method of preventative, calendar-based spraying. Economic and environmental studies have reported mixed results in terms of the impacts of IPM scouting and thresholds on pesticide use (Rajotte and others, 1987; Mullen, 1995; and Ferguson and Yee, 1995; Fernandez-Cornejo, 1996).

The first national study of biologically based IPM in the early 1990's, jointly sponsored by USDA and EPA, concluded that dozens of technical, institutional, regulatory, economic, and other constraints need addressing in order to achieve broader adoption (Zalom and Fry, 1992a). Three constraints were identified by all commodity groups: (1) lack of funding and personnel to conduct site-specific research and demonstrations; (2) producer perception that IPM is riskier than conventional methods, more expensive, and not a shortrun solution; and (3) educational degree programs that are structured toward narrow expertise rather than broad knowledge of cropping systems (Glass, 1992).

The current IPM initiative in USDA, which has been partly funded by Congress, attempts to address the funding constraint and need for demonstrations and highlights stakeholder involvement in priority setting for IPM research (Jacobsen, 1996). A few IPM research projects have started to examine biocontrols and cultural practices for several commodities, especially those that may not have adequate pest management alternatives because of current or pending EPA regulatory actions or voluntary pesticide registration cancellations.

Areawide Pest Management Systems

USDA is also developing and implementing an areawide pest management approach—through partnerships with growers, commodity groups, government agencies, and others—to contain or suppress the population levels of major insect pests in agriculture over large definable areas, as opposed to on a farm-to-farm basis (Calkins and others, 1996). Biological and cultural methods are the focus of most of these areawide programs.

Some biological control tactics, such as sterile insect releases, are most effective if implemented on a large area that encompasses many farms (U.S. Congress, 1995). For example, corn rootworm is a highly mobile pest as an adult and management is expected to be more effective over a large area. The goals of the program are to provide more sustainable pest control, at costs competitive with insecticide-based programs, and to reduce the use of chemical insecticides in agriculture. One successful biologically based areawide program was launched against the screwworm, a major parasitic pest of livestock, pets, and humans. USDA began releasing sterile male screwworm flies into wild populations in the 1950's, and by the early 1980's the screwworm became the only pest successfully eradicated from the United States (U.S. Congress, 1995).

USDA currently has five biologically based areawide IPM projects in various stages of evaluation, pilot testing, and large area implementation (table 4.4.7). The oldest, the Areawide Bollworm/Budworm Project in Mississippi, was initiated in 1987. Under this project, serious insect pests of Delta crops, especially cotton, were managed successfully with natural insect pathogens in small field tests. The project went into a large-area testing phase with 215,000 acres in 1994 and 1995.

Another areawide IPM project, the regional Coddling Moth Areawide Management Program (CAMP), uses pheromone mating disruption to control the coddling moth, the primary insect pest of apples in California, Oregon, and Washington. CAMP is a cooperative effort between ARS and three universities, and it aims to reduce organophosphate insecticide use by 80 percent in these apple- and pear-producing States (Kogan, 1996). The coddling moth had grown resistant to the organophosphate insecticide which required growers to triple applications of that chemical (Flint and Doane, 1996). Pilot testing of the project began in 1995 on five sites, and initial results indicate substantial reductions in organophosphate use and a positive response from growers (Kogan, 1996).

Two projects are examining the areawide use of attractants—semiochemical bait with tiny amounts of insecticide—to control corn rootworm in the Midwest, and Mexican corn rootworm and cotton bollworn in Texas and other States (Calkins and others, 1996). The Federal Crop Insurance Corporation has issued a crop insurance endorsement to cover any crop losses that might occur in testing sites.

Regulatory Streamlining for Alternatives

The EPA has facilitated the development of birational pesticides by establishing a tier approval system in which, under some circumstances, several tests are waived. These reduced regulation costs have helped lower the development costs of biopesticides, which are currently estimated at around $5 million per product, compared with about $50-$70 million for a chemical pesticide (Ollinger and Fernandez-Cornejo, 1995).

The EPA is also making the regulation of biorational pesticides less stringent than that of chemical pesticides. For example, Lepidopteran pheromones may now be used experimentally on up to 250 acres without an experimental-use permit and are exempted from a food tolerance measure (*Pesticides & Toxic Chemical News*).

The EPA has also facilitated the use of minimum-risk alternatives to toxic pesticides by establishing a process for exemption from costly FIFRA (Federal Insecticide, Fungicide, and Rodenticide Act) requirements. Thirty-one substances (see box) deemed to pose insignificant risks to human health and the environment have recently been deregulated. EPA considered whether the substances were common foods, had a nontoxic mode of action, had FDA recognition as safe, had no information showing significant adverse effects, persistence in the environment and other factors. Supporters of the draft proposal on exemptions felt that deregulation of these substances would particularly benefit small businesses and the organic industry and supported the expansion of this list in the future, while opponents were concerned about product effectiveness (U.S. EPA, 1996a).

National Organic Standards, Certification, and Ecolabels

Organic farming systems focus on biological and cultural methods for pest management and virtually exclude the use of synthetic chemicals. In 1990, Congress passed the Organic Foods Production Act to provide consistent national standards to consumers for

Deregulated Minimum-Risk Pesticides

The following minimum-risk pesticides, mostly from common food substances, were exempted from costly Federal Insecticide, Fungicide, and Rodenticide Act requirements by the U.S. Environmental Protection Agency in a 1996 ruling: castor oil (U.S.P. or equivalent), cedar oil, cinnamon and cinnamon oil, citric acid, citronella and its oil, cloves and clove oil, corn gluten meal, corn oil, cottonseed oil, dried blood, eugenol, garlic and garlic oil, geraniol, geranium oil, lauryl sulfate, lemongrass oil, linseed oil, malic acid, mint and mint oil, peppermint and peppermint oil, 2-phenethyl propionate (2-phenylethyl propionate), potassium sorbate, putrescent whole egg solids, rosemary and rosemary oil, sesame and sesame oil, sodium chloride (common salt), sodium lauryl sulfate, soybean oil, thyme and thyme oil, white pepper, and zinc metal strips.

Source: EPA, 1996a.

Table 4.4.7—Implementation status of USDA's biologically-based areawide projects[1]

Project and objectives	Methods	Extent of implementation	Preliminary results
Coddling Moth, **Pacific Northwest** (Apples, pears) *Objective* - reduce broad spectrum neurotoxic insecticide use and maintain yields	Mating disruption Resistant cultivars Sanitation Natural enemies Early season Bt Sterile males	1995-1996: Randall Island, CA Medford, OR Yakima, WA Howard Flats, WA Orovill, WA 1997 planned: 5 additional sites	Late-season pesticide use declined Natural enemies increased Secondary pests declined Fruit damage was below 0.1% economic threshold 1st generation moths were reduced 80% Input costs were higher
Western Corn Rootworm **Northern Corn Rootworm,** **Midwestern U.S.** (Corn) *Objective* - reduce insecticide use and area treated, maintain yields, and reduce pest populations	Monitoring Semiochemical traps Semiochemical bait (includes tiny amounts of carbaryl)	1996: Brookings, SD 1997 planned: Illinois and Indiana Iowa Kansas	90% or more of the adults were killed (below threshold level) Natural enemies increased
Mexican Corn Rootworm, **Texas & Oklahoma** (Corn) *Objective* - reduce insecticide use and area treated; maintain or increase yields	Monitoring Semiochemical traps Semiochemical bait (includes tiny amounts of carbaryl)	1996: Bell County, TX 1997 planned: Bell County, TX	Adult population reduced below threshold levels; larvae will be assessed next spring No impact on beneficials Increased management costs offset by decreased input costs
Cotton Bollworm & **Tobacco Budworm,** **Mississippi** (Cotton) *Objective* - reduce insecticide use and area treated, maintain yields, and reduce pest populations	Monitoring with pheromone traps Insect virus (Gemstar) used on early-season weed hosts	1990-93: Mississippi (0-64,000 acres)[2] 1994-95: Mississippi (215,000 acres) 1996: Mississippi (25,000 acres) 1997 planned: Mississippi (215,000 acres) 1998 planned: Mississippi (850,000 acres)	More than 70% of moths killed Reduced insecticide use Yields were maintained Input and management costs were lowered

[1] USDA's Agricultural Research Service (ARS) is administering these projects through partnerships with other Federal agencies, universities, commodity associations, and other stakeholder groups.

[2] Pilot test acreage varied due to changes in funding and experiment design, and testing was cancelled one year because of severe flooding.

Source: USDA, ERS, based on Calkins and others, 1996; Kogan, 1994; and personal communication with Carrol Calkins, USDA-ARS, Yakima, WA, Laurence Chandler, USDA-ARS, Brookings, South Dakota; James Coppedge, USDA-ARS, College Station, Texas, and Dick Hardee, USDA-ARS, Stoneville, Mississippi.

organic production and processing methods. This legislation requires that all except the smallest organic growers be certified by a State or private agency accredited under national standards currently being developed.

The National Organic Standards Board, which was appointed by USDA to help implement the Act, currently defines organic agriculture as "an ecological production management system that promotes and enhances biodiversity, biological cycles, and soil biological activity. It is based on minimum use of off-farm production inputs, on management practices that restore and enhance ecological harmony, and on practices that maintain organic integrity through processing and distribution to the consumer" (Ricker, 1996). USDA is expected to publish the draft national organic standards in the Federal Register in 1997.

Organic Production. National data indicate a growing organic niche in the U.S. farm sector. A recent survey of public and private organic certifications indicated that there were at least 4,050 certified organic farms in the United States in 1994 with over a million acres in organic production (Dunn, 1995). And these statistics underestimate the number of U.S. growers using organic production methods, since the growers must farm organically for at least 3 years before they can certify their production under most certification organizations.

About 1 percent of the total U.S. fruit and vegetable acreage is organic, a higher proportion than for field crops, livestock feed, cotton, and other commodity sectors. California, the largest fruit and vegetable producing State, reports that organic farmers account for about 2 percent of its 80,000 farmers (White, 1994).

Few case studies have examined yields, input costs, income, and other characteristics of organic production. A review of the economic literature published in the 1970's and 1980's concluded that the "variation within organic and conventional farming systems is likely as large as the differences between the two systems," and found mixed results in the comparisons for most characteristics (Knoblauch, Brown, and Braster, 1990). Organic price premiums are key in giving organic farming systems comparable or higher whole-farm profits than conventional systems (Klonsky and Livingston, 1994; Batte, Forster, and Hitzhusen, 1993).

Organic agriculture is the most thoroughly documented system of ecological pest management in the United States. At least 11 States and 33 private agencies in the United States offer certification services to organic growers to ensure they are using the ecologically based standards associated with organic farming systems. California Certified Organic Farmers is a private certification organization and the oldest certifier in the Nation.

Certified Organic Labels. Over half the States have laws that regulate the production and marketing of organic food, and about half the States require State or private certification of products and operations to ensure that they are using only approved materials and practices. National standards under development in USDA are expected to facilitate international trade as well as enhance consumer confidence in organic food commodities.

Organic food products account for only about 1 percent of total retail food sales, but organics are one of the fastest growing segments of the industry. Consumer demand for organic food products has increased throughout the 1990's. Retail sales of fresh and processed organic food products reached $2.8 billion in 1995, and have increased over 20 percent annually since 1989 (*Natural Foods Merchandiser,* 1996). Increases in the number of large-format natural food stores, supermarket organic sections, export markets and direct-marketing outlets, as well as the expanding variety of organic foods, have fueled this growth. Organic products are labeled at retail in a variety of ways, including stickers, labels, signs, and other methods that indicate the certification organization or give other information.

Voluntary Environmental Standards. In addition to stronger pesticide regulations over the last decade, voluntary codes for environmental stewardship and responsible pesticide use in agriculture have begun to emerge. These codes are instituted by the private sector, enforced by firms themselves, use sanctions such as peer pressure for compliance, focus on life-cycle impacts, emphasize management systems, and let firms define their own performance standards. They can shift some of the environmental management costs to the private sector, expand a firm's environmental focus beyond the scope of regulation, help a firm integrate environmental and business objectives, and foster long-term changes in a firm's environmental consciousness (Nash and Ehrenfeld, 1996).

The Pesticide Environmental Stewardship Program was initiated in 1992 by EPA, USDA, and FDA to facilitate this type of voluntary approach, inviting organizations that use pesticides or represent pesticide users to join as partners (U.S. EPA, 1996b). Partners agree to implement formal strategies to reduce the use and risk of pesticides and to report regularly on progress. Membership in this stewardship program has grown to 41 partners, including many commodity groups across the country, and represents at least 45,000 pesticide users. The California Department of Agriculture has established a similar program, the IPM Innovators Program, to recognize individuals and groups that have demonstrated leadership in voluntarily implemented systems that reduce pesticide risks (Brattesani and Elliott, 1996) and to raise the environmental consciousness of other groups that use pesticides and inspire them to voluntarily adopt similar activities. Also, some States are examining the potential benefits of IPM certification, while Massachusetts is already operating a "Partners with

GLOSSARY

Chemical Methods

Banded pesticide application—the spreading of pesticides (herbicides, insecticides, or fungicides) over, or next to, each row of plants in a fields. Banding herbicides often requires row cultivation to control weeds in the row middles.

Broadcast pesticide application—the spreading of pesticides (herbicides, insecticides, or fungicides) over the entire surface area of the field.

Economic thresholds—levels of pest population which, if left untreated, would result in reductions in revenue that exceed treatment costs. The use of economic thresholds in making pesticide treatment decisions requires information on pest infestation levels from scouting.

Pesticides—the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) defines a pesticide as "any substance or mixture of substances intended for preventing, destroying, repelling or mitigating any pest, and any substance or mixture of substances intended for use as a plant regulator, defoliant, or desiccant."

Pre-emergence herbicide—herbicides which are applied before weeds emerge. Pre-emergence herbicides have been the foundation of row-crop weed control for the past 30 years.

Post-emergence herbicides—herbicides which are applied after weeds emerge. Post-emergence herbicides are considered more environmentally sound than pre-emergence herbicides because they have little or no soil residual activity.

Scouting—checking a field for the presence, population levels, activity, size, and/or density of weeds, insects, or diseases. A variety of methods can be used to scout a field. Insect pests, for example, can be scouted by using sweep nets, leaf counts, plant counts, soil samples, and general observation.

Cultural Methods

Crop rotation—alternating the crops grown in a field on an annual basis, which interrupts the life cycle of insect pests by placing them in a non-host habitat.

Planting and harvesting dates—alterations in planting date and harvest date to avoid damaging pest infestations. Delayed planting of fall wheat seedlings may help avoid damage from the Hessian fly, for example.

Sanitation procedures—removing or destroying crops and plant material that are diseased, provides overwintering pest habitat, or encourages pest problems in other ways.

Tillage—can destroy pests in a variety of ways, for example, by directly destroying weeds and volunteer crop plants in and around the field.

Water management—water can be used as a pest management technique either directly, by suffocating insects, or indirectly, by changing the overall health of the plant.

Biological Methods

Beneficials—organisms that are pest predators and parasites and weed-feeding invertebrates that are used to control crop pests and weeds.

Habitat provision for natural enemies—growing crops and/or developing wild vegetative habitats to provide food (pollen, nectar, non-pest arthropods) and shelter for the natural enemies of crop pests.

Biochemical agents—include semiochemicals, plant regulators, hormones, and enzymes.

***Bacillus thuringiensis*, Bt**— bacteria that is used to control numerous larva, caterpillar, and insect pests in agriculture; *Bacillus thuringiensis* varieties *kurstaki* and *Bacillus thuringiensis* varieties *aizawai* are commonly used strains. In addition, some new varieties of corn contain natural genes and genes produced from the soil bacteria Bt to give them host-plant resistance to certain insect pests.

Gemstar— naturally occuring *Helicoverpa zea* nuclear polyhedrosis virus.

Microbial pest control agents—bacteria, such as *Bacillus thuringiensis*, viruses, fungi, and protozoa and other microorganisms or their byproducts.

Semiochemicals—pheromones, allomones, kairomones, and other naturally or synthetically produced substances that modify insect behavior.

Trap cropping—planting a small plot of a crop earlier than the rest of the crop in order to attract a particular crop pest; the pests are then killed before they attack the rest of the crop.

Sterile male technology—the male of the pest species is produced with inactive or no sperm, and is used to disrupt reproduction in the pest population.

Nature" program to recognize growers who follow a set of IPM certification guidelines (Van Zee, 1992).

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Recent ERS Research on Pest Management Issues

Proceedings of the Third National IPM Symposium/Workshop: Broadening Support for 21st Century IPM, May 1997, Miscellaneous Publication Number 1542 (Sarah Lynch, Cathy Greene, and Carol Kramer-LeBlanc, editors). IPM program assessment was a major focus of the interdisciplinary IPM symposium/workshop held last winter in Washington DC. Several papers in this proceedings explore ways to incorporate the economic, environmental, and public health impacts of IPM programs into research and extension activities.

"Organically Grown Vegetables: U.S. Acreage and Markets Expand during the 1990's," April 1997, VGS-271, *Vegetables and Specialties: Situation and Outlook Report* (Catherine Greene and Linda Calvin). Organic farming systems, which focus on ecologically-sound production practices, have been gaining ground among U.S. vegetable growers during much of the 1990's. Organic vegetables are currently being grown and certified by State and private agencies on about 1 percent of U.S. vegetable acreage—ranging from 0.2 percent to over 10 percent in top vegetable States—and implementation of national standards is expected to facilitate the use of these systems.

Pest Management on Major Field Crops, AREI Updates, No. 1, February 1997 (Merritt Padgitt). This report breaks out the use of herbicides and insecticides on major field crops (corn, soybeans, winter wheat, cotton, and potatoes) in 1995 by the various tillage systems, crop rotations, plant densities, row sizes, and number of cultivations that were used in producing these crops.

"The Microeconomic Impact of IPM Adoption," *Agricultural and Resource Economics Review*, October 1996 (Jorge Fernandez-Cornejo). This report develops a methodology to calculate the impact of integrated pest management (IPM) on pesticide use, yields, and farm profits. While the methodology in this case study is applied to IPM adoption among fresh market tomato producers for insect and disease management, the method is of general applicability. It accounts for "self-selectivity" (IPM adopters may be better farm managers or differ systematically from nonadopters in some other way) and simultaneity—farmers' IPM adoption decisions and pesticide use may be simultaneous—and the pesticide demand and yield equations are theoretically consistent with a profit function. In this study, IPM was defined operationally as the use of scouting and thresholds for making insecticide and fungicide applications and the use of one or more additional IPM techniques for managing pests.

"The Diffusion of IPM Techniques by Vegetable Growers," *Journal of Sustainable Agriculture*, Vol. 7, No. 4 (Jorge Fernandez-Cornejo and Alan Kackmeister). This study examines the adoption/diffusion paths of various integrated pest management (IPM) techniques among vegetable growers in 15 states, as well as grower education, regional research levels, and other factors that influence adoption. The authors concluded that the IPM techniques examined would reach 75 percent adoption between 2008 and 2036, except for scouting, which attains the 75 percent level during the 1990's.

Organic Vegetable Growers Surveyed in 1994, AREI Updates, No. 4, May 1996 (Jorge Fernandez-Cornejo, Doris Newton, and Renata Penn). This statistical bulletin reports the first national level statistics on organic production practices in the U.S. vegetable industry. A sample of 303 organic vegetable growers, close to one-fifth of all certified organic vegetable growers, was obtained from the 1994 USDA Chemical Use Survey, and the report presents selected pest and nutrient management practices used by these growers, as well as socioeconomic statistics describing the growers.

"Factors Influencing Herbicide Use in Corn Production in the North Central Region," *Review of Agricultural Economics*, Vol. 17, No. 2, 1995, (Biing-Hwan Lin, Harold Taylor, Herman Delvo, and Leonard Bull). In this report, factors that influence herbicide use in corn production—including tillage practices, crop rotation, application method, and farm program participation—are analyzed using field-level data for 1990-1992 from the 10 major corn producing states. The authors found that herbicide use could be greatly reduced by switching from broadcast to band applications, and that switching from conventional to conservation tillage, without using the moldboard, plow sometimes increases herbicide use.

Adoption of Integrated Pest Management in U.S. Agriculture, AIB-707, September 1994 (Ann Vandeman, Jorge Fernandez-Cornejo, Sharon Jans, and Biing-Hwan Lin). This report summarized information on the extent of adoption of surveyed integrated pest management (IPM) techniques in the production of dozens of fruit and vegetable crops and several major field crops in the early 1990's. In this report, which was based on USDA survey data, farmers were considered to be using IPM if they scouted their crop acreage and based their decision to apply pesticides on whether pests had reached an economically damaging threshold. Using this definition, over half of the acreage of surveyed growers was being produced under IPM, with adoption rates and the additional pest management practices used, varying by crop and State.
(Contact to obtain reports: Catherine Greene, (202) 219-0466 [cgreene@econ.ag.gov])

4.5 Nutrient Management

Nutrients are essential for ensuring adequate crop yields and profitability but have long been associated with surface- and ground-water contamination. Many improved practices are available to reduce nutrient losses to the environment, with varying degrees of adoption by farmers. Improving nutrient management to reduce losses to the environment requires (1) a better understanding of the link between agricultural production and water quality; (2) agricultural R&D to develop scientifically and economically sound management practices; and (3) public policies and programs that specifically encourage the adoption of resource-conserving practices.

Contents

Profitable crop production requires significant amounts of nutrients in the form of commercial fertilizers and animal wastes (see chapter 3.1, *Nutrients*), portions of which can subsequently run off into surface waters or leach into groundwater. The two primary agricultural nutrients affecting water quality are nitrogen and phosphorus. Nitrogen, primarily found in the soil as nitrate, is soluble and easily transported by surface runoff, in tile drainage, or by leachate. Phosphorus, primarily in the form of phosphate, is not as soluble as nitrate and is primarily transported by sediment in runoff.

Why Manage Nutrients?

Excessive nitrogen or phosphorus in surface waters can cause algae to grow at an accelerated rate and cloud water, which prevents aquatic plants from receiving sunlight for photosynthesis. When the algae die and are decomposed by bacteria, they deplete the oxygen dissolved in the water and threaten aquatic animal life. This process, eutrophication, can result in clogged pipelines, fish kills, and reduced recreational opportunities or enjoyment. According to EPA, nutrient pollution is the leading cause of water quality impairment in lakes and estuaries and the third leading cause in rivers (1995). Above a certain concentration, nitrate is also a concern for drinking water. Based on the human health effects, EPA has established a maximum contaminant level of 10 mg/liter for nitrate in public drinking systems. Above this level, nitrates can cause methemoglobinemia, which prevents the transport of oxygen in the bloodstream of infants and may be a cancer risk to humans (EPA, 1992). (See chapter 2.2, *Water Quality*, for more information on agriculture’s affect on water quality.)

Nutrient pollution of water resources can occur because of unusual wet weather that increases nutrient leaching and runoff. It can also occur when farmers are unaware of the offsite effects of their production decisions, or when they have no assigned cost or penalty for those effects and so choose production systems that may have greater profitability or less economic risk but higher nutrient losses.

Nutrient Balances—An Alternative Measure of Nutrient Use

Total or per-acre nutrient use is of limited value in determining whether nutrients pose an environmental threat. An alternative measure—nutrient mass or residual balance—calculates the residual nitrogen or phosphorus that may remain in the soil or be lost to the environment. Nutrient mass balances indicate how closely nutrient inputs (such as commercial fertilizer, animal manure, other wastes, and nutrients provided by previous legume crops) match nutrient outputs (the amount of nutrient taken up by the harvested crop). A positive net mass balance indicates the amount of residual nutrient that may remain in the soil or be lost to the air, carried by water runoff into surface-water systems, or carried by percolating water into ground water. However, residual nitrogen by itself does not necessarily result in water quality problems. For example, warm, moist soil conditions and dry air may volatilize residual nitrogen to the atmosphere, or vegetative buffers may capture residual nitrogen before it reaches water systems. Therefore, nitrate levels in surface and ground water in some areas of the Southeast tend to be low, even though residual nitrogen may be high.

A negative net balance indicates that the amount of nutrient removed from the field through the harvested crop exceeds the amount of nutrient applied, with the difference coming from nutrients stored in the soil or available through precipitation. Continued negative balances mine or deplete nutrients in soil, disrupt the soil ecosystem, and can damage soil productivity.

Residual balances can be computed on acres or fields to assist farmers in making nutrient management decisions. Calculating balances on a wider geographic area may portray the overall potential for nutrient losses and indicate where nutrient management could be improved. Using USDA's Cropping Practice Surveys, nutrient balances are calculated for major crops (see box, "Computing Nutrient Mass Balances"). Balance estimates are categorized as (1) *high* if the nutrient input exceeded the output in the harvested crop by more than 25 percent, (2) *moderate* if nutrient input exceeded output by less that 25 percent, and (3) *negative* if total nutrient input was less than the output. Declining percentages in the high and negative categories and an increasing percentage in the moderate category indicate improvements in nutrient management. No significant improvement is detected over the 1990-95 period (fig. 4.5.1, 4.5.2).

Computing Nutrient Mass (Residual) Balances

Per-acre, field-level data from the Cropping Practices Survey were used to estimate nutrient balances in pounds per acre for each nutrient on each sample field, using the following procedure:

NB = CF + L + NPK **-** H **-** (PR-CR), where

NB = **N**utrient **B**alance

CF = Nutrients from **C**ommerical **F**ertilizer in pounds applied per acre

L = Nitrogen from previous **L**egume crops. If the previous legume crop was soybeans, 1 pound of nitrogen credit was assumed for each bushel of soybeans harvested. If the crop in the previous year was first-year alfalfa, the nitrogen credit per acre was 50 percent of the nitrogen in harvested alfalfa. If the crop was second-year alfalfa, the nitrogen credit was 75 percent of the nitrogen in harvested alfalfa (Meisinger and Randall, 1991).

NPK = **N**itrogen, **P**hosphorus, and potassium (**K**) credits for applied manure for 1990-94 were estimated from two data sources: USDA's Area Study Survey (Alabama, Florida, Georgia, Idaho, Illinois, Indiana, Iowa, Maryland, Nebraska, and Minnesota) and the 1992 Agricultural Census (other States). The estimation procedures used were those developed by Van Dyne and Gilberson (1974) and by Gollehon and Letson (1996). The NPK credits for 1995 were estimated directly from survey data. The estimation procedures were from the *Agricultural Waste Management Field Handbook* (USDA, NRCS, 1992).

H = Nutrients assumed per unit of crop **H**arvested were 0.9 pound of nitrogen and 0.35 pound of phosphorus for each bushel of corn, 1.25 pounds of nitrogen and 0.625 pound of phosphorus for each bushel of wheat, and 0.05 pound of nitrogen and 0.013 pound of phosphorus for each pound of cotton lint and seed (Fertilizer Institute, 1982; Meisinger, 1984).

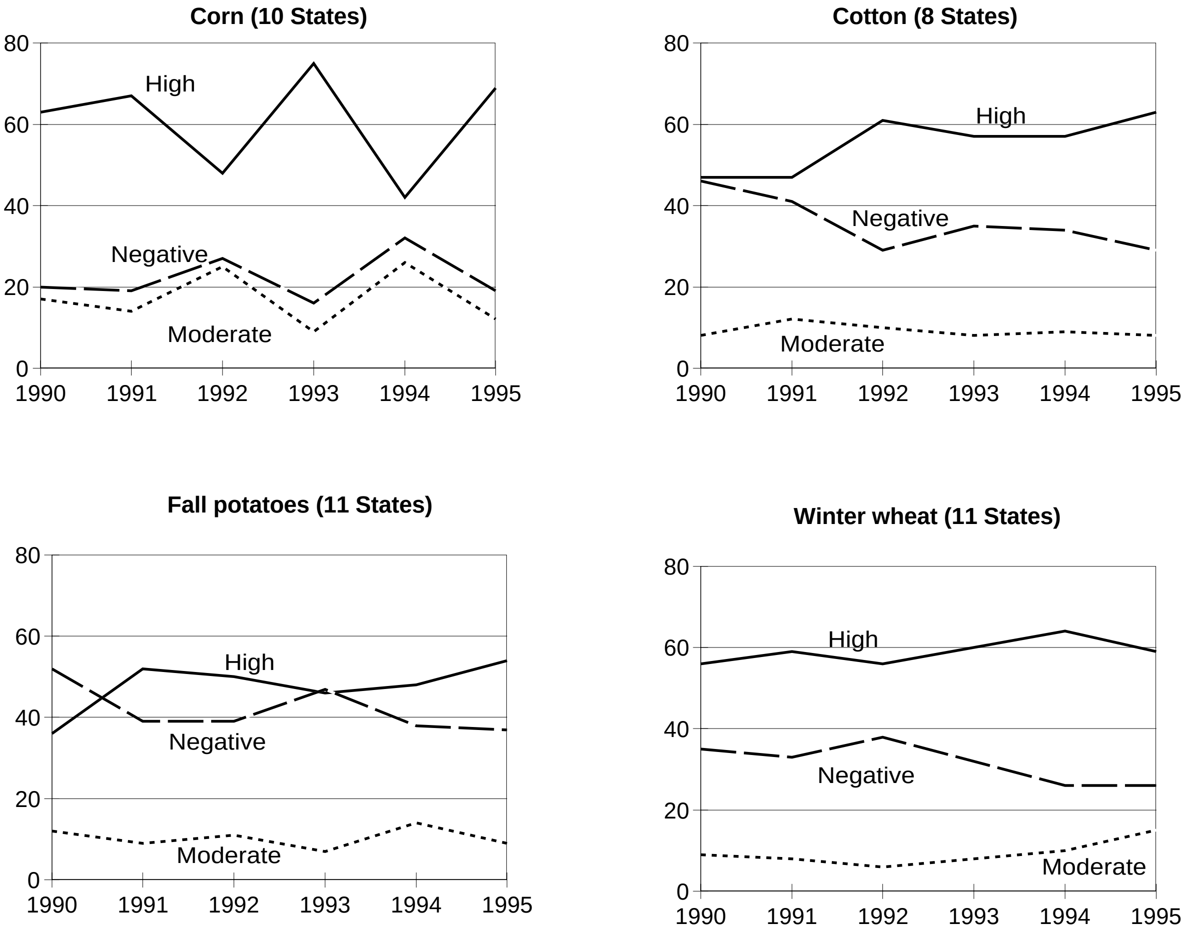
PR = Nutrients from **P**revious crop **R**esidue.

CR = Nutrients in **C**urrent crop **R**esidue remaining on the field.

Nutrients from plant residues are assumed to remain on the field and be equal in nutrient value at beginning and end of season.

State and crop-level estimates were developed by extrapolating and aggregating field-level data.

Figure 4.5.1--Nitrogen mass balances in major producing States, 1990-95: percentage of acres in high, moderate, and negative categories



Corn (10 States)

Cotton (8 States)

Fall potatoes (11 States)

Winter wheat (11 States)

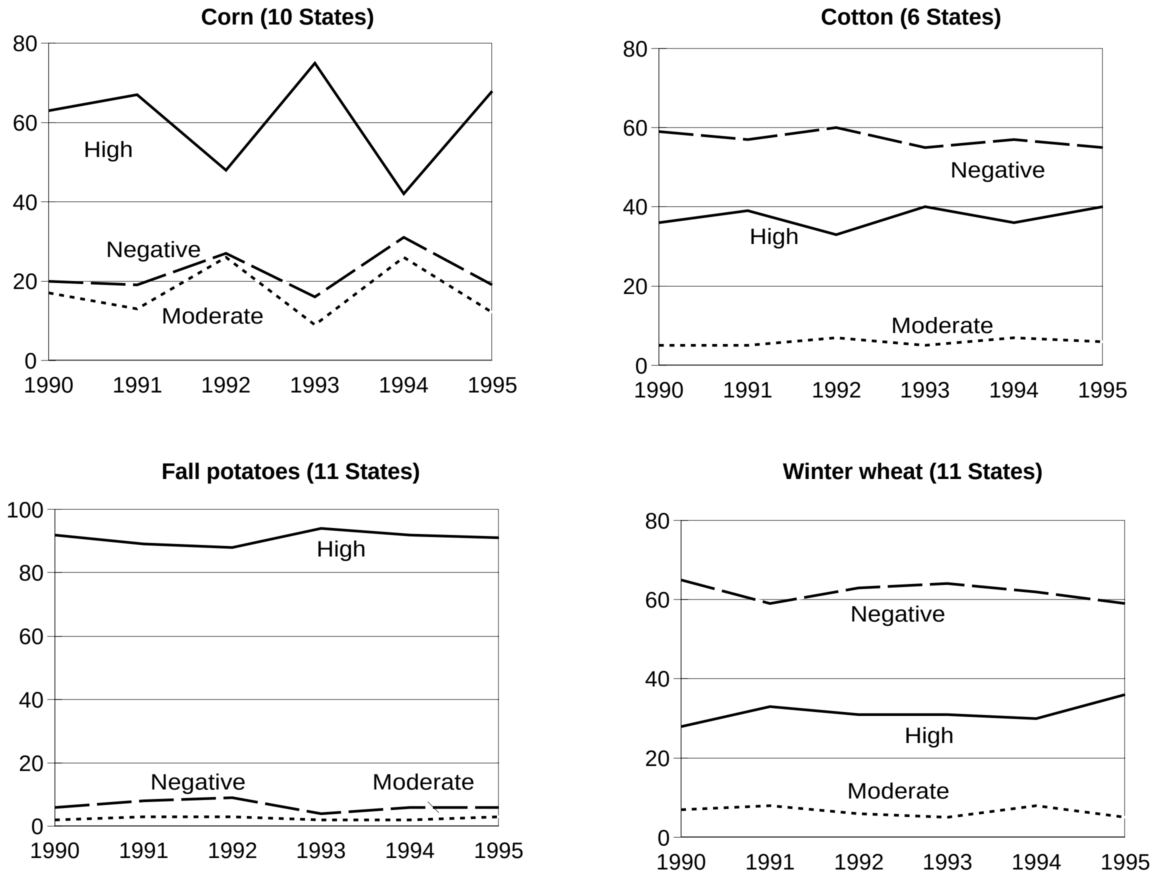
For States included, see "Cropping Practices Survey" in the appendix..

Source: USDA, ERS, estimates based on Cropping Practices Survey data.

Positive residual balances can occur if farmers underestimate available nutrients or overapply nitrogen—the most critical nutrient—in order to support high crop yields. Other factors are the relatively low marginal cost of applying extra nutrients at the time of initial application in the fall and spring before planting and the extra cost and uncertainty (due to weather delays) of making a timely, second application if needed after planting. High nutrient balances also occur when poor weather or excessive pest damage result in crop yields lower than farmers anticipate and less nutrients are taken up by the harvested crop. Consequently, balances may vary significantly from year to year. Persistent high balances on land vulnerable to leaching can be of particular concern for groundwater quality (see chapter 2.2, *Water Quality*, for areas vulnerable to groundwater contamination).

Nitrogen balances. Over half of the corn, cotton, potato, and wheat acres in major producing States had high nitrogen mass balances during 1990-95, suggesting potential nitrogen losses to the environment (fig. 4.5.1, table 4.5.1). Also, in most years, one-fifth or more of these acres had negative nitrogen balances, indicating the mining of nitrogen in the soil to supply crop needs. The percentage of corn acres with high nitrogen balance varies considerably from year to year mainly due to annual variation in yield and crop nutrient uptake. The percentages of cotton and wheat acres with a high nitrogen balance have been increasing, as farmers appear to be applying more nitrogen fertilizer in anticipation of higher crop prices in recent years (NASS, 1996).

Figure 4.5.2--Phosphate mass balances in major producing States, 1990-95: percentage of acres in high, moderate, and negative categories



For States included, see "Cropping Practices Survey" in the appendix.
Source: USDA, ERS, estimates based on Cropping Practices Survey data.

Phosphorus balances. High phosphate balances occurred on 36 percent (winter wheat) to 94 percent (potatoes) of major field crops during 1990-95 (fig. 4.5.2, table 4.5.2). In areas with high soil erosion and runoff, the high residual balance of phosphorus could contribute to water quality problems and require improved management. Phosphorus is more stable than nitrogen and more likely to remain in the soil with less loss to the environment unless the soil itself erodes away. Because of this greater stability, and to reduce costs, many farmers apply extra phosphorus one year then skip a year or more (USDA, NRCS 1995a). The large percentage of acres with negative mass balances is also evidence of this practice.

Nutrient Management Practices

Effective nutrient management, which includes assessing nutrient need, timing nutrient application, and placing nutrients close to crop roots, can help reduce nutrient losses to the environment while sustaining long-term productivity and profitability. The efficacy of each practice is strongly influenced by the conditions in each field, the farmer’s management knowledge and skill, economic factors, and weather (table 4.5.3).

Assessing nutrient needs. Farmers following conventional practices may apply fertilizer at rates based on optimistic yields and may not account for all sources of nutrients. Improved management requires more information about the nutrients available for crop needs and the use of balances to better assess nutrient need. In addition to computing acre- or field-

Table 4.5.1—Nitrogen mass balances for selected crops in major producing states, 1990-95[1]

Crop and year	Acres	Nutrient inputs				Nutrient output in harvested cropland	Nutrient mass balance			
		Commercial fertilizer	Previous legumes	Manure	Total		Average	Above 25 percent	0-25 percent	Negative
	1,000	*---Average pounds per acre---*						*Percent of acres*		
Corn										
1990	58,700	130	21	6	157	113	44	63	17	20
1991	60,350	128	22	7	157	102	55	67	14	19
1992	62,700	128	22	6	156	128	28	48	25	27
1993	57,300	123	24	6	153	92	61	75	9	16
1994	62,500	127	21	6	154	131	23	42	26	32
1995	52,200	130	28	2	160	105	55	69	12	19
Cotton										
1990	8,444	68	3	3	74	54	20	47	8	46
1991	10,850	79	3	4	86	62	24	47	12	41
1992	10,115	86	1	4	91	60	31	61	10	29
1993	10,126	80	2	3	85	57	28	57	8	35
1994	10,023	95	2	4	101	61	40	57	9	34
1995	10,480	82	2	3	87	47	40	63	8	29
Potatoes										
1990	624	191	7	5	203	149	54	56	9	35
1991	655	176	4	1	181	141	40	59	8	33
1992	607	183	3	1	187	161	26	56	6	38
1993	647	177	3	1	181	139	42	60	8	32
1994	652	246	3	--	249	142	107	64	10	26
1995	669	206	1	1	208	138	70	59	15	26
Wheat, Winter										
1990	38,650	51	0	1	52	49	3	36	12	52
1991	30,980	53	5	1	59	41	18	52	9	39
1992	33,465	54	4	1	59	44	15	50	11	39
1993	35,210	53	4	1	58	48	10	46	7	47
1994	32,930	56	4	1	61	45	16	48	14	38
1995	32,670	57	6	1	64	43	21	54	9	1

-- = Less than 0.5

[1] See "Cropping Practices Survey" in the appendix for major producing States included.

Source: USDA, ERS, estimates based on Cropping Practices Survey data (see box, "Computing Nutrient Mass Balances").

level mass balances, analyzing plant tissue during the growing season can detect any emerging nitrogen deficiency. Soil nitrogen tests can be administered both when a majority of fertilizer is applied before planting and when a majority is applied as a side-dress application.

Soil tests for nitrogen, phosphorus, potassium, PH levels, and micronutrients, though essential for improving nutrient management, are an additional expense that many farmers forgo. Nevertheless, soil nitrogen tests and plant analysis can help farmers improve their net farm income (Babcock and Blackmer, 1994; Shortle et al., 1993; Bosch et al., 1994). In particular, soil tests help those farmers who underestimate the nutrient carryover from the previous season to avoid overapplying, thus reducing nitrogen loss and improving their net farm income (Huang et al., 1996). The economic benefit of soil nitrogen testing is greatest in fields where manure was applied and where the previous season was dry (Bosch et al., 1994; Bock et al., 1992; Fuglie and Bosch, 1995). The ideal time to conduct soil nitrogen testing and application is just before plants require nutrients, because nitrogen (as nitrate in the soil) quickly dissipates. However, benefits to the farmer from soil nitrogen tests may disappear if weather conditions prevent farmers from entering fields soon after testing. Because phosphorus is relatively stable in the soil, testing for this nutrient can be conducted any time before fertilization.

Table 4.5.2—Phosphate mass balances for selected crops in major producing States, 1990-95[1]

Crop and year	Acres	Nutrient inputs: Commer-cial fertilizer	Nutrient inputs: Previous legumes	Nutrient inputs: Manure	Nutrient inputs: Total	Nutrient output in harvested cropland	Nutrient mass balance: Average	Nutrient mass balance: Above 25 percent	Nutrient mass balance: 0-25 percent	Nutrient mass balance: Negative
	1,000	*Average pounds per acre*						*Percent of acres*		
Corn										
1990	58,700	52	0	6	58	44	14	50	12	38
1991	60,350	52	0	7	59	40	19	54	11	36
1992	62,700	47	0	5	52	50	2	36	14	50
1993	57,300	47	0	6	53	36	17	57	10	33
1994	62,500	48	0	6	54	51	3	37	13	50
1995	52,200	47	0	2	49	41	8	43	11	46
Cotton										
1990	8,444	23	0	2	25	26	-1	36	5	59
1991	10,850	26	0	3	29	30	-1	39	5	57
1992	10,115	27	0	4	31	29	2	33	7	60
1993	10,126	26	0	3	29	28	1	40	5	55
1994	10,023	24	0	4	28	30	-2	36	7	57
1995	10,480	23	0	2	25	23	2	40	6	55
Potatoes										
1990	624	159	0	6	165	28	137	92	2	6
1991	655	43	0	1	144	27	117	89	3	8
1992	607	146	0	1	147	30	117	88	3	9
1993	647	148	0	1	149	26	123	94	2	4
1994	652	171	0	--	171	27	144	92	2	6
1995	669	157	0	1	158	26	132	91	3	6
Soybeans										
1990	39,600	10	0	3	13	34	-21	13	4	83
1991	41,850	9	0	3	12	33	-21	13	3	84
1992	41,600	10	0	3	13	37	-24	11	7	82
1993	42,300	9	0	3	12	32	-20	13	5	82
1994	43,750	10	0	3	13	40	-27	9	5	86
1995	41,700	11	0	1	12	35	-22	13	3	84
Wheat, Winter										
1990	38,650	19	0	1	20	25	-5	28	7	65
1991	30,980	20	0	1	21	21	0	33	8	59
1992	33,465	18	0	1	19	22	-3	31	6	63
1993	35,210	19	0	1	20	24	-4	31	5	64
1994	32,930	19	0	1	20	23	-3	30	8	62
1995	32,670	20	0	1	21	22	-1	36	5	59

-- = Less than 0.5

[1] See "Cropping Practices Survey" in the appendix for major producing States included.

Source: USDA, ERS, estimates based on Cropping Practices Survey data (see box, "Computing Nutrient Mass Balances").

In 1995, soil testing ranged from 22 percent of winter wheat acres to 83 percent of potato acres (tables 4.5.4-4.5.9). The extent of soil testing varies from year to year, but during 1990-95, most soil testing included nitrogen testing, and soil testing for nitrogen increased on potatoes and soybeans.

Testing of plant tissues during the growing season indicates any emerging nutrient deficiency, which can then be corrected by an additional nutrient application. With tissue testing, farmers can apply fertilizers at lower rates based on realistic or average yield expectations, then detect and correct (if economical to do so and if conditions permit) any deficiency that might result from above-average growing conditions. In 1994, the only year data were collected, farmers used tissue testing (primarily for nitrogen) on 61 percent of potato acres (table 4.5.7)and 12 percent of cotton acres (table 4.5.6).

Table 4.5.3—Nutrient management operations and improved versus conventional practices

Nutrient management operation	Conventional practices	Improved practices
Assessing nutrient need	Limited testing for residual nutrient levels, or plant tissue tests to detect nutrient deficiency in plant before applying nutrients.	Annual or regular soil and plant tissue testing before applying nutrients.
	Limited use of the nutrient mass balance accounting method to determine appropriate application rate. Amount applied based on recommended rates for yield maximization, with no crediting for nutrients from other sources.	Nutrient mass balance accounting method used to determine appropriate application rate based on recommended rate for realistic yield goal, with crediting given for nutrients in previous legume, irrigation water, and manure. Manure analyzed for nutrients.
	Same application rate on all parts of field.	Nutrient application rates varied according to the yield potential of soil in various parts of the field.
	The importance of soil factors overlooked.	Optimal levels of soil factors—such as soil PH, organic matter, and micro-nutrients—maintained.
Timing nutrient application	Fall and early spring applications of nitrogen before planting.	Split application of nitrogen fertilizer at planting and after planting.
	Application sometimes made before expected heavy rain.	No application before expected heavy rain.
Nutrient placement	Ground and air broadcast, and application in furrow.	Banded and injected (knifed-in) applications, and chemigation.
Nutrient product selection	Nitrate-based fertilizer sometimes used on high leaching field, and ammonia-based fertilizer on high volatilization field.	Ammonia-based fertilizer used on high leaching field, and nitrate-based fertilizer for low leaching field. Nitrogen stabilizers used in ammonia-based nitrogen fertilizer.
	No application of manure to increase organic matter in soil.	Manure applied to increase organic matter in soil.
Crop selection and management	Continuous planting of same nitrogen-using crop. No planting of cover crops between crop seasons.	Nitrogen-using crops rotated with nitrogen fixing crops. Cover crops planted between crop seasons to tie up and preserve nutrients.
Irrigation management	Conventional gravity irrigation with an excessive application of water.	Improved gravity irrigation practices or sprinkler irrigation used to apply water more timely and uniformly according to crop needs.
Manure and organic waste management	Crop residues removed. No manure or organic waste applied. No manure testing. Inadequate manure storage for properly timing manure applications.	Manure and organic waste application based on manure and waste test results and nutrient management plan. Adequate manure storage for timing manure application, with manure injected or incorporated into soil.

Source: USDA, ERS.

Table 4.5.4—Nutrient management practices on corn, 10 major producing States, 1990-95[1]

Activities and practices	1990	1991	1992	1993	1994	1995
Nutrient sources:			*Percent of planted acres*			
Commercial fertilizer	97	97	97	97	98	98
Manure only	1	1	1	1	1	1
Commercial and manure	16	18	15	17	15	13
Previous soybeans	40	40	44	46	48	50
Previous legume hay and pasture	8	7	8	5	7	7
Assessing nutrient need:			*Percent of planted acres[2]*			
Soil tested	41	41	42	38	42	34
Tested for N	61	60	82	77	54	53
Applied recommended N	na	na	85	87	84	78
Applied > recommended	na	na	5	3	7	7
Applied < recommended	na	na	10	10	9	14
Manure analyzed for manure treated acres	na	na	na	na	6	8
N adjusted for manure-analyzed acres	na	na	na	na	70	na
N adjusted for previous legume	na	na	na	na	53	54
Timing nutrient application:			*Percent of acres receiving commercial fertilizer*			
Nitrogen timing:						
Fall before planting	27	26	23	20	27	30
Spring before planting	57	50	53	51	54	52
At planting	44	48	47	48	43	42
After planting	26	31	31	35	27	29
Phosphate timing:						
Fall before planting	na	na	na	na	25	26
Spring before planting	na	na	na	na	34	31
At planting	na	na	na	na	48	48
After planting	na	na	na	na	2	2
Nutrient placement:			*Percent of acres receiving commercial fertilizer*			
Broadcast (ground)	71	72	69	71	72	73
Broadcast (air)	na	na	1	1	1	1
Chemigation	1	2	1	1	1	1
Banded	43	41	42	42	41	40
Foilar	1	0	0	-	-	0
Injected (knifed in)	55	53	54	47	53	51
Nutrient product selection:			*Percent of tons of nitrogen*			
Anhydrous and aqua ammonia	26	30	29	29	23	26
Urea	3	2	2	3	2	2
Ammonium nitrate	-	-	-	-	-	-
Nitrogen solutions (urea, ammonia, ammonia nitrate)	44	44	47	45	51	49
Mixed NPK fertilizers	24	24	21	23	24	23
N fertilizers mixed with N inhibitors (percent of acres)	8	9	8	5	9	10
Crop selection and management:			*Percent of planted acres*			
Continuous same crop	24	25	23	25	22	21
Corn soybean rotations	40	40	44	46	48	47
Planted after other row crops or small grains	23	16	18	17	17	19
Planted with cover crops	0.5	0.8	0.5	0.5	0.5	0.7

na = no data collected. - means less than 0.5.

[1] For States included, see "Cropping Practices Survey" in the appendix. [2] Indented items are a percentage of previous non-indented item.

Source: USDA, ERS, Cropping Practices Survey data

Table 4.5.5—Nutrient management practices on soybeans, 8 major producing States, 1990-95[1]

Activities and practices	1990	1991	1992	1993	1994	1995
Nutrient sources:	*Percent of planted acres*					
Commercial fertilizer	27	26	27	27	28	28
Manure only	4	6	7	6	8	5
Commercial and manure	2	2	2	1	2	1
Soybeans	12	10	20	11	12	11
Legume, hay and pasture	3	2	3	1	3	2
Assessing nutrient need:	*Percent of planted acres*[2]					
Soil tested	26	28	28	28	30	25
Tested for N	15	16	29	29	43	41
Applied recommended N	na	na	85	87	76	74
Applied > recommended	na	na	5	3	5	7
Applied < recommended	na	na	10	10	18	19
Manure analyzed for manure treated acres	na	na	na	na	5	8
N adjusted for manure-analyzed acres	na	na	na	na	75	na
N adjusted for previous legume	na	na	na	na	16	na
Timing nutrient application:	*Percent of acres receiving commercial fertilizer*					
Nitrogen timing:						
Fall before planting	25	26	33	27	31	35
Spring before planting	50	46	43	51	42	43
At planting	22	24	17	21	24	19
After planting	7	8	8	4	7	8
Phosphate timing:						
Fall before planting	na	na	na	na	42	41
Spring before planting	na	na	na	na	40	42
At planting	na	na	na	na	17	16
After planting	na	na	na	na	3	2
Nutrient placement:	*Percent of acres receiving commercial fertilizer*					
Broadcast (ground)	87	85	89	90	88	88
Broadcast (air)	na	na	na	1	1	2
Chemigation	1	2	1	1	-	-
Banded	14	14	9	9	11	11
Injected (knifed in)	2	4	1	1	2	3
Nutrient product selection:	*Percent of tons of nitrogen*					
Anhydrous and aqua ammonia	7	18	6	5	7	6
Urea	4	7	13	2	6	1
Ammonium nitrate	1	0	0	0	0	-
Nitrogen solutions	15	19	10	25	13	25
Mixed NPK fertilizers	73	57	71	68	74	68
N fertilizer mixed with N inhibitors (percent of acres)	-	-	-	-	-	-
Crop selection and management:	*Percent of planted acres*					
Continuous same crop	6	7	13	6	7	6
Corn/soybean rotation	56	55	36	58	57	63
Planted after other row crops or small grains	31	28	27	28	26	16
Planted with cover crops	3	3	4	3	3	4

na = no data collected. - means less than 0.5.

[1] For States included, see "Cropping Practices Survey" in the appendix. [2] Indented items are a percentage of previous non-indented item.

Source: USDA, ERS, Cropping Practices Survey data.

Table 4.5.6—Nutrient management practices on cotton, 6 major producing States, 1990-95[1]

Activities and practices	1990	1991	1992	1993	1994	1995
Nutrient sources:			*Percent of planted acres*			
Commercial fertilizer	80	82	80	85	87	87
Manure only	0.6	0.9	-	0.6	0.5	-
Commercial and manure	3.3	2.1	3.2	3.0	2.9	2.5
Previous legume hay or pasture	4	4	2	3	2	3
Assessing nutrient need:			*Percent of planted acres*[2]			
Soil tested	28	32	27	28	33	27
Tested for N	95	88	98	94	88	95
Applied recommended N	na	na	76	79	81	73
Applied > recommended	na	na	13	19	9	14
Applied < recommended	na	na	11	8	10	13
Tissue tested	na	na	na	na	12	na
Tested for N	na	na	na	na	96	na
Applied recommended N	na	na	na	na	97	na
Applied > recommended	na	na	na	na	0	na
Applied < recommended	na	na	na	na	3	na
Manure analyzed for manure treated acres	na	na	na	na	23	31
N adjusted for manure-analyzed acres	na	na	na	na	100	na
N adjusted for previous legume	na	na	na	36	na	na
Timing nutrient application:			*Percent of acres receiving commercial fertilizer*			
Nitrogen timing:						
Fall before planting	30	32	30	30	31	32
Spring before planting	42	46	36	43	45	43
At planting	8	11	10	8	7	7
After planting	56	57	59	58	53	52
Phosphate timing:						
Fall before planting	na	na	na	na	40	37
Spring before planting	na	na	na	na	49	47
At planting	na	na	na	na	4	4
After planting	na	na	na	na	11	17
Nutrient placement:			*Percent of acres receiving commercial fertilizer*			
Broadcast (ground)	56	58	55	55	60	55
Broadcast (air)	na	na	5	6	6	3
Chemigation	7	8	6	6	8	6
Banded	24	27	25	24	20	29
Foliar	0	4	3	2	-	-
Injected (knifed in)	45	45	42	45	46	40
Type of nitrogen fertilizer:			*Percent of tons of nitrogen*			
Anhydrous and aqua ammonia	26	30	28	22	25	27
Urea	5	6	3	5	3	2
Ammonium nitrate	2	1	-	-	-	1
Nitrogen solutions	44	36	41	47	52	45
Mixed NPK fertilizers	24	26	27	26	21	26
N fertilizer mixed with N inhibitors (percent of acres)	4	6	3	3	4	na
Crop selection and management:			*Percent of planted acres*			
Continuous crop without cover crop	61	61	66	69	69	68
Continuous crop with cover crop	2	3	2	2	1	1
Cotton-sorghum rotation	8	6	7	12	6	5
Planted after other row crops or small grains	19	17	19	18	18	17

na = no data collected. - means less than 0.5.

[1] For States included, see "Cropping Practices Survey" in the appendix. [2] Indented items are a percentage of previous non-indented item.

Source: USDA, ERS, Cropping Practices Survey data.

Table 4.5.7—Nutrient management practices on fall potatoes, 11 major producing states 1990-95[1]

Activities and practices	1990	1991	1992	1993	1994	1995
Nutrient sources:			*Percent of planted acres*			
Commercial fertilizer	99	99	100	100	100	100
Manure only	-	-	-	-	-	-
Commercial and manure	5.2	4.0	3.5	3.3	2.3	2.3
Previous legume hay or pasture	21	8	5	7	12	10
Assessing nutrient need:			*Percent of planted acres*[2]			
Soil tested	83	84	82	84	85	83
Tested for N	77	77	82	84	92	94
Applied recommended N	na	na	79	77	76	73
Applied > recommended	na	na	9	11	10	10
Applied < recommended	na	na	12	12	14	17
Tissue tested	na	na	na	na	61	na
Tested for N	na	na	na	na	60	na
Applied recommended N	na	na	na	na	83	na
Applied > recommended	na	na	na	na	3	na
Applied < recommended	na	na	na	na	14	na
Manure analyzed for manure treated acres	na	na	na	na	13	43
N adjusted for manure-analyzed acres	na	na	na	na	13	na
N adjusted for previous legume	na	na	na	na	54	na
Timing nutrient application:			*Percent of acres receiving commercial fertilizer*			
Nitrogen timing:						
Fall before planting	16	22	19	20	30	28
Spring before planting	37	41	36	35	43	40
At planting	59	56	53	54	41	46
After planting	52	60	57	57	63	73
Phosphate timing:						
Fall before planting	na	na	na	na	28	27
Spring before planting	na	na	na	na	39	37
At planting	na	na	na	na	41	46
After planting	na	na	na	na	28	30
Nutrient placement:			*Percent of acres receiving commercial fertilizer*			
Broadcast (ground)	na	na	na	na	76	79
Broadcast (air)	na	na	na	na	9	7
Chemigation	na	na	na	na	45	48
Banded	na	na	na	na	51	47
Foilar	na	na	na	na	2	-
Injected (knifed in)	na	na	na	na	6	14
Nutrient product selection:			*Percent of tons of nitrogen*			
Anhydrous and aqua ammonia	5	7	6	8	5	5
Urea	3	3	3	3	2	10
Ammonium nitrate	2	1	-	-	-	1
Nitrogen solutions (urea, ammonium nitrate, ammonia)	44	36	41	47	52	45
Mixed NPK fertilizers	24	26	27	26	22	26
Mixed with N inhibitors (percent of acres)	4	4	2	6	5	na
Crop selection and management:			*Percent of planted acres*			
Continuous same crop without cover crop	1	3	2	3	2	4
Continuous same crop with cover crop	2	2	1	2	1	2
Continuous row crops	14	17	16	16	16	19
Planted after other row crops or small grains	50	44	50	47	51	45

na = no data collected. - means less than 0.5.

[1] For States included, see "Cropping Practices Survey" in the appendix. [2] Indented items are a percentage of previous non-indented item.

Source: USDA, ERS, Cropping Practices Survey data.

Table 4.5.8—Nutrient management practices on winter wheat, 11 major producing States 1990-95[1]

Activities and practices	1990	1991	1992	1993	1994	1995
Nutrient sources:	*Percent of planted acres*					
Commercial fertilizer	83	83	84	86	86	86
Manure only	-	-	-	-	0.6	1.3
Commercial and manure	1.8	2.7	2.1	2.6	1.8	1.2
Previous legume hay and pasture	4	1	1	-	1	1
Assessing nutrient need:	*Percent of planted acres*[2]					
Soil tested	17	19	23	22	20	22
Tested for N	92	92	95	93	91	91
Applied recommended N	na	na	77	77	78	63
Applied > recommended	na	na	7	9	7	15
Applied < recommended	na	na	16	15	15	21
Manure analyzed for manure treated acres	na	na	na	na	na	12
N adjusted for manure-analyzed acres	na	na	na	na	13	na
Timing nutrient application:	*Percent of acres receiving commercial fertilizer*					
Nitrogen timing						
Fall before planting	68	73	73	72	76	77
At planting	22	22	21	22	23	23
After planting	44	45	47	44	42	47
Phosphate timing:						
Fall before planting	na	na	na	na	57	57
At planting	na	na	na	na	38	38
After planting	na	na	na	na	7	7
Nutrient placement:	*Percent of acres receiving commercial fertilizer*					
Broadcast (ground)	na	na	na	na	58	62
Broadcast (air)	na	na	na	na	3	3
Chemigation	na	na	na	na	1	1
Banded	na	na	na	na	19	21
Injected (knifed in)	na	na	na	na	46	46
Nutrient product selection:	*Percent of tons of nitrogen*					
Anhydrous and aqua ammonia	43	43	46	45	47	46
Urea	12	10	9	6	5	5
Ammonium nitrate	1	2	2	2	1	3
Nitrogen solutions (ammonia, urea, ammonium nitrate)	21	24	22	24	24	24
Mixed NPK fertilizers	23	21	22	24	24	24
N fertilizer mixed with N inhibitors (percent of acres)	2.6	2.3	1.9	1.3	2.0	na
Crop selection and management:	*Percent of planted acres*					
Continuous same crop	51	40	40	39	43	45
Wheat/fallow/wheat	na	21	20	23	23	19
Idle or fallow	27	34	23	23	21	18
Double-cropped soybeans	2	2	2	1	1	1

na = no data collected. - means less than 0.5.

[1] For States included, see "Cropping Practices Survey" in the appendix. [2] Indented items are a percentage of previous non-indented item.

Source: USDA, ERS, Cropping Practices Survey data.

Of the acres soil-tested for nitrogen, farmers typically reported applying the recommended amount for the soil and crop. Whether nitrogen tests help reduce nitrogen fertilizer use depends in part on the nitrogen recommendations provided to farmers by the State Extension Service or fertilizer dealers. However, Schlegel and Havlin (1995) found that the nitrogen rates recommended by typical models were sometimes 30 to 60 percent higher than the profit maximizing rate.

The nutrient content of any manure applied, if known, allows farmers to better determine nutrients needed from other sources. However, manure analysis occurred on only 8 percent of corn and soybean acres receiving manure in 1995, and on only 12 percent of wheat acres (tables 4.5.4-4.5.8). Previous legumes, an additional source, were credited by farmers in determining commercial nutrient needs on only about half of crop acres with previous legumes.

Timing nutrient application. Timing nitrogen applications to the biological needs of a crop leaves less nitrogen available for loss and can reduce total amount applied. Optimum times for fertilizer application vary by crop, texture of soil, climate, and stability of fertilizer (Aldrich, 1984). For example, corn requires most of its nitrogen supply in midsummer. Nitrogen applied either in the fall or early spring is more readily lost to the environment than when applied at or after planting, and farmers often apply a larger amount to make up for the anticipated loss. Splitting nitrogen fertilizer into various applications at and after planting can reduce nitrogen loss by as much as 40 percent without reducing crop yields (Meisinger and Randall, 1991). However, fall and early spring applications are still prevalent, and may be increasing for some crops. Over two-thirds of winter wheat acres and 20-35 percent of corn, soybean, cotton, and potato acres were fertilized in the fall before planting during 1990-95. The trend appears to be increasing for potatoes and winter wheat. Another 35-57 percent of soybean, cotton, potato, and corn acres received fertilizer in the spring before planting. The only major field crop with increases in after-planting applications was fall potatoes, and this at the expense of at-planting application.

Economic considerations lead many farmers to apply nitrogen before planting during the fall and spring rather than during the growing season (Feinerman et al., 1990; Huang et al., 1994). For example, uncertain weather conditions may shorten the window (time) in which fertilizer can be applied during the growing season, increasing the risk of yield loss from inadequate nitrogen availability. Such risk is magnified for farmers with shorter growing seasons. The opportunity cost of labor and application arrangements may be significantly higher during the late spring and growing season than during the fall. Also, fertilizer pricing patterns (lower in the fall than spring) tend to encourage fall application rather than spring or growing-season application.

Nutrient placement. For crops surveyed in the Cropping Practices Survey, broadcasting was the most common method of applying fertilizers. Broadcasting keeps down the cost of field operations but broadcast nitrogen is more susceptible to loss to the environment. In contrast, banded applications—including the use of injection, knifed-in, or side dressing (see glossary)—place nitrogen fertilizer closer to the seed or plant for increased crop uptake (Achorn and Broder, 1991). Banded practices can increase the efficiency of nitrogen fertilizer use. Injection of an ammonia type of nitrogen (such as anhydrous ammonia) into the soil can reduce leaching and volatilization by as much as 35 percent compared with broadcast application (Achorn and Broder, 1991) and can result in a yield increase of as much as 15 percent (Mengel, 1986). The operation cost (variable and fixed) of injection applications is higher than for broadcast applications, but the overall cost (operation and nitrogen fertilizer) is lower.

Precision farming, also referred to as site-specific farming, is a promising new technology for improving nutrient application timing, rate, and placement. This technology divides whole fields into small areas and uses a variable-rate fertilizer spreader and a global positioning system to apply the exact amount of nutrient needed at each specific location. Precision farming requires equipment for testing soils, locating position, and monitoring yields; a computer to store data; and a variable-rate applicator (see the chapter on Farm Machinery for more detail)**.** A preliminary estimate of additional field operation costs of precision farming for corn is about $7-$8 per acre (Lowenberg-DeBoer and Swinton, 1995).

Precision farming has the potential to improve net farm income by: (1) identifying places in a field where additional nutrient use will increase yield, and thus farm income, by more than the added cost; and (2) identifying places where reduced input use will reduce costs while maintaining yield. Precision farming has the potential to reduce off-site transport of agricultural chemicals with surface runoff, subsurface drainage, and leaching (Baker and others, 1997). Two years of Kansas field data indicate less total nitrogen fertilizer use with precision farming than with conventional nitrogen management (Snyder and others, 1997). However, precision farming is too new an information technology to assess how it affects long-term yield, fertilizer use, farm-level productivity, and the enironment.

Nutrient product selection. Nitrogen fertilizers can be ranked according to their chemical stability in the soil—an important factor in determining potential for environmental harm. Ammonium nitrate is the least stable in soil, followed by nitrogen solutions, anhydrous ammonia, urea, and ammonia-based fertilizer with an added nitrification inhibitor (Fertilizer Institute, 1982; Aldrich, 1984). For areas where cropland is vulnerable to leaching (sandy soils), ammonia-based fertilizer can minimize nitrogen loss. For areas where ammonia volatilization is a problem (areas with hot, dry air and moist soils), a nitrate-based fertilizer is preferable.

Nitrogen stabilizers or inhibitors (urease inhibitors and nitrification inhibitors) delay the transformation of nitrogen fertilizer from ammonia to nitrate and help match the timing of nitrate supply with peak plant demand (Hoeft, 1984). The potential benefit from nitrification inhibitors is greatest where soils are either poorly or excessively drained, no-till cultivation is used, nitrogen is applied in the fall, crops require a large amount of nitrogen fertilizer, and excessively wet soil conditions prevent the application of nitrogen in the growing season (Hoeft 1984; Nelson and Huber, 1987; Scharf and Alley, 1988). The greatest potential benefit occurs only when nitrification inhibitors are used at or below the optimal nitrogen application rate. A nitrification inhibitor added to anhydrous ammonia is most widely used in corn production. However, recent surveys reveal that corn growers in the Corn Belt are likely to apply more nitrogen fertilizer when a nitrification inhibitor is used. Such a practice not only diminishes the economic benefit associated with the use of a nitrification inhibitor, but also increases the amount of residual nitrogen left on the field for leaching (Huang and Taylor, 1996). During 1990-95, farmers used nitrification inhibitors on acreage ranging from 2 percent of winter wheat to 10 percent of corn (tables 4.5.4-4.5.8). No trends are evident.

Crop selection and management. Crops in rotation with a nitrogen-fixing legume crop can reduce nitrogen fertilizer needs and use. In addition, crops in rotation reduce soil insect species, improve plant health, and increase nitrogen uptake efficiency. Legume crops at the early stage of growth absorb residual nitrogen in the soil and therefore minimize nitrate leaching. Even with these benefits, however, crop rotations are often less profitable than monoculture particularly when crop production is subsidized by farm programs. For example, a corn-soybean rotation was shown to be less profitable than continuous corn production under farm programs that included loan rates and deficiency payments (Huang and Lantin, 1993; Huang and Daberkow, 1996). Nevertheless, more than 40 percent of corn on nonirrigated land is in rotation with soybeans or other crops to buffer uncertain markets and to aid in pest control (see chapter 4.3, *Cropping Management*, for more detail on rotations and the economic factors that influence crop choice).

Planting cover crops between crop seasons can prevent the buildup of residual nitrogen. Planting cover crops also can reduce nutrient loss by minimizing soil erosion. Small grain crops and hairy vetch are both nitrogen-scavenging cover crops. Because the economic benefit of planting cover crops is limited for field crops, the practice has not been widely adapted by U.S. farmers. During 1990-95, only 1-4 percent of major field crop acres had previous cover crops (tables 4.5.4-4.5.8).

Irrigation management. Improved irrigation practices can help farmers irrigate crops more uniformly and control the quantity of irrigation water in the soil (see chapter 4.6, *Irrigation Water Management*, for more details). The quantity of water in the soil affects the nutrient concentration in the soil and the rate of nutrient movement to the root zone (Rhoads, 1991). Too much irrigation water can promote nitrogen leaching, reduce nutrient concentration in the soil, and lower plant uptake. Too little irrigation water can stunt plant growth and reduce crop yield. Irrigation efficiency can be improved, for example, by switching from gravity irrigation to sprinkler irrigation, by scheduling irrigation according to plant need, and by using improved gravity irrigation practices such as a surge system or shorter irrigation runs. The cost of irrigation improvements can be substantial, but the economic benefit from saved irrigation water and increased yield in some areas may offset the cost.

Manure and organic waste management. Manure is a good source of organic matter for the soil. In some cases, it can also be an economical, though limited, source of plant nutrients. The organic matter in soil provides a steady supply of nutrients to the plant, and conditions the soil for the plant to achieve higher yields. However, the nutrients contained in the organic matter can also be lost to the environment through soil ersion. Because of its bulk, the economic benefit of manure is limited by available storage and reasonable transport distance (Bouldin et al., 1984). The benefit of manure varies by region; application of manure in corn production is profitable for farmers in Iowa (Chase et al., 1991). Transfer of poultry litter from the litter-surplus areas to litter-deficiency areas in Virginia is economically viable (Bosch and Napit, 1992). Most feedgrain and confined-livestock farms can benefit from manure use for crop production (Gollehon and Letson, 1996). Managing nutrients in manure for crop use requires testing manure for its nutrient content, planning its efficient use in crop production, and storing it to minimize nutrient loss until the time of the crops' greatest need. (USDA, NRCS 1992). During 1990-95, manure application to major field crops ranged from 2-3 percent of winter wheat to 13-18 percent of corn acres (tables 4.5.4-4.5.8).

Improving Nutrient Management

Federal and State governments play an important role in helping reduce agricultural nonpoint pollution of water resources (EPA, 1991). EPA establishes minimum water quality standards and regulates animal waste discharges from large confined livestock operations under the Clean Water Act. States regulate input use and use zoning, land acquisition, and easements to preserve areas deemed important for protecting water resources.

Society, acting through government, can (1) adjust the anticipated costs or benefits of certain production practices through education, technical assistance, and by taxing inputs or by offering subsidies for practice adoption; (2) restrict or regulate certain production practices, such as the use of highly leachable fertilizers in vulnerable areas; (3) help create markets for pollutants; and (4) invest in research and development to find production practices that are less environmentally damaging. Approaches 1 and 3 are economic or incentive-based approaches and are often preferred because they allow maximum flexibility in meeting environmental goals at minimum cost.

USDA prefers voluntary, incentive approaches to deal with agricultural water pollution. This preference is based on the inherent difficulty in regulating nonpoint sources of pollution, and on the belief that when educated about the problems and provided technical and financial assistance, farmers will make improvements in production practices to achieve conservation and environmental goals. In passing the Federal Agriculture Improvement and Reform Act of 1996, Congress reaffirmed its preference for dealing with agricultural resource problems using voluntary approaches.

Efficiency of Financial Incentive Programs

A recent study of USDA's Water Quality Incentives Projects (WQIP)—which provided producers with financial assistance to make changes in nutrient and other management systems to restore or enhance water resources impaired by agricultural source of pollution— found that practices requiring minor, inexpensive changes in existing farm operations tended to be adopted more frequently than those involving more expensive changes (Feather and Cooper, 1995). Belief that adoption will increase profits was found to be the most common reason for adoption: familiarity with the improved management practice was found to be the second most important reason for adoption followed by beliefs that the practice improves on-farm water quality.

To determine the sensitivity of adoption to WQIP incentive payment levels, non-adopting producers were asked if they would adopt improved management practices given various hypothetical incentive payments. In many cases, the incentive payments required to achieve a 50-percent adoption rate were much greater than the actual payments for these practices. Practices requiring larger incentive payments were typically those which involved expensive changes in the farm operation.

The results of this study have several policy implications. First, the efficiency of financial incentive programs may be increased by targeting practices providing the largest reduction in pollution per dollar of incentive payment. Second, educational programs seem to be most successful with practices that involve small, inexpensive changes in the operation and are profitable to the producer. Water-quality benefits influence adoption decisions, but profitability is the most important factor. Thus, educational programs without substantial incentive payments may have limited success encouraging practices involving large expenditures. Third, both educational and financial incentive programs should recognize that large regional differences in adoption exist over geographical areas. Instead of implementing a uniform program across the nation, region specific programs may be more effective. Lastly, using both educational and financial incentives requires fewer resources and may be more successful than implementing each program separately. A financial incentive program, for example, could be combined with an educational program targeting different practices. These two programs could be combined by requiring producers to enroll in the educational program in order to receive incentive or cost-sharing payments.

Adjusting the anticipated costs or benefits of production practices. USDA provides educational, technical, and financial assistance to encourage adoption of nutrient management and other less polluting practices (see chapter 6.2, *Water Quality Programs*). Education helps farmers understand the need for improved practices and demonstrates the practices in operation while technical assistance helps install and implement the practices. Financial assistance can help offset the added cost or risk associated with practice adoption (see box, "Efficiency of Financial Incentive Programs").

The Federal Agriculture Improvement and Reform Act of 1996 established the Environmental Quality Incentives Program (EQIP) in USDA to replace most previous financial assistance programs and to better target assistance to areas most needing actions to improve or preserve environmental quality. One half of EQIP funding is to be directed to conservation practices relating to livestock production including waste and nutrient management improvement. The program may emphasize extensive or management type practices that are more cost effective than intensive structural type measures. Such direction would favor improved nutrient management. (See chapter 6.1, *Conservation and Environmental Programs Overview* for more information on EQIP).

The relative costs of nutrient management practices can be adjusted through input or discharge taxes, such as a tax on nitrogen applied in excess of nitrogen removed (Huang and LeBlanc, 1994). In effect, the residual nitrogen tax is an effluent tax, which induces farmers to adopt improved practices to reduce the residual. Also, it can generate revenue to support development and promotion of improved practices. A nitrogen fertilizer tax in Iowa generates revenue for research and extension activities in water quality improvement. More than $15 million of tax revenue is generated annually and used to develop and promote alternative farming practices to reduce nitrate leaching.

Regulatory approaches. Regulatory approaches can impose a lower cost on farmers than do fertilizer or discharge taxes (Huang and Lantin, 1992) and can be a least-cost approach for society when unseasonal weather occurs (Baumol and Oates, 1988). Laws and programs that limit farm nutrient use in the interests of the environment— including the Clean Water Act—are described in detail in chapter 6.2, *Water Quality Programs*. Imposing restrictions on nitrogen fertilizer use can affect farmers differently, depending on current production practices (Huang, Shank, and Hewitt, 1996).

Several States have established a regulatory agency to control nitrate leaching. Currently, 13 States require that livestock farms have comprehensive nutrient management plans that account for all sources of nutrients and that match nutrient application and availability to crop need (USDA, NRCS 1995b). In 1969, Nebraska created 24 multipurpose Natural Resources Districts (NRD's) and gave them authority to levy a local property tax to fund a wide variety of services to protect Nebraska's natural resources (Nebraska Association of Resources Districts, 1990). One district, the Central Platte NRD, suffers a high level of nitrate-nitrogen in the ground water (CPNRD, 1993, 1995). Three phases of regulation were established, depending on the groundwater nitrogen level, potential impact on municipal water supply, and nitrogen levels in the zone between crop roots and ground water. Restrictions on fertilizer use increase with each phase. Nearly all farm operators have complied, completing reports on nitrogen use, taking necessary soil and water tests, and cutting back their use of commercial nitrogen fertilizer. Since the regulatory program was established in 1987, nitrate concentrations in the ground water in some areas in the Central Platte Basin have been stabilized (CPNRD, 1995).

As animal operations become larger, more States are looking at ways of protecting the environment from animal waste. Large confined animal operations can present major water quality problems, and operations greater than 1,000 animal units are subject to point-source permits under the Clean Water Act. However, these permits address only storage of manure on the site, and not disposal. In 1993, Pennsylvania became the first State to pass a comprehensive nutrient management law aimed at concentrated animal operations. Animal operations with over two animal units per acre of land available for spreading must have a farmlevel nutrient management plan that demonstrates that waste is being safely collected and disposed of (Beagle and Lanyon, 1994). Land-use laws that affect agriculture are being used by municipalities, counties, and other local governments. Zoning ordinances are used in many areas, especially around the rural-urban fringe, to ban confined animal operations.

Establishing markets for pollutants. Another way to improve nutrient management is to facilitate the transfer of manure from those farms that have excess to those that need additional nutrients. This can be done by establishing a market for trading manure products and for gathering and exchanging technical information. A successful market for the poultry litter has been established in Arkansas, the largest broiler-

Glossary

Plant tissue analysis—A test that uses chlorophyll (or greenness) sensing to detect nitrogen deficiency during the plant glowing period. Correction of any nitrogen deficiency is then made through chemigation or other foliar application (Sander et al., 1994).

Nutrient recommendations—The rate of the plant nutrient to be applied is the difference between the amount of nutrients required by the crop based on a realistic yield goal and the amount of the nutrients already available for plant uptake, as determined by soil nutrient tests and nutrient credits for other sources. Many land grant universities provide nutrient recommendations based on information obtained from long-term field trials.

Credits for other nutrient sources—Other sources of nutrients include nitrogen from legumes planted in the previous crop, nitrate in irrigation water and precipitation, and nitrogen, phosphorus, and potassium in animal manure and other (such as municipal) wastes.

Split applications—Total fertilizer for crop need is split into several applications during the growth of the crop.

Chemigation—Nitrogen solutions applied through irrigation water.

Broadcast applications—Fertilizer broadcast in either granule or liquid form on all field surfaces. Most ground broadcast equipment for granular fertilizer uses one or two disks to broadcast fertilizer in 12- to 15-meter swaths. Nitrogen solutions are broadcast using various types of spray nozzles. Aircraft is used for aerial application.

Injection, knifed-in, or incorporation—Nitrogen fertilizer is injected or knifed-in usually 12-24 cm below the soil surface. It can also be incorporated into the soil by tillage. High-pressure liquid nitrogen such as anhydrous ammonia is the most common form of nitrogen injected into the soil. Nitrogen solutions in low-pressure liquid form are also injected into the soil.

Side-dressing or banded application—Granule or liquid nitrogen fertilizer is placed to one side of the plant or placed every other row at planting or during the growing season.

Precision (prescription or site-specific) farming—A large field is divided into small grids according to soil and nutrient conditions. Various rates of nutrients are applied to those grids according to their nutrient status by using locator equipment.

Nitrification inhibitors—Chemical compounds that can be added to the ammonia fertilizers to slow the conversion of ammonium nitrogen to nitrate nitrogen which is susceptible to leaching. N-inhibitors can be used with manure and other forms of organic nitrogen fertilizer.

Urease inhibitors—Chemical compounds that can be added to urea to slow the conversion of urea to ammonium and therefore to slow nitrate leaching.

Slow-release nitrogen fertilizer—Fertilizer coated with chemicals that can retard release of nitrogen from applied fertilizer and prolong the supply of nitrogen for plant uptake.

Rotating crops: A multi-year crop sequence, for example, nonlegume crops then legume crops.

Improved irrigation practices—Use of improved gravity irrigation, a sprinkler irrigation system, soil moisture testing, and an irrigation schedule to tailor irrigation to crop needs and to apply irrigation water uniformly.

Factors influencing vigorous crop growth—Selecting disease- and insect-resistant plant, planting a crop at optimal time, and using integrated pest management can improve plant health and increase nitrogen uptake and thus reduce nitrogen available for leaching.

Cover crops—Planting a cover crop after harvest to take up residual nitrogen and therefore minimize leaching.

Crop residues—Incorporation of crop residual into the soil helps immobilize residual nitrogen.

producing State. In 1991, Winrock International began a project aimed at transferring excess litter in the western part of the State to rice farmers in eastern Arkansas as a natural soil amendment to improve the fertility of zero-grade rice fields where topsoil has been scraped off (Winrock International, 1995). Rice straw, in turn, is an important bedding material for poultry houses in western Arkansas. A poultry litter hotline was launched in 1993 to link prospective buyers and sellers. Also, Tyson Foods, the largest poultry processor, approved the same trucks delivering clean bedding from the Delta area to its contracted poultry farms to back-haul litter from the poultry farms to the Delta rice farms, reducing the cost of transporting litter. An average of 30 litter buyers and sellers are listed on the hotline through the year, with double that number in December and January. The litter market has increased incomes of both poultry farmers and rice farmers, while mitigating water quality problems in western Arkansas.

Research, development, and demonstration. The Federal Government also plays a major role in research, development, and demonstration of improved nutrient management. During 1991-94, USDA funded various Hydrologic Unit Area (HUA) and Demonstration Projects (DP), which helped farmers to implement improved nutrient management over a wide range of geographic settings, agricultural types, and water quality problems across the Nation (USDA, NRCS, 1995a). Case studies of eight DP's and eight HUA's found reductions in annual nitrogen application because of the improved nutrient management practices. Also, USDA, in cooperation with the U.S. Geological Survey, U.S. Environmental Protection Agency, and State experiment stations, established various Management Systems Evaluation Areas (MESA's) to better understand the linkages between farming practices and water quality in the Midwest (ARS, 1995). Nutrient management is the major focus of these projects, which include monitoring activities, modification of farming systems, alternative and new farming practices, site-specific management, nitrogen testing, and socioeconomic studies of farming systems.

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Recent ERS Research on Nutrient Management

"On-farm Costs of Reducing Residual Nitrogen on Cropland Vulnerable to Nitrate Leaching," *Review of Agricultural Economics*, Vol. 18, No. 4, Sept. 1996 (Wen-yuan Huang, David Shank, and Tracy Irwin Hewitt). A farm-level dynamic model considering nitrogen carryover effects was used to analze the costs to a farmer of complying with a restriction on nitrogen fertilizer use on cropland vulnerable to nitrate leaching. While the theoretical results were indeterminate, empirical results from an Iowa case study indicated that a fertilizer use restriction on cropland highly vulnerable to leaching will have a smaller compliance cost than on cropland with a moderate leaching potential.

"Incentive Payments to Encourage Farmer Adoption of Water Quality Protection Practices," *American Journal of Agricultural Economics*, Vol. 78, No.1, Feb. 1996 (Joseph C. Cooper and Russ W. Keim). This paper uses both a bivariate probit with sample selection model and a double hurdle model to predict the impacts of different incentive payments on farmer adoption of integrated pest management, legume crediting, manure tests, split applications of nitrogen, and soil moisture testing. The results can be used to aid decisions on how to allocate program budgets among the preferred production practices.

"Economic and Environmental Implications of Soil Nitrogen Testing: A Switching-Regression Analysis," *American Journal of Agricultural Economics*, Vol. 77, No. 4, Nov. 1995 (Keith O. Fuglie and Darrell J. Bosch). A simultaneous equations, or "switching-regression," model is developed to assess the impact of soil nitrogen (N) testing on N use, crop yields, and net returns in corn growing areas of Nebraska. The results indicate that when there is uncertainty about the quantity of available carryover N, testing for N enables farmers to reduce fertilizer use without affecting crop yields. However, the value of information from N tests depends critically on cropping history and soil characteristics.

"The Role of Planting Flexibility and the Acreage Reduction Program (ARP) in Encouraging Sustainable Agricultural Practices," *Journal of Sustainable Agriculture*, Vol. 7, No. 1, Sept. 1995 (Wen-yuan Huang and Stan G. Daberkow). This article examines the impact of increasing planting flexibility (P) on program participation, farm income, crop diversity, and government payments. For a representative western Corn Belt farm, increasing P to more than 63 percent with zero ARP would result in farmers being better off in switching from continuous corn to a corn-soybean rotation. However, increasing the P and reducing the ARP may sacrifice some environmental benefits.

Voluntary Incentives for Reducing Agricultural Nonpoint Source Water Pollution. AIB-716, May 1995 (Peter M. Feather and Joeph Cooper). This report examines the success of existing incentive programs in achieving adoption of manure crediting, legume crediting, split N application, irrigation scheduling, and deep soil nitrate testing. Results indicate large incentive payments may be necessary to achieve high adoption levels, and adoption rates differ both across practices and across geographic areas. Programs involving cost-sharing and incentive payments could be more successful if incentives were altered to account for these differences.

"Voluntary Versus Mandatory Agricultural Policies to Protect Water Quality: Adoption of Nitrogen Testing in Nebraska," *Review of Agricultural Economics*, Vol 17, No. 1 Jan. 1995. (Bosch, D. L., Z. L. Cook, and K.O. Fuglie). This article evaluates the effectiveness of regulation versus a combination of voluntary incentive approaches for increasing Nebraska farmers' use of soil and/or tissue testing on the fields planted to corn. The results indicate that while regulation leads to higher levels of N test adoption, it does not have an "educational" effect on adopters. Educational programs may be needed to complement regulations to ensure that farmers change their behavior to achieve the goals of water quality protection programs .

"Market-Based Incentives for Addressing Non-point Water Quality Problems: A Residual Nitrogen Tax Approach," *Review of Agricultural Economics*, Vol. 16, No. 4, Sept. 1994(Wen-yuan Huang and Michael LeBlanc). This study analyzes the implications of a tax scheme which would penalize farmers for applying nitrogen in excess of a crop's nitrogen uptake and reward them for growing crops that capture and utilize residual soil nitrogen. Corn production is used to illustrate the differential impacts of residual nitrogen tax on farm income in Corn Belt States.

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Recent ERS Research on Nutrient Management (cont.)

An Economic Analysis of Agricultural Practices Related to Water Quality: the Ontario (Oregon) Hydrologic Unit Area. ERS Staff Report No. AGES-9418. June 1994 (C. S. Kim, Ronald Fleming, Richard M. Adams, Marshall English, and C. Sandretto). This report evaluates the effects of adopting Best Management Practices (BMPs) on groundwater quality in Ontario (Oregon) area by incorporating time lags associated with nitrate leaching and groundwater flow. Results indicate that Federal drinking water standard of no more 10 ppm nitrate in groundwater may be accomplished in 12 years by adopting improved irrigation systems such as auto-cutback systems or solid-set sprinkler systems. However, the adoption of both improved irrigation systems and nutrient management systems, such as side-dressing and ceasing fall fertilization, would be necessary to meet the strict Oregon drinking water standard of 7 ppm.

"The Role of Information in the Adoption of Best Management Practices for Water Quality Improvement." *Agricultural Economics*, No. 11 April 1994. (Peter M. Feather and Gregory S. Amacher). This paper tests the hypothesis that a lack of producer information regarding both the profitability and the environmental benefits of adopting improved practices may be a reason why widespread adoption of these practices has not occurred. A two-stage adoption model is specified and estimated using data from a survey of producers. The results indicate that producer perceptions play an important role in decision to adopt. Changing these perceptions by means of an educational program may be a reasonable alternative to financial incentives.

Timing Nitrogen Fertilizer Applications to Improve Water Quality. ERS Staff Report No. AGES-9407, February 1994 (Wen-yuan Huang, Noel D. Uri, and LeRoy Hansen). Analytical models are developed to determine the necessary conditions for the optimal timing of nitrogen fertilizer application. The empirical results explain various observed timings of nitrogen fertilizer application to cotton in Mississippi, and provide an estimate of a farmer’s cost in complying with a restriction on the timing of nitrogen fertilizer application.

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4.6. Irrigation Water Management

Water management is an important element of irrigated crop production. Efficient irrigation systems and water management practices can help maintain farm profitability in an era of limited, higher-cost water supplies. Efficient water management may also reduce the impact of irrigated production on offsite water quantity and quality. However, measures to increase water-use efficiency may not be sufficient to achieve environmental goals in the absence of other adjustments within the irrigated sector. As is often the case, technology is not the whole solution anywhere, but part of the solution almost everywhere.

Contents

The U.S. Department of Agriculture identifies improvements in water management as one of the primary agricultural policy objectives for the 1990's (USDA, 1994). Irrigation water management (IWM) involves the managed allocation of water and related inputs in irrigated crop production, such that economic returns are enhanced relative to available water. Conservation and allocation of limited water supplies is central to irrigation management decisions, whether at the field, farm, irrigation-district, or river-basin level.

Why Manage Irrigation Water?

Irrigation water is managed to conserve water supplies, to reduce water-quality impacts, and to improve producer net returns.

Water Conservation. Water savings through improved management of irrigation supplies are considered essential to meeting future water needs. Irrigation is the most significant use of water, accounting for over 95 percent of freshwater withdrawals consumed in several Western States and roughly 80 percent nationwide (see chapter 2.1, *Water Use and Pricing)*. However, expanding water demands for municipal, industrial, recreational, and environmental purposes increasingly compete for available water supplies. Since opportunities for large-scale water-supply development are limited, additional water demands must be met largely through conservation and reallocation of existing irrigation supplies (Moore, 1991; Schaible and others, 1991; Vaux, 1986; Howe, 1985).

Water Quality. Improved water management can also help minimize offsite water-quality impacts of irrigated production. Irrigated agriculture affects water quality in several ways, including higher chemical-use rates associated with irrigated crop production, increased field salinity and erosion due to applied water, accelerated pollutant transport with drainage flows, degradation due to increased deep percolation to saline formations, and greater instream pollutant concentrations due to reduced flows. Strategies to improve the Nation's water quality must address the effect of irrigation on surface and ground water bodies (National Research Council, 1996).

Farm Returns. Finally, improvements in IWM can help maintain the long-term viability of the irrigated agricultural sector. Irrigated cropland is important to the U.S. farm economy, accounting for about 40 percent of total crop sales with just 15 percent of the Nation's harvested cropland in 1992 (USDC, 1994). Water savings at the farm level can help offset the effect of rising water costs and restricted water supplies on producer income. Improved water management may also reduce expenditures for energy, chemicals, and labor inputs, while enhancing revenues through higher crop yields and improved crop quality.

Use of Improved Irrigation Technology and Management

How producers respond to higher water costs and limited water supplies is important to policymakers. Producers may reduce water use per acre by applying less than full crop-consumptive requirements (deficit irrigation), shifting to alternative crops or varieties of the same crop that use less water, or adopting more efficient irrigation technologies. In some cases, producers may convert from irrigated to dryland farming or retire land from production. Many irrigators have responded to water scarcity through the use of improved irrigation technologies—often in combination with other water-conserving strategies—and irrigators will likely look to technology as one of several means of conserving water in the future.

Various management practices and irrigation technologies are available to enhance efficiency of applied water in irrigated agriculture (see box, "Irrigation Water-Use Efficiency"). Irrigation improvements often involve upgrades in physical application systems, with improved field application efficiencies and higher yield potentials. Improved water management practices, such as irrigation scheduling and water-flow measurement, may also be required to achieve maximum potentials of the physical system. In addition, management of drainage flows may be an important concern in many irrigated areas (table 4.6.1). In some cases, the effectiveness of improved irrigation practices may be enhanced when implemented in combination with other farming practices such as conservation tillage and nutrient management.

Irrigation Water-Use Efficiency

Water-use efficiency measures are commonly used to characterize the water-conserving potential of irrigation systems. Alternative efficiency measures reflect various stages of water use and levels of spatial aggregation. **Irrigation efficiency**, broadly defined at the field level, is the ratio of the average depth of irrigation water beneficially used (consumptive use plus leaching requirement) to the average depth applied, expressed as a percentage. **Application efficiency** is the ratio of the average depth of irrigation water stored in the root zone for crop consumptive use to the average depth applied, expressed as a percentage. Crop-water consumption includes stored water used by the plant for transpiration and tissue building, plus incidental evaporation from plant and field surfaces. Leaching requirement, which accounts for the major difference between irrigation efficiency and application efficiency, is the quantity of water required to flush soil salts below the plant root zone. Field-level losses include surface runoff at the end of the field, deep percolation below the crop-root zone (not used for leaching), and excess evaporation from soil and water surfaces. **Conveyance efficiency** is the ratio of total water delivered to the total water diverted or pumped into an open channel or pipeline, expressed as a percentage. Conveyance efficiency may be computed at the farm, project, or basin level. Conveyance losses include evaporation, ditch seepage, operational spills, and water lost to noncrop vegetative consumption. **Project efficiency** is calculated based on onfarm irrigation efficiency and both on- and off-farm conveyance efficiency, and is adjusted for drainage reuse within the service area. Project efficiency may not consider all runoff and deep percolation a loss since some of the water may be available for reuse within the project.

Irrigation Application Systems

Irrigation application systems may be grouped under two broad system types: gravity flow and pressurized systems. (For an explanation of irrigation systems discussed here, see boxes, "Gravity (Pressurized) Irrigation Systems and Practices," pp. 229-230.)

Gravity-Flow Systems. Many irrigation systems rely on gravity to distribute water across the field. Land treatments—such as soil borders and furrows—are used to control lateral water movement and channel water flow down the field. Water is conveyed to the field by means of open ditches, above-ground pipe (including gated pipe), or underground pipe, and released along the upper end of the field through siphon tubes, ditch gates, or pipe valves. Fields are

Table 4.6.1—Irrigation technology and water management: conventional methods and improved practices

System and aspect	Conventional technology or management practice	Improved technology or management practice
Onfarm conveyance	Open earthen ditches.	Concrete or other ditch linings; above-ground pipe; below-ground pipe.
Gravity application systems:		
Release of water	Dirt or canvass checks with siphon tubes.	Ditch portals or gates; gated pipe; gated pipe with surge flow or cablegation.
Field runoff	Water allowed to move off field.	Applications controlled to avoid runoff; tailwater return systems.
Furrow management	Full furrow wetting; furrow bottoms uneven.	Alternate furrow wetting; furrow bottoms smooth and consistent.
Field gradient	Natural field slope, often substantial; uneven field surface.	Land leveled to reduce and smooth field surface gradient.
Length of irrigation run	Length of field, often 1/2 mile or more.	Shorter runs, 1/4 mile or less.
Pressurized application systems:		
Pressure requirements	High pressure, typically above 60 psi.	Reduced pressure requirements, often 10-30 psi.
Water distribution	Large water dispersal pattern.	More narrow water dispersal through sprinkler droptubes, improved emitter spacing, and low-flow systems.
Automation	Handmove systems; manually operated systems.	Self-propelled systems; computer control of water applications.
Versatility	Limited to specific crops; used only to apply irrigation water.	Multiple crops; various uses—irrigation, chemigation, manure application, frost protection, crop cooling.
Water management:		
Assessing crop needs	Judgment estimates.	Soil moisture monitoring; plant tissue monitoring; weather-based computations.
Timing of applied water	Fixed calendar schedule.	Water applied as needed by crop; managed for profit (not yield); managed for improved effectiveness of rainfall.
Measurement of water	Not metered.	Measured using canal flumes, weirs, and meters; external and inpipe flow meters.
Drainage	Runoff to surface-water system or evaporation ponds; percolation to aquifers.	Applications managed to limit drainage; reuse through tailwater pumpback; dual-use systems with subirrigation.

Source: USDA, ERS.

generally rectangular with water runs typically ranging from one-eighth to one-half mile in length. Gravity systems are best suited to medium- and fine-textured soils with higher moisture-holding capacities; field slope should be minimal and fairly uniform to permit controlled water advance.

Although total acreage in gravity systems has declined by 20 percent since 1979, gravity-flow systems still account for over half of irrigated acreage nationwide (table 4.6.2). Gravity-flow systems are used in all irrigated areas, and are particularly predominant in the Southwest (California, Nevada, Arizona, New Mexico), Central Rockies (Wyoming, Colorado, Utah), Southern Plains (Texas, Oklahoma), and Delta (Arkansas, Louisiana, Mississippi) regions. The predominance of gravity systems in arid regions of the West reflects early project development on broad, flat alluvial plains; high crop water-consumption requirements; and increased soil salt-

Table 4.6.2—Changes in irrigation system acreage, 1979-94

System	1979	1994	Change 1979-94
	Million acres		Percent
All systems	50.1	46.4	-7
Gravity-flow systems	31.2	25.1	-20
Sprinkler systems	18.4	21.5	17
Center pivot	8.6	14.8	72
Mechanical move	5.1	3.7	-27
Hand move	3.7	1.9	-48
Solid set and permanent	1.0	1.0	2
Low-flow irrigation (drip/trickle)	.3	1.8	445
Subirrigation	.2	.4	49

Source: USDA, ERS, based on USDC, 1982 and 1996.

Table 4.6.3—Irrigation application systems, by type, 1994

System	Acres	Share of all systems
	Million	Percent
All systems	46.4	100
Gravity flow systems	25.1	54
Row/furrow application	14.2	31
Open ditches	5.0	11
Above-ground pipe	7.4	16
Underground pipe	1.8	4
Border/basin application	7.5	16
Open ditches	5.1	11
Above-ground pipe	.9	2
Underground pipe	1.5	3
Uncontrolled flooding application	2.3	5
Open ditches	2.3	5
Above-ground pipe	.0	0
Underground pipe	.0	0
Sprinkler systems	21.5	46
Center pivot	14.8	32
High pressure	3.2	7
Medium pressure	5.9	13
Low pressure	5.7	12
Mechanical move	3.7	8
Linear and wheel-move	3.0	7
All other	.6	1
Hand move	1.9	4
Solid set & permanent	1.0	2
Low-flow irrigation (drip/trickle)	1.8	4
Subirrigation	.4	1

Note: Percents may not sum to totals due to multiple systems on some irrigated acres and rounding.

Source: USDA, ERS, based on USDC, 1996.

leaching requirements. Furrow application systems comprise nearly 60 percent of all gravity-flow systems; border/basin and uncontrolled-flood application systems account for the remaining acreage (table 4.6.3).

Water losses are comparatively high under traditional gravity-flow systems due to percolation losses below the crop-root zone and water runoff at the end of the field. Field application efficiencies typically range from 40 to 65 percent, although improved systems with proper management may achieve efficiencies of up to 85 percent (Negri and Hanchar, 1989).

Various land treatment and management measures have been developed to reduce water losses under gravity-flow systems (table 4.6.1). Measures include improved onfarm water-conveyance systems, precision field leveling, shortened water runs, alternate furrow irrigation, surge flow and cablegation, and tailwater reuse.

Improved water-conveyance systems are an important potential source of farm-level water savings. System upgrades include ditchlining, ditch reorganization, and pipeline installation. According to the 1994 Farm and Ranch Irrigation Survey (FRIS), traditional open-ditch systems remain the principal means of onfarm water conveyance for gravity-flow systems, with almost 60 percent of gravity-acreage served (USDC, 1996). Above-ground pipelines—including gated pipe—accounted for a third of gravity-flow acreage served, with underground lines serving the remaining acreage.

Improvements in traditional gravity technology can increase the uniformity of applied water, while reducing percolation losses and minimizing water runoff. Gated-pipe systems are concentrated in the Northern and Southern Plains and Delta regions. Surge-flow and cablegation systems—designed to control water deliveries from gated pipe—are used on 5 percent of gravity-flow acreage, predominantly in

Gravity Irrigation Systems and Practices

Open-ditch conveyance systems have been the traditional means to supplying gravity irrigation systems. Open ditches may be earthen, although improved systems are typically lined with concrete or other less permeable materials to reduce seepage loss. Water is delivered to gravity-flow fields through siphon tubes, portals, or ditch gates.

Furrow systems, the dominant gravity application system, are distinguished by small, shallow channels used to guide water downslope across the field. Furrows are generally straight, although they may be curved to follow the land contour on steeply sloping fields. Row crops are typically grown on the ridge or bed between the furrows, spaced from 2 to 4 feet apart. Corrugations—or small, closely spaced furrows—may be used for close-growing field crops.

Border (or flood) application systems divide the field into strips, separated by parallel ridges. Water flows downslope as a sheet, guided by ridges 10 to 100 feet apart. On steeply sloping lands, ridges are more closely spaced and may be curved to follow the land contour. Border systems are suited to orchards and vineyards, and close-growing field crops such as alfalfa, pasture, and small grains.

Uncontrolled flooding is a gravity-flood system without constructed ridges, relying on natural slope to distribute water.

Improved System and Practices:

Pipeline conveyance systems are often installed to reduce labor and maintenance costs, as well as water losses to seepage, evaporation, spills, and noncrop vegetative consumption. ***Underground pipeline*** constructed of steel, plastic, or concrete is permanently installed; ***above-ground pipeline*** generally consists of lightweight, portable aluminum, plastic, or flexible rubber-based hose. One form of above-ground pipeline—***gated-pipe***—distributes water to gravity-flow systems from individual gates (valves) along the pipe.

Field leveling involves grading and earthmoving to eliminate variation in field gradient—smoothing the field surface and often reducing field slope. Field leveling helps to control water advance and improve uniformity of soil saturation under gravity-flow systems. Precision leveling is generally undertaken with a laser-guided system.

Level basin systems differ from traditional border application systems in that field slope is level and field ends are closed. Water is applied at high volumes to achieve an even, rapid ponding of the desired application depth within basins. Higher application efficiencies reflect uniform infiltration rates and elimination of surface runoff.

Shortened water runs reduce the length of furrow (or basin) to increase uniformity of applied water across the field. Reduced water runs are most effective on coarse soils with high soil-water infiltration rates. Water runs of one-half to one mile in length may be reduced to one-quarter mile or less (with reorganization of the onfarm conveyance system).

Surge flow is an adaptation of gated-pipe systems in which water is delivered to the furrow in timed releases. Initial water surges travel partway down the furrow, and all standing water is allowed to infiltrate. The wetted soil surface forms a water seal permitting successive surges to travel further down the furrow with less upslope deep percolation. This technique significantly reduces the time needed for water to be distributed the full length of the field, thereby increasing application efficiency.

Cablegation is a gated-pipe system in which a moveable plug passes slowly through a long section of gated pipe, with the rate of movement controlled by a cable and brake. Due to the oversizing and required slope of the pipe, water will gradually cease flowing into the first rows irrigated as the plug progresses down the pipe. Improved water management is achieved by varying the speed of the plug, which controls the timing of water flows into each furrow.

Alternate furrow irrigation involves wetting every second furrow only. This technique limits deep percolation losses by encouraging lateral moisture movement. Applied water and time required per irrigation may be significantly less than under full furrow systems, but more irrigations may be required to supply crop needs. This technique is very effective when the desired strategy is to irrigate to a “less than field capacity” level in order to more fully utilize rainfall.

Special furrows have been employed to enhance water management. ***Wide-spaced furrows*** function much like alternative furrow irrigation, except that every row is irrigated with rows spaced further apart. ***Compacted furrows*** involve packing the soil within the furrow to provide a smooth, firm surface to speed water advance. ***Furrow diking*** places dikes in the furrows to capture additional rainfall, eliminating runoff and reducing irrigation needs. Furrow diking on gravity-irrigated fields is typically used in combination with alternate furrow irrigation.

Tailwater reuse systems recover irrigation runoff in pits below the field and pump it to the head of the field for reuse.

Pressurized Irrigation Systems and Practices

Pipeline conveyance is most often used to deliver water to fields with pressurized systems. Water, once under pressure, requires a pipeline for conveyance. Pipelines may be above or below ground.

Center-pivot sprinklers are the dominant pressure technology. A center-pivot sprinkler is a self-propelled system in which a single pipeline supported by a row of mobile A-frame towers is suspended 6 to 12 feet above the field. Water is pumped into the pipe at the center of the field as towers rotate slowly around the pivot point, irrigating a large circular area. Sprinkler nozzles mounted on or suspended from the pipeline distribute water under pressure as the pipeline rotates. The nozzles are graduated small to large so that the faster moving outer circle receives the same amount of water as the slower moving inside. Typical center-pivot sprinklers are one-quarter mile long and irrigate 128- to 132-acre circular fields. Center pivots have proven to be very flexible and can accommodate a variety of crops, soils, and topography with minimal modification.

Hand move is a portable sprinkler system in which lightweight pipeline sections are moved manually for successive irrigation sets of 40 to 60 feet. Lateral pipelines are connected to a mainline, which may be portable or buried. Handmove systems are often used for small, irregular fields. Handmove systems are not suited to tall-growing field crops due to difficulty in repositioning laterals. Labor requirements are higher than for all other sprinklers.

Solid set refers to a stationary sprinkler system. Water-supply pipelines are generally fixed—usually below the soil surface—with sprinkler nozzles elevated above the surface. In some cases, handmove systems may be installed prior to the crop season and removed at or after harvest, effectively serving as solid set. Solid-set systems are commonly used in orchards and vineyards for frost protection and crop cooling, and are widely used in turf production and landscaping.

Big gun systems use a large sprinkler mounted on a wheeled cart or trailer, fed by a flexible hose. The sprinkler is usually self-propelled while applying water. The system may require successive moves to irrigate the field. Big guns require high operating pressures, with 100 psi not uncommon. These systems have been adapted to spread livestock waste in many locations.

Side-roll wheel-move systems have large-diameter wheels mounted on a pipeline, enabling the line to be rolled as a unit to successive positions across the field. A gasoline engine generally powers the system movement. This system is roughly analogous to a handmove system on wheels. Crop type is an important consideration for this system since the pipeline is roughly 3 feet above the ground.

Improved Systems and Practices:

Improved center pivots have been developed that reduce both water application losses and energy requirements. Older center pivots, with the sprinklers attached directly to the pipe, operate at relatively high pressure (60-80 psi), with wide water-spray patterns. Newer center pivots usually locate the sprinklers on tubes below the pipe and operate at lower pressures (15-45 psi). Many existing center pivots have been retrofitted with system innovations to reduce water losses and energy needs.

Linear or ***lateral-move*** systems are similar to center-pivot systems, except that the lateral line and towers move in a continuous straight path across a rectangular field. Water may be supplied by a flexible hose or pressurized from a concrete-lined ditch along the field edge.

LEPA (Low-energy precision application) is an adaptation of center pivot (or lateral-move) systems that uses droptubes extending down from the pipeline to apply water at low pressure below the plant canopy, usually only a few inches above the ground. Applying water close to the ground cuts water loss from evaporation and wind and increases application uniformity. On soils with slower infiltration rates, furrow dikes are often used to avoid runoff.

Low-flow irrigation systems include ***drip***/***trickle*** and ***micro-sprinkler*** systems. ***Drip and trickle*** systems use small-diameter tubes placed on or below the field's surface. Frequent, slow applications of water are applied to soil through small holes or emitters. The emitters are supplied by a network of main, submain, and lateral lines. Water is dispensed directly to the root zone, precluding runoff or deep percolation and minimizing evaporation.
Micro-sprinklers use a similar supply system, with low-volume sprinkler heads located about 1 foot above the ground. (Micro-sprinklers are used in place of multiple drip emitters when wetting a broader area or perimeter.) Low-flow systems are generally reserved for perennial crops, such as orchard products and vineyards, or high-valued vegetable crops.

the Plains States. Alternate furrow irrigation is practiced on over 20 percent of gravity-flow acres, with special furrows (widespaced, compacted, or diked) applied on more than 10 percent of acres. Roughly 5 percent of FRIS respondents indicated that water runs had been shortened to facilitate water management, primarily in the Southwest (Arizona, California) and Southern Plains. About 12 percent of all irrigated acres have been precision laser-leveled, predominantly on gravity-flow systems in the Southwest, Delta, and Southeast regions. High-efficiency level-basin systems are concentrated in the Southwest. Deficit irrigation techniques—such as reduced irrigation set-times, partial-field irrigation, and reduced irrigations—are practiced on roughly 10 percent of gravity-flow acres, with highest acreage concentrations in the Northwest (Washington, Oregon, Idaho). Tailwater reuse systems—which recirculate runoff water on the field—have been installed on over 20 percent of gravity-system acreage nationwide. Tailwater reuse systems are disbursed throughout the major gravity-irrigated States, with California leading both in total acreage (1.9 million) and share of gravity acres (38 percent) with tailwater systems.

Pressurized Systems. The decline in gravity-flow acreage has been accompanied by an increase in acreage under pressurized systems. Pressurized systems—including sprinkler and low-flow irrigation systems—use pressure to distribute water. With rare exceptions, the pressure to distribute water involves pumping, which requires energy. Acreage in pressurized systems expanded from 19 million acres (37 percent of total irrigated acreage) in 1979 to 23 million acres (50 percent) in 1994 (table 4.6.2).

Sprinkler systems—in which water is sprayed over the field surface, usually from above-ground piping—accounted for 46 percent of irrigated acreage in 1994 (table 4.6.3). Concentrations of sprinkler acreage are highest in the Northern Pacific, Northern Plains, and Northern Mountain States. Sprinkler systems are also used extensively for supplemental irrigation and specialty-crop irrigation in the humid eastern States.

Sprinkler irrigation has been adopted in many areas as a water-conserving alternative to gravity-flow systems. Field application efficiencies typically range from 60 to 85 percent under proper management (Negri and Hanchar, 1989). Sprinklers may be operated on moderately sloping or rolling terrain unsuited to gravity systems, and are well suited to coarser soils with higher water infiltration rates. Sprinkler design is important, and careful consideration of soil type, wetting area per spray nozzle, operating pressure, and the rate of sprinkler movement are required to avoid plant stress from too little water and excess runoff from too much water.

Capital costs for sprinkler systems are higher than for gravity-flow systems, although gravity-system installation often requires greater expenditures for land preparation. Operating costs for sprinkler systems are often higher than for gravity systems as they require more energy and more sophisticated technical and management capability. Labor costs are typically lower under sprinkler systems, particularly with self-propelled systems.

Sprinkler technologies include a wide range of adaptations, with significant shifts in technology shares in recent years. The development of self-propelled center-pivot systems in the 1960's greatly expanded the acreage suitable for irrigation, and accounted for much of the growth in acreage irrigated during the 1970's. Acres irrigated with center pivots increased by 6.2 million acres from 1979 to 1994, with about half of the increase attributable to net increases in irrigated area under sprinkler and about half from the net replacement of other sprinkler types with center pivot (table 4.6.2). Center-pivot systems accounted for nearly 70 percent of sprinkler acreage in 1994, or 32 percent of total irrigated acreage (table 4.6.3). Largest acreage concentrations under center-pivot are in the Northern Plains, Southern Plains, and Delta regions.

Sprinkler systems other than center pivot—including hand move, mechanical move, and solid set—made up about 31 percent of total sprinkler acreage in 1994, down from 53 percent in 1979. Acreage in handmove systems has declined by nearly one-half since 1979; mechanical-move systems have declined by more than 25 percent (table 4.6.2).

Center-pivot technology serves as the foundation for many technological innovations—such as low-pressure center pivot, linear-move, and low-energy precision application (LEPA) systems—which combine high application efficiencies with reduced energy and labor requirements. Approximately 40 percent of center pivot acres in 1994 were operated under low pressure (below 30 pounds per square inch (psi)), with just 22 percent operating at high pressure (above 60 psi). (Forty-two percent of center pivot acres were high-pressure systems as recently as 1988.) Adoption of low-pressure systems has been particularly strong in the Southern Plains, reflecting higher-cost groundwater pumping in much of the region. Current advances in sprinkler technology focus on location of spray heads and low-pressure sprinklers and nozzles; the trend is toward energy- and water-conserving nozzles located closer to the soil. In addition, advances are being made in remote control of sprinklers and individual nozzle control for precision agriculture.

Low-flow irrigation systems are a form of pressurized system in which water is applied in small, controlled quantities near or below ground level. Low-flow irrigation systems—including drip, trickle, and micro-sprinklers—comprise 4 percent of irrigated cropland acreage (table 4.6.3), up more than four-fold since 1979 (table 4.6.2). Low-flow systems are most commonly used for production of vegetables and perennial crops such as orchards and vineyards, although experimentation and limited commercial applications are occurring with certain row and field crops. Low-flow irrigation systems are located primarily in California and Florida, reflecting large acreages in specialty produce and orchard production.

Field application efficiency of 95 percent or greater can be achieved under low-flow systems, although proper design is required to avoid moisture stress and soil-salinity accumulation. High capital costs and short lifespan of components characterize most systems. Filtration of the water supply and careful system maintenance may be required to prevent clogging of small orifices. Advances in low-flow technology focus on field depth and spacing of tubing, emitter spacing, durability of materials, and reduced costs.

Water Management Practices

Determining when and how much irrigation water to apply is an important part of the irrigation management process. Well-informed decisions increase the likelihood that water is applied according to crop needs, with minimal water loss. Improved management practices are often more cost-effective than structural improvements, although structural upgrades may be required to achieve highest management potential.

Irrigation scheduling involves the application of irrigation water based on a systematic monitoring of crop soil-moisture requirements. Sophisticated scheduling methods—based on sensors, microprocessors, and computer-aided decision tools—may be used to determine the optimal timing and depth of irrigation to meet changing crop needs over the production season.

Various methods are available to assess crop water needs. Crop water requirements can be indirectly estimated through climate variables. Local weather-station data—including temperature, humidity, wind speed, and solar radiation—are applied in formulas to calculate crop water needs for a wide range of crops and locales. Soil moisture available for plant growth may also be measured directly through periodic soil testing. Soil probes are used to obtain soil samples at various depths for “feel and visual” evaluation. More sophisticated devices—such as tensiometers, neutron probes, and various electrical conductivity devices—can be used to accurately quantify the amount of water removed from the soil profile. Finally, plant moisture monitors may be used to detect crop water availability and stress in plant tissue.

In separate Farm and Ranch Surveys for years 1984 and 1994, irrigators were asked to indicate all methods used in deciding when to irrigate (USDC, 1986 and 1996). Survey results suggest that a slightly larger share of irrigators are using advanced, information-intensive methods to schedule irrigation, but that current levels indicate potential for much improvement. In the 1994 FRIS, 10 percent of irrigators used soil moisture-sensing devices (up from 8 percent in 1984), 5 percent used commercial scheduling (up from 3 percent), 4 percent used media reports on plant water requirements (down 1 percent), and 2 percent used computer simulations (not asked in 1984).

Water flow measurement is an important component of water management at the farm level. Measurement of water flows through the onfarm conveyance system ensures optimal water deliveries to the field, as determined by irrigation scheduling methods. Measuring devices—often installed in conjunction with conveyance system upgrades—include weirs, flumes, and in-canal flow meters for open ditches, and external and internal meters for pipe.

Irrigation Drainage Systems

The collection and disposal of drainage flows from irrigation and precipitation is an important management consideration in many irrigated areas. Irrigation drainage includes surface runoff and deep percolation from water applied to meet crop consumptive needs. In some areas, periodic flooding of fields may also be required to leach soil salts from the crop root zone, often increasing the need for drainage systems.

Irrigation drainage is often collected and reused in irrigated production. Tailwater systems recover drainage flows below the field (or in low-lying areas of the farm), recirculating the water to the top of the field for reuse. Drainage flows may also be used as irrigation supplies downslope, both onfarm and off-farm. In some cases, drainage systems may be used to drain excess water during wet periods as well as "subirrigate" during dry periods by regulating underlying water tables. In many cases, drainage flows of poor quality become a disposal issue. Primary disposal methods include onfarm evaporation ponds, direct discharge to off-farm surface water bodies through drainage canals, and reuse in salt-tolerant crop and tree production.

Other Practices Affecting Irrigation

Other practices—while not water-management practices *per se*—can be important components of an irrigated farming system. Such practices, in combination with improved irrigation systems, may enhance returns to irrigated production while reducing offsite environmental impacts.

Nutrient and Pest Management. Irrigation affects the optimal timing and application rate of chemical applications for nutrient and pest management. Fertilizer use is typically greater for high-valued, high-yielding irrigated production. Weed and pest conditions may also increase under irrigated field conditions, necessitating increased use of pesticides, herbicides, and fungicides. Careful nutrient and pest management increases the effectiveness of water and applied chemicals, while reducing offsite impacts.

Chemigation—or the application of fertilizers, pesticides, and other chemicals through irrigation water—permits controlled applications when used in conjunction with highly efficient irrigation systems. Chemigation can reduce the costs of applying chemicals, while avoiding equipment use and soil compaction. Chemigation is used on all major crops, with the largest treated acreages in orchard crops, hay, and corn—and the greatest concentration of use in potato, rice, and sugarbeet production (USDC, 1996).

Erosion Control. Soil erosion can be a serious problem for less efficient irrigation systems on sloping fields. Soil erosion creates barriers to even water flow in furrows, reduces long-term field productivity, and contributes to offsite water-quality problems. Irrigation-induced erosion is particularly severe in areas of the Northern Pacific, Southern Pacific, and Mountain regions (USDA, 1992).

Measures to improve uniformity of applied irrigation water can help control soil loss. Gravity-flow systems may be modified to reduce flow velocity or field slope in accordance with soil-water infiltration rates. Soil erosion may also be a problem with sprinkler systems, particular on steeply sloping fields and under outer spans of center-pivot systems where water application rates are higher. System adjustments to reduce erosion include reduced water applications per irrigation set, larger pattern sprinkler heads, and booms to increase sprinkler head spacing.

Other practices may also limit soil erosion on irrigated fields. Crop residue management to maintain vegetative material on the soil surface increases infiltration while protecting the soil from erosive water flow. In some cases, deep tillage can reduce runoff through increased infiltration. Land treatment measures may be installed to slow runoff and trap sediment on the farm. These include furrow dikes in the field, vegetative filter strips below the field, mini-basins in tailwater ditches, larger sediment ponds constructed in drainage ditches, and tailwater reuse systems.

A promising new soil amendment—Polyacrylamide, more commonly known as PAM—may be added to irrigation water to stabilize soil and water-borne sediment. Under experimental field-trial conditions, proper application of PAM with the first irrigation has substantially reduced soil erosion in furrow systems. Potential benefits include reduced topsoil loss, enhanced water infiltration, improved uptake of nutrients and pesticides, reduced furrow-reshaping operations, and reduced sediment-control requirements below the field. An estimated 50,000 irrigated acres were treated with PAM after just 1 year on the market, including 30,000 acres in the Pacific Northwest. Research is underway to determine the best PAM formulations and application techniques (Sojka and Lentz, 1996).

Irrigation Technology and Environmental Benefits

Adoption of improved irrigation technology has been advanced as a means to reduce offsite water quantity and quality problems. The effectiveness of technology in achieving environmental goals has important implications for regional water policy.

Water Conservation

Improved irrigation and conveyance technologies may substantially increase onfarm water-use efficiency. Whether technology adoption can achieve significant

Table 4.6.4—Irrigation water conservation for alternative crop-water consumptive requirements and field application efficiencies

Hypothetical crop	Consumptive water use	Application efficiency	Irrigation water applied	Application losses
	Inches	*Percent*	*Inches*	
Low water need	12	40	30	18
	12	60	20	8
	12	80	15	3
	12	100	12	0
High water need	24	40	60	36
	24	60	40	16
	24	80	30	6
	24	100	24	0

Source: USDA, ERS.

water savings for nonfarm and instream uses, however, will depend on many factors.

In general, a given percentage increase in field application efficiency will yield a less-than-proportional reduction in applied water. For example, a 50-percent increase in field application efficiency—from 40 percent to 60 percent—may reduce applied water by one-third (table 4.6.4). Actual quantities of water savings depend in part on the crop irrigated; the more water a crop requires, the greater the potential water savings through improved water management. Water savings also reflect the initial condition of the irrigation system.

Improvements in inefficient systems may result in substantial water savings, often at relatively low cost. Under more efficient systems, a comparable increase in efficiency results in lower water savings at a higher cost. For example, an increase from 40 to 60 percent in field application efficiency will yield greater water savings than an increase from 60 to 80 percent for the same crop (table 4.6.4). The increase from 40 to 60 percent can generally be achieved at lower cost through less expensive system modifications and management adjustments. As the target field application efficiency increases, there are fewer, more expensive technologies and management practices available to achieve the additional water savings.

Water withdrawn for irrigation purposes is either consumed in a beneficial or nonbeneficial use, or accounted for as nonconsumptive use—evaporation, field runoff, and deep percolation. Of the possible dispositions of irrigation withdrawals shown in table 4.6.5, water consumptively used to grow crops is represented by cell 1. Leaching applications for soil salinity control (cells 3, 5) represent a nonconsumptive, beneficial use. Irrigation efficiency at the field level reflects the share of applied water (cells 1 through 6) attributed to beneficial uses (cells 1, 3, 5). Historically, measures to increase irrigation efficiency have focused on reducing nonbeneficial irrigation-system losses (cells 2, 4, 6), without adequately considering the effect on drainage return flows and consumptive use.

Improved irrigation efficiency reduces nonbeneficial water losses (cells 2, 4, 6), which may be either reusable or nonreusable. Reductions in nonreusable field loss (cells 2, 4) under improved systems

Table 4.6.5—Use and disposition of irrigation withdrawals

	Consumptive use	Nonconsumptive use	
	Nonreusable	Nonreusable portion	Reusable portion
Beneficial uses	Cell #1: Crop evapotranspiration	Cell #3: Nonreusable deep percolation for salt leaching due to quality impairment	Cell #5: Reusable deep percolation for salt leaching
Nonbeneficial uses	Cell #2: Noncrop evapotranspiration and evaporation from sprinklers, open water, and excess wet soil area	Cell #4: Nonreusable runoff and excess deep percolation due to quality impairment	Cell #6: Reusable runoff and excess deep percolation

Source: USDA, ERS, based on Allen and others, 1996.

contribute directly to reduced water demand. However, reductions in reusable field loss (cell 6) may not translate into water savings. Reusable field loss—including surface-water return flow and aquifer recharge—represents an important water source for downstream withdrawals and environmental purposes in many locations. The portion of applied irrigation water that re-enters the hydrologic system as downstream water supply varies greatly depending on physical, hydrologic, and topographic factors. Further, reusable supply does not necessarily imply the water is immediately available. Runoff and subsurface flows may be discharged downstream of the need area while temporal lags in transporting runoff and recharge to useable water sources may be measured in months, years, or decades.

Efforts to increase irrigation efficiency can *directly* affect crop consumptive use (cell 1) in two ways. First, the greater uniformity of applied water associated with many improved technologies may result in higher crop yields, with resulting increases in consumptive water requirements. That is, the water "saved" through improved efficiency is used to augment crop yield on the same field. Second, if consumptive water use (and crop yield) per acre remains constant, water "saved" through improved efficiency may be used on other irrigated lands—both onfarm and across farms—subject to conveyance and legal restrictions. Improved irrigation efficiency can also affect consumptive use *indirectly* by altering land and water opportunity values across crops. Changes in relative values may prompt substitution among land, water, management, and other inputs; resultant changes in cropping patterns and onfarm water use can involve substantial shifts in water applied at the regional level.

While opportunities exist to increase water-use efficiency in irrigated agriculture, the quantity of "new" water acquired through reduced irrigation losses will depend on various factors. The effectiveness of onfarm improvements in augmenting water flows for instream and nonfarm uses may be limited by increased consumptive water use from expanded onfarm production, reduced irrigation return flows to surface-water systems, and limits on efficiency gains due to widespread irrigation improvements already in place. In addition, the availability and use of conserved water offsite depends on the physical storage and delivery system, the structure of water rights, and the availability of water to satisfy all claims. Where "saved" flows are available as increased non-reserved flows, and junior water-right holders receive only partial entitlements, water conserved upstream may be claimed by downstream irrigation interests. Unintended environmental impacts that can accompany improved efficiencies—such as reductions in downstream wetland habitat, reduced groundwater recharge, and modified stream return-flow—may be a concern in some areas.

Conservation efforts based on improved irrigation efficiency alone may need to be broadened to meet emerging water demands. Net water savings at the sub-basin level may require reductions in both consumptive use and nonreusable, nonconsumptive losses (shaded area of table 4.6.5, cells 1 through 4). Policies to reduce water demand may need to target reductions in crop consumptive use—through improved crop varieties, crop substitution, deficit irrigation, and acreage reductions. Assessment of nonreusable drainage loss and nonbeneficial consumptive use is site-specific and often difficult to quantify, but may be an important source of water savings in some areas. In addition, the reusable portion of irrigation applications (cells 5 and 6) should also be examined for conservation potential, recognizing spatial and temporal effects on surface and subsurface drainage flows. If the policy goal is to provide water for downstream urban and environmental uses, an effective conservation program may require reform of water rights and regulations to ensure allocation of conserved water for the desired purpose.

Various ERS-supported research has examined the effects of irrigation water policy on water use and conservation. Significant water savings are more likely to be observed at the extensive margin—through changes in irrigated land base and acreage by crop—rather than through adjustments in per-acre water applications (Moore and others, 1994). While limited water savings can often be achieved through lower-cost efficiency gains, more significant water savings generally require reductions in consumptive use—with implications for producer profit (Bernardo and Whittlesey, 1989). In addition, substitutions among crops and inputs can result in significant regional water savings (Schaible and others, 1995; Moore and others, 1994; Bernardo and Whittlesey, 1989). Schaible and others (1995) found that improvements in onfarm water-use efficiency increased the level of regional water savings attributable to crop substitution. A mix of conservation policies may help to distribute the costs of water conservation across water users and regions (Schaible and others, 1995).

Water Quality

Several ERS studies have addressed the effect of water-conserving technology on water quality. Findings suggest that onfarm technologies can have important water-quality impacts, although benefits are sensitive to the type of practice and the attributes and uses of collecting water bodies.

Research findings on nitrate contamination of ground water in eastern Oregon (Kim and others, 1994) and south-central Nebraska (Magleby and others, 1995) indicate the beneficial effect of technology adoption on water quality. However, the ability to affect water quality through improved irrigation technology depends, in part, on underlying aquifer conditions, including the depth to water table and rates of groundwater flows.

Research findings on sediment control in south-central Idaho (Magleby and others, 1989) suggest that irrigation practices can help to reduce sediment loadings in collecting streams. Environmental benefits may vary significantly across irrigation investment categories, however, with highest potential returns to non-structural water management practices. The effectiveness of improved irrigation practices in achieving water-quality benefits may be enhanced when implemented in combination with other conservation practices, such as conservation tillage and filter strips.

Polices to improve water quality may need to target both high-priority areas and cost-effective conservation practices in a whole-farm context. In many cases, improved water quality can be an important joint product with water conservation. Together, the combined benefits of increased onfarm efficiency may justify improved technologies, and may help to speed adoption at a rate greater than water savings alone can justify.

Factors Affecting Technology Adoption

The choice of irrigation technology is highly site-specific, reflecting locational, technical, and market factors. Field characteristics—such as field size and shape, field gradient, and soil type—are perhaps the most important physical considerations in selecting an irrigation system. Other important factors include technology cost (useful life, financing options); water supply characteristics (cost, quality, reliability, flow rate); crop characteristics (spacing, height); climate (precipitation, temperature, wind velocity); market factors (crop prices; energy cost, labor supply); producer characteristics (farming traditions, management expertise, risk aversion, tenant/owner status, commitment to farming); and regulatory provisions (groundwater pumping restrictions, drainage discharge limits, water transfer provisions). In many cases, current technology choice is limited by fixed investments in existing systems at the site.

The 1994 FRIS reports that 38 percent of farms made system improvements from 1990 to 1994, while no improvements were reported on 56 percent of farms. Those farms reporting improvements tended to be larger, accounting for 58 percent of the irrigated acres. Potential benefits of improved irrigation reflect, in part, the rate of technology adoption. FRIS collected information on several key factors affecting technology adoption, including capital requirements, technology information, water-pricing policy, and water-supply considerations.

Capital Requirements

Improvements in irrigation systems are often highly capital-intensive. FRIS reports that investment in onfarm irrigation equipment, facilities, and land improvements totaled $800 million in 1994, or nearly $10,000 per farm reporting expenditures (USDC, 1996). Capital expenditures included $573 million for irrigation equipment and machinery, $92 million for construction and deepening of wells, $82 million for permanent storage and distribution systems, and $51 million for land clearing and leveling. Replacement of existing systems accounted for the largest share of irrigation capital expenditures (64 percent), followed by irrigation expansion (19 percent) and conservation improvements (17 percent).

While improved irrigation technologies are often economically profitable in a long-run farm plan, high capital outlays may limit their adoption. FRIS reports that nearly 30 percent of respondents indicated that installation of improved practices was either too expensive or could not be financed (USDC, 1996). Smaller farms were less likely to invest in improvements, reflecting more limited financial resources and difficulties in adapting some types of improved systems to smaller fields.

Technology Information

Lack of information on the availability, use, and profitability of improved irrigation technologies may limit adoption rates. Improved technologies are less familiar and often more sophisticated than traditional practices, requiring additional technical and management expertise. In some cases, improved irrigation systems may necessitate changes in current farming practices and equipment complements. For many producers, the benefits of new technologies are uncertain. Of farmers reporting no system improvements over 1990-94, 74 percent were unaware of improvements that “fit” their operation (explained in part by insufficient information), while 20 percent indicated heightened production risk as a contributing factor (USDC, 1996).

Water Cost

Limited cost savings for water conservation reduce incentives to adopt improved irrigation practices. Limited cost-savings reflect low purchased-water prices and, in some cases, low energy expenditures for pumping and pressurization. In some cases, the cost of irrigation water is substantially less than both the value of water to producers and the opportunity costs of water in nonfarm uses. (For more discussion of water sources and cost, see chapter 2.1, *Water Use and Pricing.*)

Prices paid for off-farm surface-water supplies averaged $16 per acre-foot, or $36/acre, in 1994 (USDC, 1996). Surface-water prices are generally based on operation and maintenance costs of the delivery system. Deliveries are often charged on a fixed rate per irrigated acre, and are not necessarily adjusted for reduced water demand with improved management. Groundwater costs are generally limited to the cost of access—variable and fixed cost of pumping—and vary greatly depending on well yield, pumplift, power source, and other factors. In areas with significant groundwater pumplifts or high-cost surface water, water cost is an incentive to adopt conserving technologies.

According to the 1994 FRIS, irrigators recognize the benefits of conservation since only 6 percent of survey respondents reported that water-conserving practices have no economic benefit. Adoption incentives are greatest for producers relying on high-cost water supplies; producers using low-cost ground- and surface-water are less apt to invest in improved technologies (Caswell and Zilberman, 1985; Negri and Brooks, 1990).

Water Supply

The off-farm water storage and delivery system may limit improvements in irrigation management at the farm-level. High onfarm water-use efficiency depends on adequate and timely supplies of water. This requires a flexible surface-water system with sufficient off-farm storage and conveyance capacity, and effective control facilities and operating policies. Many older conveyance systems cannot be adapted to delivering water on demand without capital improvements. Limited off-farm water storage may further restrict water deliveries. Coordination is needed between the off-farm conveyance system and onfarm irrigation system to ensure compatible design and water-scheduling procedures.

Uncertainty of water supplies is an additional limiting factor. Surface-water supplies for junior water-right holders often vary significantly with water storage conditions and other factors. Producers may apply excessive water during peak-flow periods in an attempt to buffer the effects of potential late-season shortages. Variable water supplies may also restrict investment in more efficient structural system improvements, while favoring the use of portable systems and development of supplemental groundwater supplies. Risk of loss of future water rights further limits incentives to invest in water-conserving technologies. Of those irrigators responding to the question on barriers to adoption, almost 20 percent indicated that future water rights was a critical concern (USDC, 1996). Not surprisingly, the greatest concentration of farmers with this concern are in States with growing urban and environmental demands—California, Idaho, Texas, Nebraska, Colorado, Oregon, Washington, Utah, and Florida.

Policies and Programs Promoting Improved Irrigation Water Management

Policies and programs to promote improved water management in irrigated agriculture include direct public incentive programs, such as cost-sharing and technical assistance for water-conserving practices, and various institutional reforms that increase producer incentives to adopt conserving practices.

Public Incentive Programs

In some cases, an improved practice may not be readily adopted at the farm level, although its use could result in substantial offsite economic and environmental benefits. Public investment in onfarm cost-sharing and technical assistance may be justified where market incentives alone are insufficient to achieve desired rates of technology adoption.

Onfarm Cost-Sharing. With the signing of the Federal Agricultural Improvement and Reform Act of 1996, USDA cost-sharing enters a new era. Under the new legislation, the Environmental Quality Incentives Program (EQIP) was established to provide technical and financial assistance to farmers and ranchers for improved irrigation management, as well as improvements in cropping and grazing systems; wildlife habitat; sediment control; and manure, nutrient, and pest management. EQIP replaces most previous USDA programs providing financial assistance for IWM, including the Agricultural Conservation Program, the Water Quality Incentives Program, the Colorado River Basin Salinity Control Program, and the Great Plains Conservation Program.

Under EQIP, cost-share and incentive payments are available for a range of eligible structural and management practices. Payments are based on a targeting process, subject to payment limitations by individual and practice. Funds are to be allocated based on several criteria, including (1) significance of the resource problem in the area, (2) environmental benefits per dollar expended, (3) State or local contributions toward treatment costs, and (4) the effectiveness in meeting water-quality standards or other environmental objectives under Federal or State law. EQIP was authorized at $130 million in fiscal year 1996 and $200 million annually for fiscal years 1997-2002, with half of the funding dedicated to livestock production practices.

Limited cost-sharing for water conservation measures is also provided through the Bureau of Reclamation, U.S. Department of Interior. Under provisions of the 1992 Central Valley Project Improvement Act (CVPIA; P.L. 102-575), the Bureau of Reclamation is authorized to provide cost-sharing to irrigators supplied by the federally financed Central Valley Project (CVP) in central California. The Bureau may fund up to 100 percent of the cost of water-conserving measures. In return, the Federal Government receives a proportionate share of water conserved—equal to its financial contribution—to be used to meet Federal obligations for restoration of fish and wildlife habitat in the Central Valley region.

State and local governments may also provide financial support for water conservation. Various States—including Arizona, Colorado, Kansas, Montana, Texas, Utah, and Washington—offer grants for water conserving practices. Kansas, for example, has recently initiated cost-sharing for irrigation improvements designed to slow the decline in groundwater reserves. Many States provide low-interest loans or tax credits specifically for water-conserving equipment.

Technical Assistance. Technical assistance for selection, design, and operation of improved irrigation technologies is available through various public agencies and institutions. The USDA Natural Resources Conservation Service (NRCS) provides technical assistance under its conservation operations program and the EQIP program through local conservation districts. The Bureau of Reclamation also provides technical assistance to western irrigators receiving Federal project water. At the State level, technical assistance is available through irrigation and farm management specialists associated with the Cooperative Extension Service and land-grant institutions. Private irrigation consultants, irrigation districts, and irrigation equipment dealers are also important sources of water management information.

FRIS reports that the most commonly used sources of water-management information are extension agents or university specialists, 44 percent of farms; neighboring farmers, 44 percent; irrigation equipment dealers, 37 percent; and irrigation specialists from NRCS and other Federal agencies, 26 percent. Media reports, water suppliers, private consultants, and other sources each serve less than 20 percent of farms (USDC, 1996). Larger farms tend to rely on multiple sources, with greater emphasis on private consultants, irrigation specialists from universities and government agencies, and irrigation equipment dealers. In general, most producers rely on more than one information source for guidance in irrigation decisions.

Water Policy Reform

Water policy adjustments at the State and Federal level have encouraged improved water management in irrigated agriculture. However, the type and magnitude of adjustments vary widely across States, and Federal reforms have generally not been comprehensive.

Water Pricing. Changes in Federal water prices involving higher rates, per unit-water charges, and block-rate pricing may help to induce adoption of water-conserving technologies. However, pricing reform alone is not likely to prompt the level of overall water conservation desired on federally financed projects. Moore and Dinar (1995) conclude that irrigators supplied by federal water projects in southern California view water as a quantity-rationed input; while price adjustments have distributional impacts, water use is not likely to be significantly affected by small price increases under the current institutional system. Studies have suggested that irrigation water in general has a low price elasticity of demand, implying that prices would have to increase significantly in order to conserve meaningful quantities of water (Moore and others, 1994; Negri and Brooks, 1990; Caswell and Zilberman, 1985). Substitution of groundwater supplies, where physically available and economically viable, may further limit the effect of public water-pricing policy on investment in conserving technologies. Water-pricing policies may be more effective when implemented in conjunction with other determinants of technology choice and crop production.

Water Transfers. Market provisions for the sale of water rights or temporary lease of water would encourage the conservation of agricultural water by providing farmers compensation for unused water entitlements. However, legal and institutional barriers at the Federal, State and local levels have restricted widespread development of operational markets for water. For most Federal water projects, changes in water deliveries are subject to administrative review, and water is generally not transferred beyond the project service area. Further, laws governing water use and transfer are vested with the individual State. In most States, irrigators do not retain rights to water conserved through improved irrigation efficiency. Thus, water “saved” is not available for transfer and is most often used on the farm for higher yields or irrigation expansion. Meanwhile, political concerns have focused on downstream impacts and secondary effects of reduced agricultural activity on local communities.

In recent years, barriers to water marketing have been reduced in some locations. Statutory changes at the State level have increasingly recognized both the need to transfer water to meet new demands, and rights to water “salvaged” through conservation. Recent reform of water transfer policies under the CVPIA may suggest a relaxing of constraints on transfers involving Federal water supplies.

Water Conservation Programs. The Federal Government requires development of irrigation conservation plans—specifying improved irrigation management systems and practices—under certain conditions. USDA conservation plans must be in place for farms with highly erodible soils to qualify for program funding. An approved plan is also required for farmers receiving cost-share and incentive payments under EQIP. In addition, access to publicly financed water supplies is increasingly tied to improved water management. Water districts receiving Federal water through the Bureau of Reclamation are required to develop water conservation plans, including explicit contractual language on goals, implementation measures, and timetables in some cases.

States are assuming an increasing role in irrigation water conservation, although legal authorities and program activities vary widely. Many States, mostly in the West, have established water conservation programs. States may require local water conservation plans, and several have established local management areas in critical water resource areas. State-level activities include conservation planning, water-use permitting with conservation provisions, program monitoring and evaluation, financial support for conservation practices, and technical assistance.

Water policy reform—involving water pricing, transfer provisions, and conservation programs—provides increased incentives for improved management of water supplies at the farm level. Meanwhile, opportunities for improved water management have expanded with advances in irrigation equipment and practices, lower cost of many technologies, and expanded information resources. As regional water-supply pressures intensify, agriculture will rely increasingly on improved water management to sustain productivity and increase the economic value of irrigation water.

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5.1 Agricultural Technology Development

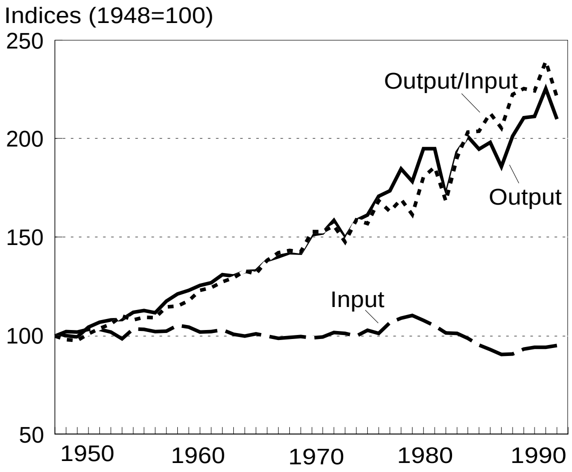
Research and technology development have been the foundation of impressive productivity gains in the agricultural sector. The ability of the sector to conserve natural resources and protect the environment depends, in part, on the technologies used. Agricultural research is the source of new technologies, and important new technologies have emerged that may benefit the environment if adopted. Many factors— including public policies, profitability, and agronomic factors—affect technology development, adoption, and diffusion.

Contents

Research and technology development have been the foundation for productivity gains in the agricultural sector, averaging 1.8 percent per year during 1948-93 (see box, “Agricultural Productivity,” p. 224, and fig. 5.1.1). Growing concerns for the environment have expanded the priorities for U.S. agriculture. Many technologies being developed have the potential not only to increase farm productivity but also to reduce the environmental and resource costs sometimes associated with agricultural production. These include technologies that conserve land and water by increasing yields with the same or fewer inputs and technologies that protect environmental quality, such as pest- and disease-resistant crops that require fewer chemicals.

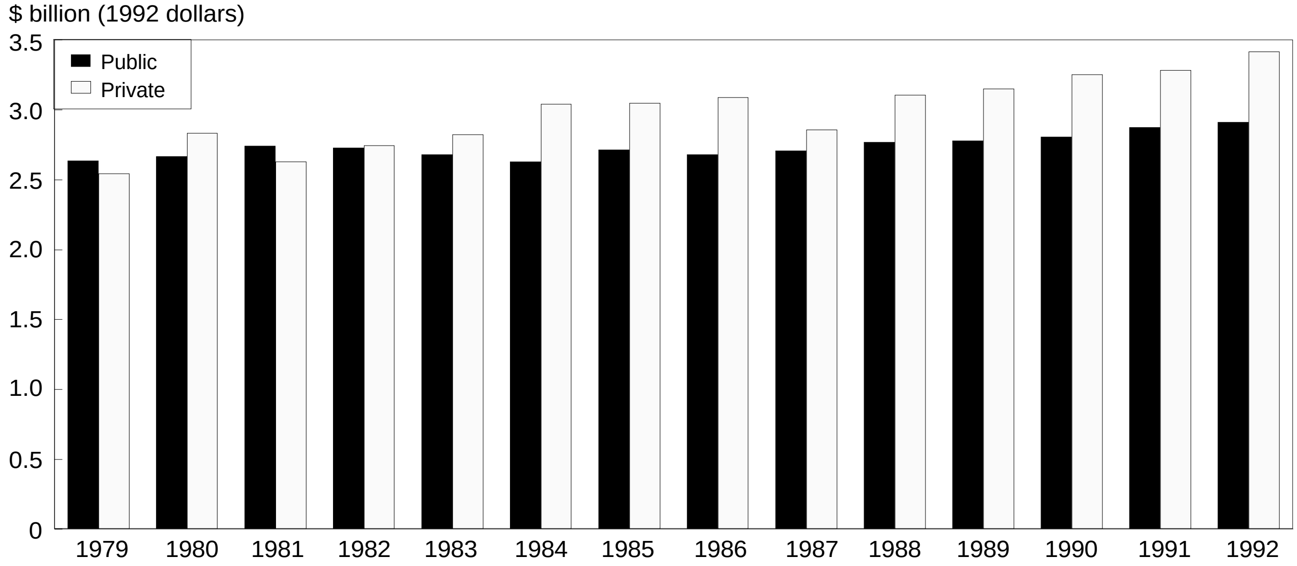
Two forces guide technological development. The first is “demand-pull,” where the needs of the marketplace create the demand for a product. Both public and private-sector scientists, inventors, and entrepreneurs often seek to meet this demand. The second force is “supply-push.” Here the impetus for development comes from scientists and inventors who find a new and valuable technology. This technology can then be introduced into the marketplace. Both forces (singly and together) produce important and

Figure 5.1.1--Productivity growth in U.S. agriculture, 1948-93



Source: USDA, ERS estimates.

Figure 5.1.2--Agricultural research funding, 1979-92



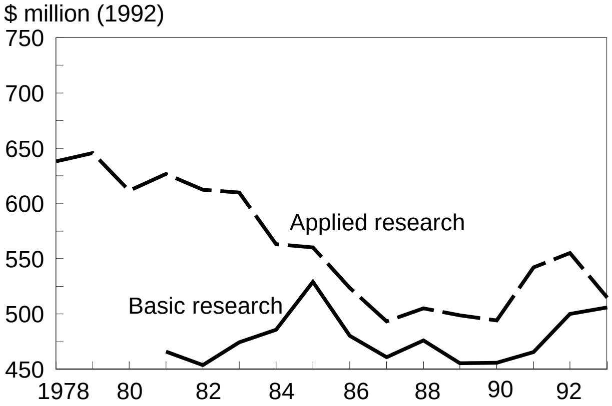
Source: USDA, ERS, based on Current Research Information System; and Klotz, Fuglie, and Pray,1995.

useful technologies, and the government can use both to encourage innovations that foster environmental quality and resource conservation. Policies such as environmental regulation can boost the demand-pull forces for environmentally benign technologies. Other government policies can foster supply-push forces for the desirable technologies. These policies include funding research and development, technology transfer activities, and efforts to understand and facilitate technology adoption.

The two major players in the agricultural research and technology development system are the public sector and private industry. After World War II, the public sector was the primary supporter and conductor of agricultural research. In recent years, the private sector has become a major contributor to the development of new agricultural technologies. Private-sector spending for food and agricultural research now exceeds agricultural research expenditures by the public sector (Fuglie and others, 1996; Huffman and Evenson, 1993; Klotz and others, 1995; and Pray, 1993). Private-sector agricultural research expenditures are estimated to have increased from $2.5 billion in 1979 to $3.4 billion in 1992 (fig. 5.1.2) (Klotz and others, 1995). Public-sector expenditures were $2.9 billion in 1992 (Fuglie and others, 1996).

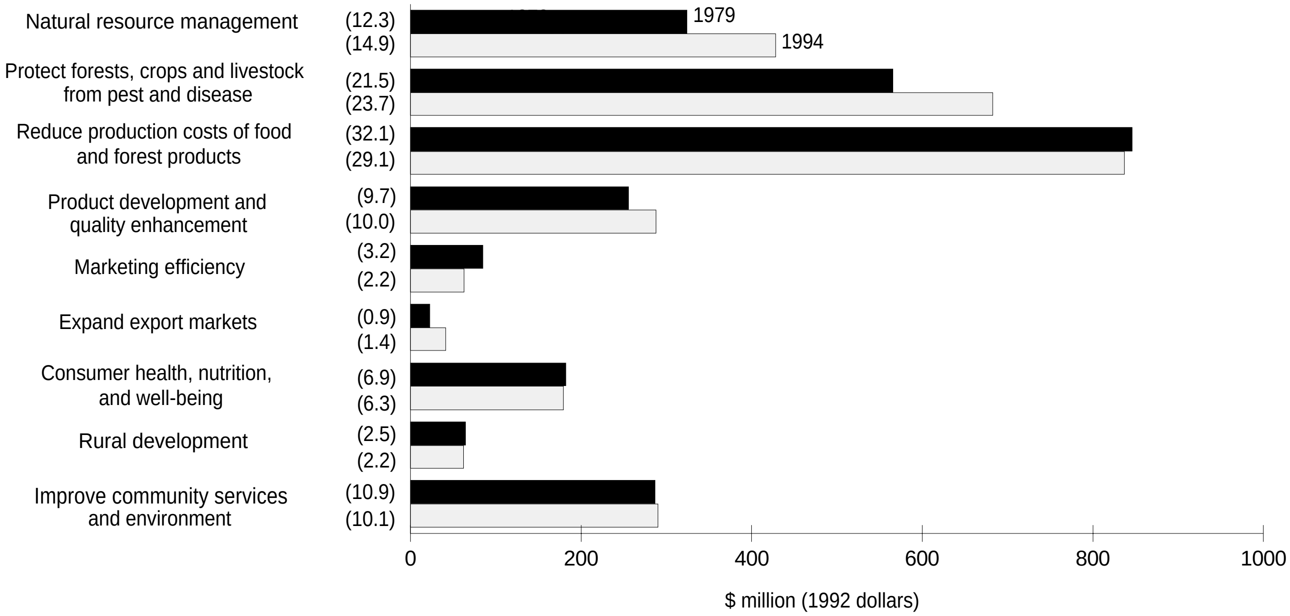
Public-sector and private-industry research differ in their focus. Public scientists conduct more basic or fundamental research, which seeks a fuller understanding of phenomena without specific applications to products or processes. Basic research is the foundation for all other research efforts and outcomes. Approximately 47 percent of public research funds are allocated to basic research efforts (fig. 5.1.3), which has higher rates of return than applied research. While the payoff to society of investing in basic research is high, the results of such research generally cannot be appropriated. The gains benefit society as whole, therefore the private sector has little market incentive to conduct basic or pre-technology research. Only 15 percent of

Figure 5.1.3--USDA expenditures for basic and applied research, 1978-93



Estimated for 1992, and proposed for 1993.
Source: USDA, ERS, based on National Science Foundation, 1992.

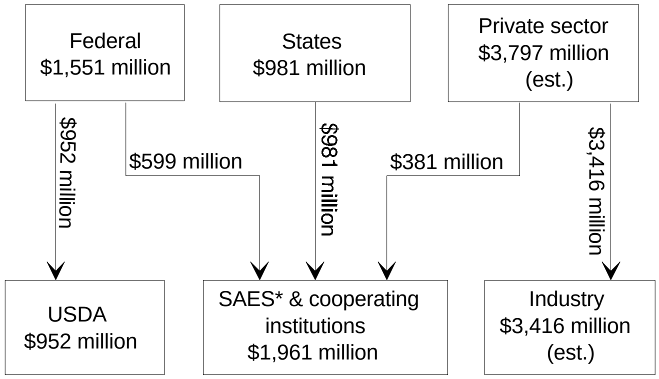
Figure 5.1.4--Allocation of public funds for agricultural research, 1979 and 1994



Numbers in parentheses indicate each item's percentage of public funds for agricultural research that year.
Source: USDA, ERS, based on USDA, Current Research Information System data, 1979-95.

private-sector funds are used in basic research (USDA, 1993; Agricultural Research Institute, 1985). Likewise, there is limited incentive for private-sector research that improves government or consumer decisionmaking as regards, say, the relationship of agriculture to natural resources, global climate change, ecosystem loss, human nutrition and diet, and food safety (for the distribution of public-sector research, see fig. 5.1.4). Private research focuses on bringing products to market, and generally must contribute to the overall profitability of the firm. More than 40 percent of private agricultural R&D expenditures are for product development research. In contrast, less than 10 percent of public agricultural R&D expenditures are applied to product development research. Therefore, a combination of public-sector and private-sector research is important in developing new agricultural technologies.

Figure 5.1.5--Sources and flows of funding for agricultural research in 1992



*SAES are the State Agricultural Experiment Stations; Cooperating institutions include the 1890, forestry, and veterinary schools

Sources: USDA, ERS, based on USDA, Current Research Information System, 1979-95. Private sector/industry expenditures are from Klotz, Fuglie, and Pray, 1995.

Public Sector Research and Development

Public agricultural research involves a unique partnership between the Federal Government (chiefly USDA) and the States. USDA and the State Agricultural Experiment Stations (SAES) together conduct almost $3 billion of research (Fuglie and others, 1996). USDA conducts about $950 million worth of research in-house through its research agencies, primarily the Agricultural Research Service, the Forest Service, and the Economic Research Service. The SAES and cooperating institutions conduct about $1.9 billion worth of research, making them the largest performer of research in the public sector. USDA pays for about $1.5 billion of total public research, the States less than $1 billion, with additional funds supplied by the private sector (fig. 5.1.5). USDA uses several funding instruments to provide research money to States. One instrument is ***formula funds***, allocated in block form to States based on rural population and number of farms. ***National Research Initiative competitive grants*** are allotted according to peer review. ***Special grants*** are awarded by Congress, whereas other USDA ***contracts, grants, and cooperative agreements*** are determined by USDA. (See Fuglie and others, 1996, for a more detailed description of these mechanisms.) Since 1983, competitive and special grants have grown in importance as funding sources and reached 13 percent and 16 percent in 1993. Formula funds declined from 74 percent of USDA funds in 1983 to less than 53 percent in 1993. Cooperative agreements stayed around 17 percent.

Because State-level research is so important, and these instruments fund research differently, the merits of these instruments are being discussed in the political arena. Traditionally, State-level research has fostered a decentralized research approach as well as geographically specific applied research. In the early 1970's, some critics contended that agricultural research had become too applied, moving too far from basic biological research (National Research Council, 1992). These critics called for greater peer review and competition for research funds, as well as a shift to more basic biological research and away from commodity-specific applied research. This shift included moving from formula funding to competitive grants. Behind this recommendation was the belief that biotechnological breakthroughs based on basic biological research were needed to maintain historical rates of agricultural productivity growth. Continuing to rely on formula funds, which fostered geographically specific commodity research, might not generate the needed breakthroughs.

These recommendations have themselves met with criticism. Buttel (1986) warned that the shift toward competitive grants might narrow the focus of agricultural research in two ways. First, the research problem areas addressed might be narrowed and public-sector research would then be redirected toward profit-maximizing goals of private biotechnology firms. The public sector would move

Agricultural Productivity

From 1948 to 1993, aggregate U.S. agricultural output more than doubled, growing at an average annual rate of 1.7 percent (fig. 5.1.1). In contrast, aggregate input use (the sum of land, labor, machinery, chemicals, etc.) averaged a slight decrease (-0.1 percent per year). Thus, the growth in output was due to increased productivity. Output per unit of input, indicated by the multifactor productivity index, grew by an average of 1.8 percent per year during 1948-93. This was above the 1.1-percent average rate in the private nonfarm economy.

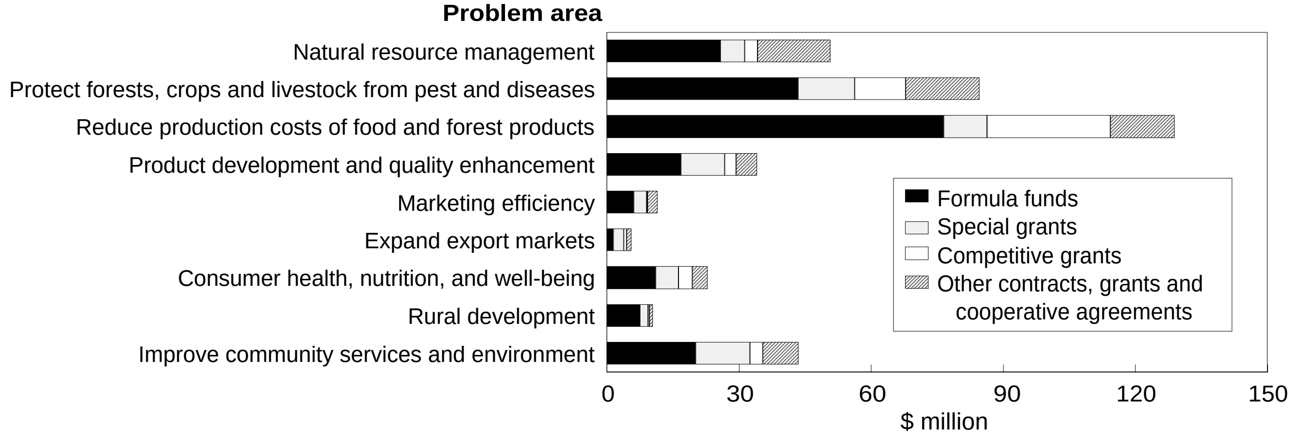
Growth in inputs is typically identified as the driving force of economic growth. In agriculture, the driving force has been productivity growth. The ability to increase production significantly using the same or fewer aggregate inputs could not have occurred without the development of new agricultural technologies—higher yielding varieties, improved livestock breeds, and innovative tillage and irrigation equipment.

The relatively stable aggregate input level disguises larger shifts in individual inputs: purchased (intermediate) inputs changed and capital increased while labor input declined. Agricultural producers held down production costs by substituting capital, primarily durable equipment, and intermediate inputs for labor. This is clear from labor's decreasing share in total input cost. Labor's cost share (including the imputation of self-employed labor) fell from 41 percent in 1948 to 23 percent in 1993. In contrast, the share of capital in total cost increased from 9 percent in 1948 to 28 percent in 1993. Intermediate inputs accounted for approximately 50 percent of the total cost of agricultural inputs in both years.

The stable share of total input cost for intermediate inputs disguises significant shifts within this broad category during 1948-93. While intermediate inputs in aggregate increased at an average rate of 1.3 percent per year, pesticide consumption increased an average of 6.1 percent per year; and feed, seed, and livestock purchases, 2.2 percent per year. In contrast, fertilizer increased only 1.7 percent, and energy inputs less than 1 percent (0.8 percent) annually.

Among other input categories, labor in agriculture decreased at an average annual rate of 2.7 percent over the postwar period, with greater reductions occurring in self-employed labor than in hired labor. Capital input to agriculture (particularly durable equipment) increased dramatically in the immediate postwar period, but the average annual rate of growth over the entire 1948-93 period was less than 1 percent (0.7 percent). Service flows from farm real estate—land and service buildings—declined modestly.

Figure 5.1.6--USDA funds to SAES and other institutions, 1993



Source: USDA, ERS, based on USDA, Current Research Information System, 1979-95.

away from emphasizing social rates of return, which would reduce the value of public research to society as a whole. While natural resource and environmental research has a high value to society, it is seldom profit-maximizing. Second, declines in formula funding could possibly skew the geographic distribution of USDA research funds granted to individual States. States with strong programs in molecular and cellular biology would fare well under the new system, but Experiment Stations further from the frontier of biological research might be starved for funds. The choice of a funding mechanism can thus have significant consequences for natural resource and environmental research.

Different instruments have, historically, focused on different research goals (fig. 5.1.6). For example, competitive grants are concentrated on two goals—control of pests/diseases and reduced production costs. Special grants and cooperative agreements are used to fund a greater portion of research on natural resource, environmental, food safety, and rural development issues.

Because environmental protection and resource management are often site-specific, concentrating funding in fewer States may leave certain States without adequate funds to conduct research effectively and meet their needs. However, concentrating funds in States with strong research programs could increase the likelihood of finding solutions to various resource and environmental problems. In evaluating the degree to which funding instruments affect the geographic distribution of funds across States, Frisvold and Day (1992) showed that (1) formula funds are the most evenly distributed across States, (2) competitive grants are the most unevenly distributed, and (3) special grants and cooperative agreements lie between.

Therefore, competitive grants (as predicted by Buttel) are concentrated among fewer SAES and are used to fund a narrower set of research objectives than other instruments. However, the emphasis on competitive grants has not significantly shifted the geographical or topical distribution of total USDA funding of SAES. Distributional curves for overall funds are virtually unchanged from 1983 to 1992. Furthermore, while the distribution of research funds among research categories is very different for formula and competitive grants, total USDA funding closely matches that of formula funds. There are two reasons for this. First, competitive grants comprise only 11 percent of USDA funds to SAES. Second, special grants and cooperative agreements counterbalance the effect of competitive grants. Therefore, shifts in funding method appear not to have greatly affected natural resource and environmental research at SAES and cooperating institutions thus far. However, a significant shift toward competitive grants could limit the traditional sources of funding for this research, unless the allocation process could be changed to increase the priority of resource and environmental research.

Private Research and Development

Private industry has been moving into new areas of research—specifically, biological and chemical technologies such as agricultural chemicals, plant breeding, and animal health. Private-sector expenditures in these research areas increased from

Figure 5.1.7--Private agricultural research by industry

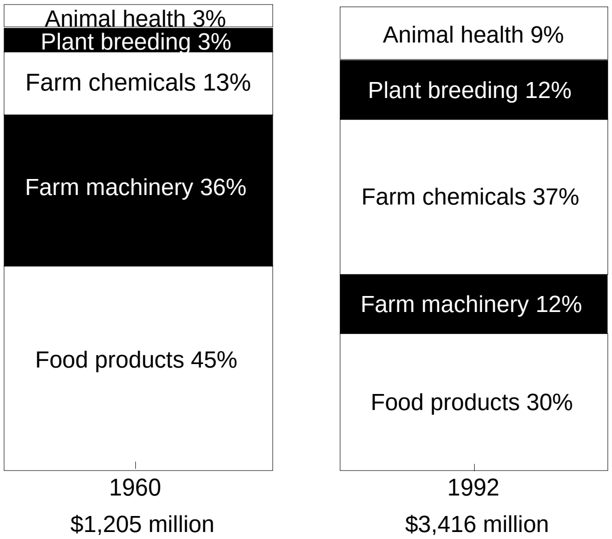


Figure in 1992 dollars.
Source: USDA, ERS, based on Klotz, Fuglie, and Pray, 1995.

19 percent of agricultural research in 1960 to 58 percent in 1992 (fig. 5.1.7). Historically, the public sector has conducted yield-increasing agricultural research, especially in plant breeding, and private sector research has focused on "downstream" technologies, such as food processing and farm machinery. Private-sector researchers have new incentives to expand agricultural R&D, albeit into areas that are more commercially oriented than public research.

Scientific advances in biology in the past 20 years, coupled with government policies and regulations, expanded private-sector incentives for conducting agricultural research. Public investments in basic research created new technological opportunities for private research. Scientific breakthroughs, such as the development of biotechnology applications, helped facilitate agricultural research. For example, tissue cell culture reduced the time required for developing new plant varieties. Also, gene transfer technologies enabled researchers to tailor crops for specific uses, such as crops that are resistant to disease, pests, or harsh environmental conditions; that are more nutritious; or that improve food processing.

Besides scientific advancements, intellectual property rights (IPR's) were strengthened for new plant varieties and biological inventions. IPR's have encouraged private research by allowing innovative firms to capture a greater share of the benefits from research (discussed more below). Regulations are often associated with increased product development costs, as has been the case with pesticide regulation and the development of pesticides (Ollinger and Fernandez-Cornejo, 1995). However, regulation can also stimulate private-sector research that is beneficial to private industry. For example, regulations attempting to protect the environment, food safety, and nutrition have encouraged research on technologies that are more compatible with these regulatory goals.

Role of Intellectual Property Rights

To foster research and innovation, the results from these efforts must be appropriable. The Patent Act of 1790 established a system of property rights protection to encourage manufacturers and inventors to develop new industrial inputs and consumer products. However, the principal contribution of this patent act to agriculture was the protection offered for mechanical and chemical inventions. Biological inventions were considered products of nature and were not patentable. Therefore, appropriating the gains from technological advances in plant breeding was difficult. Simply possessing a biological invention provided the means to reproduce it. Producers of a new plant or animal could only profit from their invention once, even though it could be used for generations. The development of hybrid seed technologies in the 1920's changed this because hybrid crops reproduce at decreasing yields, and thus, require farmers to repurchase seed every year. Private-sector plant breeding efforts then focused on hybrid seeds.

The extension of IPR's to new plant varieties and biological inventions, including the development of biotechnologies, has stimulated private companies to invest in plant breeding. The Plant Patent Act of 1930 and the Plant Variety Protection Act (PVPA) of 1970 established plant breeders' rights for new plants and plant varieties (see box, "Intellectual Property Rights"). In 1980, a Supreme Court decision (*Diamond v. Chakrabarty*) authorized the use of Utility Patents for biological inventions, specifically microorganisms. Several recent decisions by the Patent and Trademark Office broadened the use of Utility Patents for plants (ex parte Hibberd in 1985) and animals (ex parte Allen in 1987). As a result, private-sector research expenditures for plant breeding have increased from $6 million in 1960 to $400 million in 1992 (Klotz, Fuglie, and Pray, 1995; Fuglie, Klotz, and Gill, 1995). Nearly 70 percent of private-sector plant breeding research expenditures in 1989 was for corn, vegetables, and soybeans. Private

Intellectual Property Rights for New Plant Varieties and Biological Inventions

Utility Patents
Utility Patents are administered by the Patent and Trademark Office (PTO) of the U.S. Department of Commerce and grant ownership of new inputs and products for 20 years. Biological inventions were not patentable until 1980 when a decision by the Supreme Court in *Diamond v. Chakrabarty* authorized the use of Utility Patents for microorganisms. In 1985, the PTO's Board of Appeals and Interferences approved the use of Utility Patents for plants, and in 1987, for animals. Although Utility Patents offer owners the strongest form of protection for new plant varieties, they are more difficult to acquire compared with other options for obtaining plant breeders' rights.

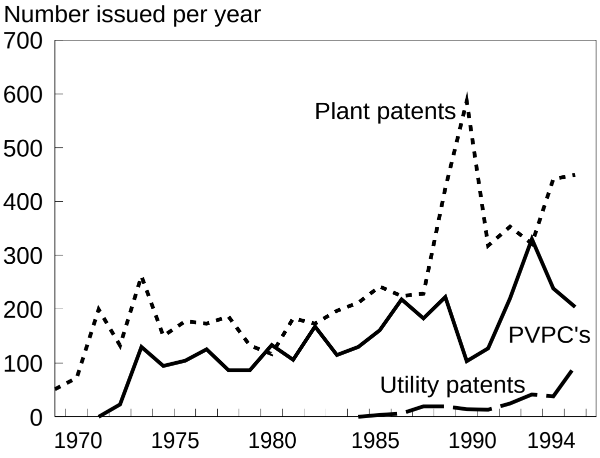
Plant Patents
The Plant Patent Act amended the Patent Act of 1970 and provided plant breeders protection for 17 years for asexually reproduced plant varieties. Specifically these include fruits, nuts, and ornamentals, but exclude tuber crops. As with Utility Patents, PTO administers Plant Patents.

Plant Variety Protection Certificates (PVPC's)
The Plant Variety Protection Act of 1970 created PVPC's, which established plant breeders' rights for new plant varieties produced from seed, particularly field crops. PVPC's are awarded for new plant varieties determined to be distinct, uniform, and stable. A 1980 amendment extended coverage to vegetables. Amendments in 1994 restricted farmer rights to resell protected seed, provided protection for tuber crops, and extended property rights protection from 17 to 20 years. A provision was also added to protect plant breeders from cosmetic infringements or superficial changes in the appearance of protected plant varieties that do not increase yield or value. A 1995 Supreme Court decision, *Asgrow v. Winterboer,* further restricted farmer rights to resell protected seed. The U.S. Department of Agriculture administers PVPC's.

Source: USDA, ERS, based on Fuglie and others, 1996.

firms have also reacted to changes in IPR's by investing heavily in biotechnology techniques. Expenditures on agricultural biotechnology research rose from almost nothing in the mid-1980's to $595 million in 1992.

Figure 5.1.8--Intellectual property rights issued for new plant varieties, 1970-94

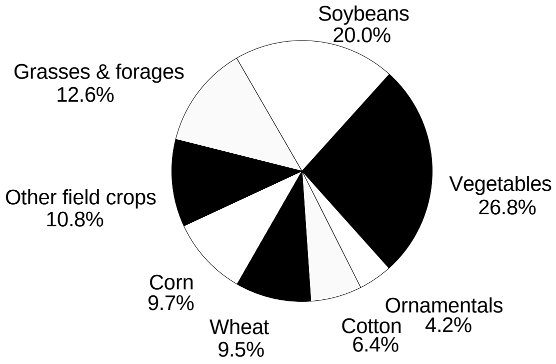


Source: USDA, ERS, based on Agricultural Marketing Service, Patent and Trademark Office data.

The number of Plant Patents, Plant Variety Protection Certificates (PVPC's), and Utility Patents issued over the last 25 years has risen (fig. 5.1.8). The PVPA stimulated the development of new field crop varieties. By the end of 1994, 3,306 PVPC's had been issued for new crop varieties. The number of PVPC's issued for new varieties of field crops, grasses, and vegetables climbed from 153 in 1971-74 to 992 in 1991-94. New soybean, corn, and vegetable varieties accounted for 56 percent of total PVPC's awarded (fig. 5.1.9). The private sector owns approximately 87 percent of the total PVPC's issued. Oats was the only crop for which the public sector held a higher share of PVPC's. Utility Patents are the most difficult to obtain and have been awarded primarily for new biotechnology innovations, such as genetically engineered varieties. By December 1994, 324 Utility Patents had been issued for multicellular organisms. Of these, 286 were issued for new plants or plant parts and 38 were issued for animals. As with PVPC's, most Utility Patents were awarded to the private sector (Fuglie, Klotz, and Gill, 1995).

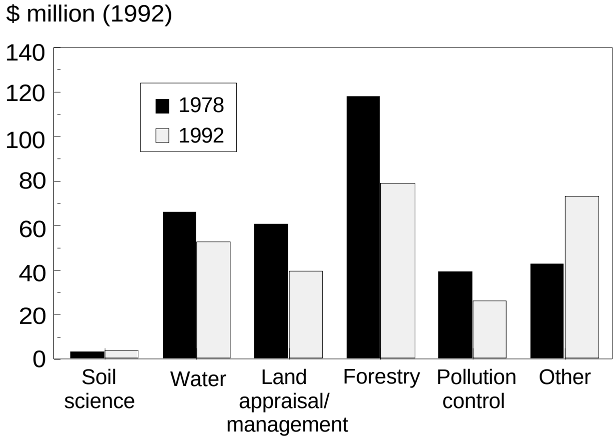
IPR's have encouraged the private sector to develop new agricultural technologies by enabling firms to capture a greater share of the commercial value of

Figure 5.1.9--Use of plant variety protection certificates issued in 1971-94 (3,306 in total)



Source: USDA, ERS, based on Fuglie and others, 1996.

Figure 5.1.10--USDA funding for in-house research on natural resources and the environment



Source: USDA, ERS, based on USDA, Current Research Information System, 1979-95.

their inventions. However, IPR's remain controversial since they can involve tradeoffs between competing objectives. The increased market power afforded to firms holding IPR's could result in higher seed prices. Scientific progress could also be hindered if IPR's slow the exchange of information on new technologies. Policies, such as cooperative research efforts between the public and private sectors and the licensing of new technologies by the public sector, can facilitate the transfer of technologies or information.

Natural Resource and Environmental Research

The increasing complexity of environmental problems is likely to heighten expectations of the agricultural sector. Agricultural research needs to find ways to minimize any negative environmental consequence of agricultural production, while preserving (and ideally increasing) yields. Public support of research on new technologies to conserve natural resources and enhance environmental quality is necessary because environmental resources are largely public goods, that is, goods for which there are few private incentives to protect or conserve (Ruttan, 1971). USDA helps determine which environmental and resource issues are of national importance. States conduct research to be used in national and regional priority setting, as well as in determining regional solutions for these issues.

USDA Natural Resource Research

Natural resource research concerns the use, management, and conservation of natural resources and the environment. USDA natural resource research was approximately 18 percent of the total research conducted by the Federal Government in this field during 1992.[1] Natural resource research funded by USDA research agencies fell between 1978 and 1992. However, the share of USDA research funds devoted to natural resource research remained steady from 1984 to 1992, between 33 percent and 37 percent.

USDA inhouse research subjects in natural resources and the environment include soil science, land appraisal and management, water, forestry, pollution control, and other (including interdisciplinary). Forestry (which includes research on new and improved forest products) was the largest recipient of funds, in both 1978 and 1992 (fig. 5.1.10). Soil science funding grew slightly. The most dramatic increase was in the category entitled "other," especially for interdisciplinary research, weather research, and remote sensing. This results, in part, from the Global Change Initiative. Funds for water, land assessment, pollution control, and forestry declined between 1978 and 1992. Interdisciplinary projects may have absorbed some of these research funds.

The proportion of total USDA natural resource research allocated inhouse declined from 81 percent in 1978 to 72 percent in 1991. Universities and research institutions outside USDA are conducting an

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[1] Funding data are drawn from the Current Research Information System, Tables III and IV. Table III reports appropriations for the pertinent fiscal year, while Table IV reports fiscal-year obligations. Consequently, the numbers are best used together as a measure of relative trends, rather than absolute funding statistics.

increasing percentage of agency-funded natural resources and environmental research. Also, a growing percentage of funding is going to institutions other than SAES, such as other universities and research institutions, as USDA looks beyond the SAES system for partners in natural resource research.

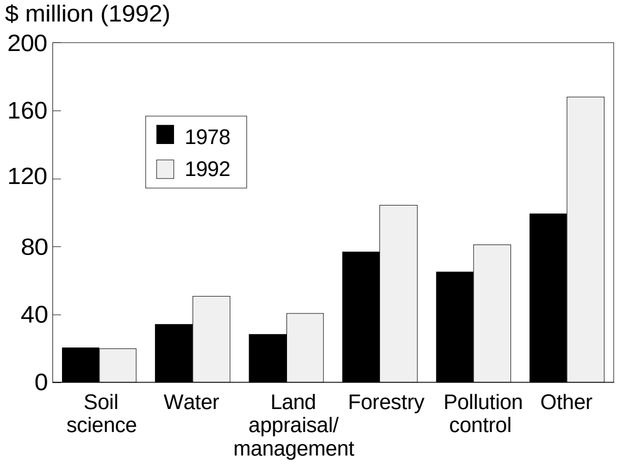
SAES Natural Resource Research

SAES and other cooperating institutions conduct the largest percentage of natural resource and environmental research. SAES receive funds from a variety of sources, including USDA agencies, State appropriations, product sales, and private industry. Between 1978 and 1991, SAES natural resource research funds rose substantially, surpassing USDA inhouse resource research in 1979.

Natural resource funding at SAES and cooperating institutions was spread relatively evenly among research areas (fig. 5.1.11). The category "other" was the largest recipient of funds, with the leading research problem areas being an interdisciplinary research category and the fish and wildlife category. Forestry was the next largest recipient of appropriations. Unlike USDA inhouse research, each research subject received increased funding over 1978-92.

State revenues have been an increasingly important funding source for natural resource research at SAES. After 1981, State appropriations to Experiment Stations rose steadily. By 1991, appropriations had increased almost 37 percent over the 1978 level, to more than $179 million. State funds have approached the level of inhouse funding by USDA, which suggests that the influence of State-level priorities may be increasing.

Figure 5.1.11--Funding at State agricultural experiment stations for research on natural resources and the environment



Includes cooperating institutions.

Source: USDA, ERS, based on USDA, Current Research Information System, 1979-95.

The impact of these trends on natural resource and environmental research is unclear. Increased activity at the State level suggests that more resources may be invested in applied work with a regional focus. Applied site-specific research is an important element of many resource-conserving agricultural techniques (integrated pest management, precision farming, nutrient management systems). On the other hand, certain environmental problems affect and are affected by agriculture on a larger scale. Such concerns as acid rain and nonpoint-source water contamination cannot easily be assigned to a particular State and may call for national efforts.

The returns to natural resource and environmental research are not easily measured, because many environmental goods and natural resources are difficult to value in themselves. While the appropriability of resource and environmental research is low for the private sector, the value of the resources is very high for society, suggesting a strong role for the public sector.

Adoption and Transfer of Green Technology

From society’s point of view, a technology that will conserve scarce resources or protect the environment should be brought to the marketplace and adopted by agricultural producers (if its benefits exceed its costs). The more efficient use of inputs and resources offered by new technologies benefits the farmer (lowered costs of production) and the public (conservation of resources and preservation of the environment, characteristic of “green” technologies). Developers will only bring new technologies to the marketplace if they are profitable and producers will use them only if the benefits outweigh the costs (see box, "Area Studies of Technology Adoption,” p. 250). Off-farm environmental benefits are generally not part of the developer’s or the producer’s calculation, so there will be less use of the technology than if the full benefits and costs to society were included. Despite the potential value to society, certain green technologies are not developed, adopted, or diffused widely. (*Adoption* refers to the decision by individual producers on whether to use a technology, whereas *diffusion* is the rate and extent of technology adoption over time.)

Area Studies of Technology Adoption

Between 1991 and 1993, USDA surveyed 10 major U.S. watersheds to gain a better understanding of the factors affecting the adoption of resource-conserving agricultural technologies. Also, the studies sought to clarify how these technologies affected resource use, production efficiency, and farm income. The studies collected data on farm production practices and natural resource characteristics, such as soil and land quality. ERS researchers used multivariate regression to analyze the effects of agricultural policies, resource attributes, and farm characteristics on farmers' decisions to adopt specific agricultural technologies designed to conserve environmental resources. (For the areas surveyed, see "Area Studies Project," in the appendix, p. 329.)

A consistent finding of this work is that natural resource characteristics are major determinants of technology adoption. The performance of resource-conserving technologies varied considerably from one farm to another, depending largely upon soil quality and climatic factors. While a new technology may help some farms to conserve environmental resources while maintaining or even increasing production efficiency, it may not be as effective on a neighboring farm with different resource conditions or cropping practices. For example, soil nitrogen testing was found to reduce chemical fertilizer use (without reducing crop yields) on fields with substantial organic nitrogen carryover from the previous cropping season (Fuglie and Bosch, 1995). However, on other farms without significant nitrogen carryover, soil testing did not affect fertilizer use. Another example was the adoption of no-till farming. By using no-till instead of a conventional tillage system, farmers can reduce soil erosion to a fraction of the previous rate. However, in some areas, climatic factors and soil conditions appeared to limit the viability of no-till farming. The results from these and ongoing analyses of the Area Studies data are helping to identify factors that may be constraining the more widespread adoption of resource-conserving technologies.

Technology Transfer Programs at USDA and SAES

Valuable technologies developed in the public sector will not always be marketed by the private sector. Therefore, USDA and the SAES work to bring useful technologies to the agricultural sector. Both groups transfer a variety of innovations, both shielded and unshielded (protected by IPR's or not). The Technology Transfer Act of 1986 greatly increased the ability of federally funded institutions to transfer successful technologies to the marketplace.

Table 5.1.1—USDA technology transfer activites, 1987-93

Year	Patents awarded	Patent license royalties	Active CRADA's[1]	Value of CRADA's[2]
	Number	*$1,000*	*Number*	*$ million*
1987	34		85	1.6
1988	28	97	48	8.7
1989	47	418	86	15.6
1990	42	567	104	18.9
1991	57	834	139	25.6
1992	56	1,044	160	30.0
1993	57	1,483	185	34.0
1994	32	1,426	212	61.3

[1] Cooperative Research and Development Agreements.

[2] Includes the value of USDA and private-sector resources committed to the CRADA's.

Source: USDA, ERS, based on Talent, 1994; and Watkins, 1996.

Cooperative Research and Development Agreements (CRADA's) are public-private agreements usually between the Federal Government and private industry. This mechanism allows USDA and SAES to transfer technologies, research results, and scientific resources (not money) to industry through joint research ventures. The cooperating firm can provide any of these resources, and can also transfer money to the Federal agency as part of a research agreement. Cooperating firms have the first right to any patented inventions resulting from the agreement (ARS, 1992). USDA has established more than 500 CRADA's, making it among the leading Federal agencies in this area (table 5.1.1). USDA provides basic scientific knowledge often unavailable to private industry, and receives insight into industry needs and resources, as well as shared fees and royalties.

Patents and licensing are another set of mechanisms used by USDA, as well as SAES. Public entities can patent inventions meeting the criteria of the U.S. Patent and Trademark Office. The institutions, such as USDA, can then grant an exclusive or nonexclusive license to a private company to use or market the invention. Exclusive licensing of patents often provides incentives for a company to develop a technology. Before federally funded institutions were allowed to grant exclusive licenses, companies were often unwilling to make the investments necessary to bring these inventions to the marketplace (ARS, 1993). USDA maintains publicly available lists of patents available for licensing.

Two institutions are primarily responsible for bringing ARS inventions and knowledge to the private sector. The ARS Office of Technology Transfer patents, licenses, and markets ARS technologies and negotiates CRADA's. To facilitate close cooperation between inventors and firms, ARS has patent advisors and technology transfer coordinators at laboratories throughout the country. A second group, the Technology Transfer Information Center, provides informational support to ARS through the National Agricultural Library. The center manages information ARS needs to set priorities for research programs and to patent and license new inventions. Center staff aide ARS scientists by finding other relevant research results inside and outside the agricultural sector. The center also provides information to the public on ARS research and inventions. One product of the center, TEKTRAN, is an electronic database containing more than 25,000 summaries of ARS research findings. The summaries include an interpretive summary in nonscientific language, a technical abstract, and information on the contact scientist.

One example of a successful USDA technology transfer is the Biosys/ARS partnership. Scientists at ARS developed a parasitic nematode that controls two serious corn pests, the corn earworm and the fall armyworm. Biosys (a biotechnology company) is commercializing this technology, which is expected to prevent crop losses totaling several hundred million dollars (ARS, 1994).

SAES and other university institutions also may have offices of technology transfer. These are generally used for shielded innovations. This office will determine the commercial prospects of research output. Generally, those innovations that are sufficiently developed will go through the patent and licensing process (Parker and Zilberman, 1993). If further research is needed, the university may pursue a CRADA. Unshielded innovations usually pass through the extension system for information transfers through conferences, publications, education, or training (Parker and Zilberman, 1993).

Adoption

The characteristics and availability of the green technology will largely determine producers' decision to adopt. Technologies that offer only marginal improvements to existing methods or are difficult or costly to use often diffuse slowly. Agro-ecological factors, such as soil type, water availability, and climate, may also limit the adaptability and profitability of new technologies. Some emerging agricultural biotechnologies may give farmers new alternatives and opportunities for maintaining productivity while following environmental regulations designed to reduce environmental costs. However, many new agricultural technologies are complex and require a much higher level of human capital and managerial skills than in the past, increasing the costs of their adoption. Certain technologies may be economically desirable over time, but require substantial capital investment (for example, certain precision farming technologies). All these factors may result in a green technology not being voluntarily adopted widely enough to meet environmental goals.

The Government can pursue two types of policies and programs that encourage the adoption of beneficial technologies. First, through regulation or taxation, the Government can increase the cost or ban the use of environmentally damaging or natural resource-intensive inputs. Second, it can offer financial or technical assistance to farmers who adopt the preferred technology. Each approach will affect the actual diffusion of the technology differently, as well as determine who will bear the cost.

USDA uses a variety of policies to promote environmentally beneficial technologies, including cost-sharing, technical assistance, and extension education (see box, "Developing a Green Technology"). Practices approved for cost-sharing by USDA usually yield long-term benefits and are practices that the farmer would not, or could not, soon undertake without financial and technical assistance. USDA currently has programs that provide cost-sharing and other funding to farmers who adopt practices that improve or enhance water quality (see chapter 6.2, *Water Quality Programs*). USDA also has programs, such as conservation compliance, to encourage the adoption of soil management practices on highly erodible lands, which can reduce soil sedimentation and chemical runoff caused by erosion (see chapter 6.4, *Conservation Compliance*; Fuglie, 1995; and Fuglie and Klotz, 1994).

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Developing a Green Technology - An Example

The Minnesota Agri-Power (MAP) project is developing a power plant that uses biomass from alfalfa stems to generate electricity. The project, coordinated by the Center for Alternative Plant and Animal Products at the University of Minnesota, also includes the production of an alfalfa leaf-meal coproduct.

The MAP project was borne out of two Federal environmental goals: the Department of Energy's (DOE) efforts to reduce the level of emissions associated with electricity production from fossil fuels, thereby positively affecting global climate change; and USDA's efforts to increase farm adoption of environmentally beneficial crop rotations and to revitalize rural economies by finding new markets for agricultural products. Accordingly, USDA and DOE began the "Biomass Power for Rural Development Project" to cost-share renewable energy technology demonstration and commercializations. The development of this technology was aided by regulatory statutes. In 1994, Minnesota passed legislation requiring power companies to derive a certain portion of their total electrical energy from farm-grown biomass. This created a market for the electricity provided by MAP.

Many levels of research (basic, applied, and developmental) went into this effort. DOE basic research raised concerns about changing global climate and indicated that biomass energy could have atmospheric benefits. Agricultural research into the properties of alfalfa plants gave scientists the knowledge that such crops can be used to produce energy. Additional agricultural work (more applied in nature) has demonstrated that rotations with alfalfa can offer significant environmental benefits—for example, improved nitrogen balance and less nitrogen runoff, reduced soil erosion, and wildlife benefits.

The Minnesota Agri-Power project team had already completed significant research and feasibility study before receiving the Biomass Power for Rural Development grant. A team was assembled that included the University of Minnesota, the Minnesota Valley Alfalfa Producers (a farmer cooperative), USDA-ARS and Natural Resource Conservation Service, the State Departments of Natural Resources and Agriculture, local officials, Westinghouse Electrical Corp., and other private power, engineering and financing companies. As a land grant university, the University of Minnesota could draw on agricultural engineers, applied economists, soil scientists, agronomists, and plant geneticists, as well as agricultural experiment station resources and the Extension Service. This team, coordinated by the Center for Alternative Plant and Animal Products, will continue to work on the next phase of development.

Throughout, MAP's goal has been to develop environmentally and economically sustainable agriculturally based power. Economists have provided analysis on expected market conditions, economic yields, and the effects of farm programs. The project developers also wanted to ensure farmer participation. Early in the first feasibility study, the Department of Adult Agricultural Education conducted a series of focus groups with farmers to solicit farmer input in the planning and assessment process.

The technology transfer mechanisms used in this project are relatively new. Since DOE and USDA want to commercialize the technology, private sector participation was a requirement for receiving a grant. One strength of cooperative research agreements is that they bring together different expertise (public, private, and academic) to achieve interdisciplinary objectives. The use of newly available collaborations, as in this project, shows great promise for continuing the past successes of the agricultural research establishment in the area of environmental protection.

Source: USDA, ERS, based mostly on Center for Alternative Plant and Animal Products, 1994.

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Recent ERS Reports on Research and Technology Issues

Agricultural Research and Development: Public and Private Investments Under Alternative Markets and Institutions, AER-735, July 1996 (Keith Fuglie, Nicole Ballenger, Kelly Day, Cassandra Klotz, Michael Ollinger, John Reilly, Utpal Vasavada, and Jet Yee). This report discusses the history of agricultural research and research policy, and reviews the high rate of return on public agricultural research. Public funding of agricultural research, which has been relatively stagnant, is unlikely to increase. Private agricultural research has been affected by stronger intellectual property rights and public-private cooperative research mechanisms.

"Productivity: Agriculture's Engine of Growth," *Agricultural Outlook*, May 1996 (Eldon Ball and Richard Nehring). The article reports agricultural productivity growth statistics. The concepts behind productivity measurement are described, as well as factors influencing growth rate changes. The article also explains why the new indexing procedures are more accurate and easily interpreted.

Private-Sector Agricultural Research Expenditures in the United States, 1960-92, ERS Staff Paper No. AGES-9525, Oct. 1995 (Cassandra Klotz, Keith Fuglie, and Carl Pray). Private agricultural research has grown substantially, especially among chemical and biological technologies. However, data on private agricultural research spending are incomplete and fragmented.

Regulation, Innovation, and Market Structre in the U.S. Pesticide Industry, AER-719, June 1995 (Michael Ollinger and Jorge Fernandez-Cornejo). Pesticide regulation encourages the development of "less toxic" pesticides, but also discourages new chemical pesticides and affects minor crop-use pesticides. Various other impacts of pesticide regulation are discussed.

New Crop Varieties, AREI Update No. 14, 1995 (Keith Fuglie, Cassandra Klotz, and Mohinder Gill). This update of crop varieties indicates that expanded legal protection for new crop varieties has stimulated private-sector breeding efforts. Plant patents are the most popular intellectual property rights, followed by Plant Variety Protection Certificates and Utility Patents.

Agricultural Research, AREI Update No. 5, revised, 1995 (Keith Fuglie, Kelly Day, George Frisvold, and Cassandra Klotz). This update presents data showing that private research now exceeds public research, and also grew at a faster rate in 1992. The report also presents funding data for all 50 States' agricultural experiment stations by source, and gives the flow of research funds between Federal, State, and private sectors for 1992.

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6.1. Conservation and Environmental Programs Overview

USDA conducts a broad range of conservation programs intended to protect natural resources and the environment from the adverse consequences of agricultural production. Recently, the Federal Agriculture Improvement and Reform Act of 1996 modified and extended a number of these programs, and consolidated four cost-sharing programs into a new Environmental Quality Incentives Program (EQIP). The 1996 Act also created several new conservation programs intended to protect wildlife and grazing lands, and to reduce economic losses in floodplains. In 1996, USDA's conservation program expenditures represented half of total Federal conservation and environmental spending affecting agricultural lands, and over half of USDA's conservation expenditures were for rental or easements payments on lands in conserving uses.

Contents

Since the 1930's, USDA has administered a broad range of conservation and environmental programs to assist farmers, ranchers, and landowners in conserving and improving soil, water, and other natural resources associated with agricultural land. Current USDA conservation programs follow one or more of the following basic policy approaches:

- Technical assistance and extension education,
- Cost-sharing assistance for practice installation,
- Public works project activities,
- Rental and easement payments to place land into conservation uses,
- Compliance provisions, which require the implementation of approved conservation plans or the avoidance of certain land use changes if the operator wishes to remain eligible for USDA program benefits, and
- Conservation data and research aimed at developing an information base and improving conservation practices and program delivery.

The first two approaches are used to some degree in most USDA conservation programs, but are most prevalent in the new Environmental Quality Incentives Program (EQIP) and the programs it replaced. The third approach—public works project activities—is used for watershed protection and flood prevention activities. The fourth approach—payments for placing lands in conserving uses—has been used at various times in the past, such as the "Soil Bank" program of the late 1950's, and currently characterizes the Conservation Reserve (CRP) and Wetlands Reserve (WRP) Programs. The compliance approach to conservation originated in the 1985 Food Security Act with the conservation compliance, sodbuster, and swampbuster provisions. This approach essentially adds soil and wetland conservation as additional requirements for receipt of a wide array of farm program payments. The sixth approach—research and data development—is essential to the other five approaches and is undertaken by the Agricultural Research Service (ARS), the Cooperative State Research, Education, and Extension Service (CSREES), the Economic Research Service (ERS), the Forest Service (FS), and the Natural Resources Conservation Service (NRCS).

For the most part, the Federal Government has not employed direct regulation to deal with nonpoint source natural resource and environmental problems associated with agricultural lands. (The conservation compliance, sodbuster, and swampbuster provisions are not regulatory since they apply only to those who participate in farm programs, and farm program participation is voluntary.) However, the Environmental Protection Agency (EPA) does regulate the production and use of pesticides under FIFRA, as amended by the Food Quality Protection Act, and animal waste discharges from large confined livestock operations under the Clean Water Act. An increasing number of States also regulate pesticide use and land-use practices. Voluntary approaches to agricultural resource problems not only avoid the inherent difficulty in regulating nonpoint sources of pollution, but also educate and fund farmers so that they might willingly make improvements in production practices to achieve conservation and environmental goals. In passing the Federal Agriculture Improvement and Reform Act of 1996 (1996 Farm Act), Congress reaffirmed its preference for dealing with agricultural natural resource problems through voluntary approaches.

New USDA Conservation Programs

Environmental Quality Incentives Program (EQIP). EQIP was established by the 1996 Farm Act as a new program to consolidate and better target the functions of the Agricultural Conservation Program (ACP), the Water Quality Incentives Program (WQIP), the Great Plains Conservation Program (GPCP), and the Colorado River Basin Salinity Program (CRBSP). These four terminated programs are discussed more in the next section. EQIP will be administered by NRCS with the concurrence of the Farm Service Agency (FSA).

The objective of EQIP is to encourage farmers and ranchers to adopt practices that reduce environmental and resource problems. By statute, half of the available funds for EQIP are to be targeted at conservation practices relating to livestock production, and there is general statutory guidance to manage EQIP so as to maximize environmental benefits per dollar expended. During 1996-2002, USDA will provide technical assistance, education, cost-sharing, and incentive payments to producers who enter into 5- to 10-year contracts implementing EQIP conservation plans. The program will be available to farmers and ranchers who own or operate land on which crops or livestock are produced, including cropland, pasture, rangeland, and other lands identified by the Secretary.

Producers who implement land management practices (e.g. nutrient management, tillage management, grazing management) can receive technical assistance, education, and incentive payment amounts to be determined by the Secretary. Producers that implement structural practices (e.g. animal waste management facilities, terraces, filterstrips) can receive technical assistance, education, and cost-sharing of up to 75 percent of the projected cost of the practice(s). However, large confined livestock operations generally will be ineligible for cost sharing to construct animal waste management facilities.

An evaluation and selection process is being used to target EQIP funds. First, NRCS solicits priority area proposals from local work groups through the State Conservationist. These proposals are evaluated at the national level, and based on the proposals and other information on conservation needs, EQIP funds are allocated to the States. Once allocations are made, it is the responsibility of the State Conservationist to see that environmental benefits per dollar are maximized. Nearly 600 project area proposals were submitted to the national level in FY 1997.

Some producers outside priority areas may also receive EQIP assistance, especially for low-cost but environmentally effective practices such as nutrient testing. USDA has proposed that up to 35 percent of EQIP funds be available for identified problems outside priority areas.

Program funding for EQIP will be $200 million annually through 2002 except for fiscal year 1996 when funding was $130 million. Congress authorized this $130 million to be paid out through ACP, WQIP, GPCP, and CRBSP to fulfill EQIP purposes. In general, cost-share and incentive payments paid to a producer under EQIP may not exceed $10,000 for any fiscal year or $50,000 for a multi-year contract. However, the Secretary has the authority to pay a producer more if it is determined to be essential to the purposes of the program.

Wildlife Habitat Incentives Program (WHIP). WHIP was created by the 1996 Farm Act to provide cost-sharing assistance to landowners for developing habitat for upland wildlife, wetland wildlife, threatened and endangered species, fish, and other types of wildlife. The 1996 Farm Act authorized a total of $50 million from CRP funds to conduct the program for fiscal years 1996-2002. NRCS will administer the program.

With the assistance of NRCS, participating landowners will develop plans that include schedules for installing wildlife habitat development practices and requirements for maintaining the habitat for the life of the agreement. Agreements will last a minimum of 10 years from the date the practices are established. Cost-share payments may be used to establish practices needed to meet the objectives of the program, and replace practices that fail for reasons beyond the landowner's control.

Conservation Farm Option (CFO). The 1996 Farm Act established CFO pilot programs for producers of wheat, feed grains, cotton, and rice. NRCS will administer CFO with the concurrence of FSA. Only owners or operators with contract acreage enrolled in the Agricultural Market Transition Program are eligible for participation. Under the pilot programs, producers can receive one consolidated annual USDA conservation payment in lieu of separate payments from CRP, WRP, and EQIP. The producer must implement a conservation farm plan that addresses soil, water, and related resources, water quality, wetlands, and/or wildlife habitat. Participation is voluntary and based upon a 10-year contract between the Commodity Credit Corporation (CCC) and the producer, with a potential 5-year extension. The 1996 Farm Act authorized funding for fiscal 1997 at $7.5 million, increasing to $62.5 million in 2002. A total of $197.5 million of CCC funds is dedicated to this option for FY 1997-2002. However, Congress subsequently limited the program to $2 million for 1997 in the 1997 Agricultural Appropriations Act. USDA is expected to issue program regulations by late summer, 1997.

Farmland Protection Program (FPP). FPP was established by the 1996 Farm Act to purchase voluntary conservation easements or other interests in lands with prime, unique, or other highly productive soils. NRCS will administer FPP with the concurrence of FSA. To be eligible, land must be subject to a pending offer from a State, tribe, or local government for the purposes of protecting topsoil by limiting nonagricultural uses of the land. The Farm Act authorized up to $35 million of CCC funds to carry out this program.

In 1996, States, Indian tribes, and local governments offered 628 proposed easements covering over 175,000 acres of land in 20 States. The proposals had a total projected easement cost of $330 million. Of this amount USDA was asked to provide $130 million. USDA has evaluated these proposals and has issued cooperative agreements to allocate $14.5 million from the CCC for fiscal year 1996. The program is limited to $2 million in the FY 1997 Appropriations Act.

Flood Risk Reduction Program. The 1996 Farm Act authorized USDA to offer flood risk reduction contracts to producers with frequently flooded contract acreage under the Agricultural Market Transition Act. FSA will administer this program. Individuals can receive up to 95 percent of projected production flexibility contract payments, under the Agricultural Market Transition Act, that the USDA estimates the producer would otherwise have received from the time of the contract though September 30, 2002. In return, producers must agree to the termination of their production flexibility contract, comply with swampbuster and conservation compliance provisions, and forgo future disaster payments, crop insurance payments, conservation program payments, and loans for contract commodities, oilseeds, and extra long staple cotton. Flood risk reduction funding is also provided through the CCC.

Conservation of Private Grazing Land Initiative. The 1996 Farm Act required USDA to conduct, subject to the availability of appropriated funds, a coordinated technical, educational, and related assistance program for owners and managers of non-Federal grazing lands including rangeland, pastureland, grazed forest land, and hay land. NRCS will conduct this Initiative. The Initiative builds on the growing public awareness of the importance of private grazing lands, which comprise nearly 642 million acres, or half the Nation's 1.4 billion acres of private land. Working through local conservation districts, the purpose of the program is to preserve water quality, improve wildlife and fish habitat, help with weed and brush problems, enhance recreational opportunities, and improve aesthetics. The 1996 Farm Act authorized appropriations of $20 million in FY 1996 (subsequently limited to $10 million), $40 million in FY 1997, and $60 million in FY 1998 and each subsequent year.

USDA Conservation Programs Terminated by the 1996 Farm Act

Agricultural Conservation Program (ACP). Initiated in 1936 and administered by the Farm Service Agency (FSA, formerly Agricultural Stabilization and Conservation Service), ACP provided cost-sharing (up to $3,500 annually or $35,000 under 10-year agreements) and technical assistance to farmers who carried out approved conservation and environmental protection practices on agricultural land and farmsteads. During the past 20 years, outlays generally ran between $175 million and $200 million each year. The number of participants gradually declined from more than 300,000 annually in the mid-1970's to some 85,000 farmers in 1995 (table 6.1.1). Since the 1980s, an increasing amount and proportion of cost-sharing was directed to water quality practices (including those in Water Quality Program activities). In 1995, 27 percent of ACP cost-sharing went for water quality practices, up from 7 percent in 1988 (table 6.1.2). A new practice, Integrated Crop Management (ICM), was made available under ACP in 1990 and was applied on 341,000 acres in 1995. The practice includes pest scouting, nutrient testing, and other improved management practices. Authority for ACP terminated on April 4, 1996, when its functions were subsumed by EQIP, although ACP expenditures from previously obligated funds will continue to service prior long-term agreements.

Water Quality Incentive Projects (WQIP). WQIP was created by the Food, Agriculture, Conservation and Trade Act of 1990, and was administered as a practice under ACP. The goal of WQIP was to reduce agricultural pollutants by subsidizing farm management practices that restore or enhance water resources affected by agricultural nonpoint source pollution. Areas eligible for WQIP included watersheds identified by States as being impaired by nonpoint source pollution under Section 319 of the Clean Water Act; areas identified by State agencies for environmental protection and so designated by the Governor; and areas where sinkholes could convey runoff directly into groundwater. A total of 242 projects were started during FY 1993-95.

Eligible producers entered into 3- to 5-year agreements with USDA to implement approved management practices on their farm, as part of an overall water quality plan, in return for an incentive payment. The WQIP supported 39 different practices for protecting water quality. In 1995, WQIP assistance was applied on over 800,000 acres at an average incentive payment of nearly $8 per acre. WQIP was consolidated into EQIP by the 1996 Farm Act.

Great Plains Conservation Program (GPCP). GPCP, initiated in 1957 and administered by NRCS, has provided technical and financial assistance in 556 counties in the 10 Great Plains States for conservation treatment on entire operating units. Financial cost-share assistance of up to 75 percent was limited to $3,500 per person per year. Contracts were 3 to 10 years in length. In 1995, over 7,400 farms were active in the program, covering nearly 16 million acres (table 6.1.1). GPCP was terminated on April 4, 1996, when its functions were subsumed by EQIP.

Colorado River Salinity Control Program (CRSCP). Initiated in 1984, CRSCP was jointly administered by USDA and the U.S. Department of the Interior to identify salt source areas in the Colorado River Basin; assist landowners and farm operators in installing practices to reduce salinity in the Colorado River; carry out research, education, and demonstration activities; and monitor and evaluate the activities being performed. Farmers could receive up to 70 percent cost-sharing to install improved irrigation systems designed to increase irrigation efficiency and to reduce the movement of salt into groundwater. Total payments were limited to $100,000 per farm. Once an application was approved, landowners entered into a contract for 3 to 10 years. Besides agreeing to build and install the salinity control project, the landowner also agreed to operate and maintain the project. In 1995, CRSCP had 597 participants receiving an average of $38,000 (table 6.1.1). CRSCP was consolidated into EQIP under the 1996 Farm Act, although expenditures will continue to service prior contracts.

Ongoing USDA Conservation Programs[1]

Conservation Technical Assistance (CTA). Since 1936, CTA, administered by NRCS through local Conservation Districts, has provided technical assistance to farmers for planning and implementing soil and water conservation and water quality practices. Farmers adopting practices under USDA conservation programs and other producers who ask

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[1] Water quality programs, the Conservation Reserve Program, Conservation Compliance, and wetland programs are discussed in subsequent chapters.

Table 6.1.1—Status of selected USDA conservation programs, fiscal 1989-95

Program[1]	1989	1990	1991	1992	1993	1994	1995
Agricultural Conservation Program:							
Number of participants (thousand)	124.4	123.8	123.9	120.2	114.9	122.4	84.8
Average assistance per participant ($) [2]	1,480	1,608	1,470	1,580	1,685	1,659	1,679
% technical / % cost-sharing [4]	6/94	6/94	6/94	6/94	6/94	6/94	10/90
Conservation Technical Assistance:							
Cooperators assisted (million)	1.3	1.8	1.2	1.2	1.2	1.0	0.7
Cooperators applying practices (million)	1.0	0.4	0.9	0.5	0.5	0.4	0.3
Resource management system acres (million)	25.2	27.4	18.4	18.0	15.9	16.5	17.8
Acres serviced by CTA (million)	62.6	60.7	59.6	59.6	62.1	57.2	37.0
Extension Education:							
Water Quality Program FTE [3]	NA	NA	NA	698	711	748	764
(% of total)				(4.3%)	(4.5%)	(4.7%)	(4.9%)
Sustainable Agr. Initiative FTE	NA	NA	NA	634	635	623	640
(% of total)				(4.0%)	(4.0%)	(3.9%)	(4.1%)
Great Plains Conservation Program:							
Total active contracts (whole farm units)	5,129	5,443	5,779	6,336	6,761	6,761	7,419
New contracts during year	953	971	1,047	1,185	1,129	1,166	483
Applications awaiting funding	1,725	1,909	2,580	2,680	2,599	2,599	2,551
Acres under active contracts (million)	15.2	16.6	15.1	19.4	19.9	15.7	15.8
Counties covered in 10 States	518	518	518	556	556	556	556
Avg. cost/new contract ($1,000) [2]	21	22	23	21	22	22	22
% technical / % cost-sharing	40/60	38/62	33/67	36/64	35/65	35/65	35/65
Forestry Incentives Program:							
Number of participants	5,048	4.760	5,417	5,179	5,467	5,614	4,520
Acres treated (1,000)	198	187	215	208	214	227	166
Average assistance per acre [2]	$62	$61	$63	$61	NA	$54	$56
Average assistance per participant/year [2]	$2,436	$2,394	$2,511	$2,452	$2,268	$2,423	$2,276
% technical / % cost-sharing	10/90	11/89	9/91	10/90	10/90	10/90	10/90
Emergency Conservation Program:							
Number of farms assisted	4,861	8,958	6,877	4,907	4,929	12,515	9,227
Acres served (million)	2.5	1.1	1.0	1.0	1.4	0.93	0.87
Avg. assistance per acre[2]	$3	$17	$9	$11	$31	$41	$33
Colorado River Salinity Control Program:							
Participants	127	172	214	349	527	517	597
States with participants	3	3	3	3	3	3	3
Avg. assistance per participant ($1,000) [2]	43	60	69	42	26	28	38
Conservation Loans and Easements:							
Soil and water loans:							
(million $)	5.9	6.1	5.5	2.7	2.3	3.7	0
(number)	360	247	206	138	123	157	0
Conservation easements	266	388	114	84	120	167	69
Acres in easements	20,980	33,280	10,310	8,340	17,580	24,380	5,690
Properties transferred for conservation purpose--							
Number	14	9	141	73	79	54	56
Acres	4,047	8,954	50,447	21,692	21,090	13,392	13,351
Small Watershed Program:							
Projects authorized for planning	18	18	11	35	33	33	17
Projects authorized for installation	19	19	23	11	22	22	17
Obligations for planning (million $)	8.4	8.6	8.9	9.2	9.5	11.1	10.5
Obligations for installation (million $)	137.0	130.1	140.8	144.2	158.3	179.9	71.8
Resource Conservation and Development Program:							
Active areas (number)	189	194	209	236	250	275	277
State and local funding (million $)	NA	108.1	160.5	131.1	75.1	43.5	20.8
State and local funding per Federal $	NA	$3.96	$5.37	$4.03	$2.31	$13	$14

NA = Not available. [1] For Federal expenditures on technical and cost-sharing assistance, see table 6.1.3.

[2] Includes both technical and cost-sharing assistance. [3] Full-time equivalents.

[4] Technical assistance paid from ACP funding. In addition, NRCS used funds appropriated for conservation operations to finance ACP-related technical assistance.

Source: USDA, ERS, based on annual program reports of the various agencies and Office of Budget and Program Analysis data.

Table 6.1.2—Agricultural Conservation Program (ACP) expenditures by primary purpose, fiscal 1988-95

Primary purpose	Cost-share expenditures							Percent of total						
	1988	1990	1991	1992	1993	1994	1995	1988	1990	1991	1992	1993	1994	1995
	$million							*Percent*						
Erosion control	133.8	112.2	111.5	106.3	93.7	107.0	70.1	71.2	64.7	61.7	58.9	55.6	55.9	51.3
Water conservation	27.7	24.7	23.6	22.8	22.5	25.0	17.3	14.7	14.3	13.0	12.6	13.3	13.1	12.7
Surface water quality (SWQ):														
Sediment	1.7	3.5	4.9	5.9	5.7	5.9	4.8	0.9	2.0	2.7	3.3	3.4	3.1	3.5
Animal waste	6.8	13.8	18.4	20.5	20.9	24.9	20.6	3.6	7.9	10.2	11.3	12.4	13.0	15.1
Fertilizer	1.4	2.8	4.8	5.8	5.9	8.1	6.5	0.7	1.6	2.7	3.2	3.5	4.3	4.7
Toxics	0.4	0.3	0.6	1.1	1.1	1.7	1.8	0.2	0.2	0.3	0.6	0.7	0.9	1.3
Salinity	2.4	1.2	0.8	0.9	1.0	1.1	1.1	1.3	0.7	0.4	0.5	0.6	0.6	0.8
Other SWQ	0.7	0.8	1.0	2.5	3.3	2.5	1.7	0.4	0.5	0.6	1.4	2.0	1.3	1.3
Subtotal SWQ	13.4	22.4	30.5	36.7	38.0	44.2	36.6	7.1	12.9	16.9	20.3	22.6	23.1	26.8
Ground water quality	0.3	0.3	0.4	0.4	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.1	0.1	0.2
Energy	0.9	1.1	1.2	1.2	1.4	1.5	1.4	0.5	0.6	0.7	0.7	0.8	0.8	1.0
Wildlife	1.3	1.3	1.5	1.4	1.1	1.4	1.0	0.7	0.7	0.8	0.8	0.7	0.7	0.8
Wood production	9.1	9.9	10.9	10.2	9.8	10.1	8.4	4.8	5.7	6.0	5.7	5.8	5.3	6.1
All other	1.5	1.5	1.2	1.5	1.9	1.8	1.5	0.8	0.9	0.7	0.8	1.1	0.9	1.1
Total[1]	188.0	173.4	180.8	180.5	168.7	191.3	136.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0

[1] These data differ slightly from the more recent information in table 6.1.3, but are the only available source of expenditures by primary purpose.

Source: USDA, ERS, based on ASCS, Annual Statistical Summaries of the Agricultural Conservation Program.

for assistance in adopting approved NRCS practices can receive technical assistance. In 1995, CTA provided assistance to approximately 700,000 cooperators on about 37 million acres (table 6.1.1), down from earlier years. In recent years, CTA has prepared and assisted in implementing conservation plans for highly erodible lands to help farmers maintain eligibility for USDA program benefits.

Water Bank Program (WBP). Authorized in 1970, the WBP is primarily designed to preserve, restore, and improve high-priority wetlands. In the process, WBP also provides habitat for migratory waterfowl and other wildlife, improves water quality, reduces soil erosion, conserves surface waters, improves subsurface moisture, contributes to flood control, and enhances the natural beauty of the landscape. Under the WBP, USDA enters into agreements with landowners and operators in important migratory waterfowl nesting, breeding, and feeding areas for the conservation of specified wetlands. The agreements are for 10 years with provision for renewal. The program operates primarily in the northern part of the central flyway, and the northern and southern parts of the Mississippi flyway. Until 1994, the WBP was administered by FSA, after which the program became the responsibility of NRCS. In 1995, approximately 700,000 acres were in the program with annual payments of nearly $10 million. North Dakota, Mississippi, Arkansas, and South Dakota had the most acres enrolled of 12 States. Congressional appropriators eliminated funding for the WBP in FY 1995, reflecting deficit reduction pressures. As a result, payments to farmers end as their 10-year contracts expire and no additional acres can be enrolled in the program. However, certain lands subject to expiring WBP contracts are eligible for possible enrollment in the CRP.

Emergency Conservation Program (ECP). ECP was initiated in 1978 and is administered by FSA. The program provides financial assistance to farmers in rehabilitating cropland damaged by natural disasters and for conserving water during severe drought. There is a payment limit of $200,000 per person per disaster. Expenditures jumped in 1993-95 as a result of numerous hurricanes, floods, drought, and tornados (table 6.1.3).

Emergency Watershed Protection Program. This program was initiated in 1950 and is administered by NRCS. It provides technical and financial assistance to local institutions for removal of storm and flood debris from stream channels and for restoration of stream channels and levees to reduce threast to life and property. Local institutions receiving aid must contribute 25 percent of total cost. Expenditures in 1994 and 1995 rose because of special appropriations to help the Midwest recover from the 1993 flood.

Extension Education. The Cooperative State Research, Extension, and Education Service

Table 6.1.3—USDA conservation expenditures, by activity and program, fiscal years 1983-97[1]

Activity/program	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995 actual	1996 approp.	1997[2] request
1. Technical assistance, extension, and administration:															
Natural Resources Conservation Service (NRCS)								*$ million*[1]							
Conservation Technical Assistance (CTA)	276.9	293.7	302.0	286.7	332.0	366.4	386.7	396.7	426.5	477.9	515.2	523.2	500.0	538.9	565.4
Great Plains Conservation Program (GPCP)	9.1	9.1	9.1	8.9	9.1	8.7	8.2	8.0	8.3	9.1	8.9	9.3	9.1	0.0	0.0
Resource Conservation & Development (RC&D)	16.3	16.3	17.8	17.4	17.8	18.2	18.4	23.1	24.2	26.0	29.9	28.3	30.4	29.0	29.4
Small Watershed Program (planning)	8.9	8.7	8.9	8.5	8.7	8.7	8.7	8.8	9.2	9.5	9.5	10.9	10.5	5.6	7.7
Watershed Protection / Flood Prevention	101.6	75.7	76.9	77.8	68.1	67.7	65.9	63.2	70.3	74.3	80.4	77.9	70.0	60.0	76.0
Colorado River Salinity Control Program	0.0	0.0	0.0	0.0	1.4	1.8	2.0	4.4	5.9	5.9	5.5	5.5	3.9	0.3	0.2
Forestry Incentives Program (FIP)	1.3	1.3	1.3	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.3	0.7	0.6	0.6
Water Bank Program (WBP)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.7	1.1	1.1	0.4	0.0	0.0	0.0
Wetland Reserve Program (WRP)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.9	3.5	8.8	6.0	17.0
Subtotal NRCS	414.0	404.8	416.0	400.5	438.2	472.6	491.2	506.0	546.4	605.0	656.7	660.3	633.4	640.4	696.2
Farm Service Agency (FSA)															
Agricultural Conservation Program (ACP)	11.0	11.2	11.2	10.5	9.3	11.2	10.1	11.3	10.6	10.8	11.2	11.7	6.0	4.5	4.5
Conservation Reserve Program (CRP)	0.0	0.0	0.0	10.8	21.9	5.6	27.9	16.4	5.7	11.4	8.9	4.7	5.3	6.6	21.4
Emergency Conservation Program (ECP)	0.1	0.7	0.6	0.2	0.1	0.2	0.4	0.6	0.5	0.8	1.5	1.0	1.8	0.0	0.0
Rural Clean Water Program (RCWP)	-0.9	0.3	0.0	3.4	2.5	0.0	-0.7	0.9	0.8	0.4	0.0	0.0	0.0	0.0	0.0
FSA salaries & expenses, conservation	32.8	35.3	33.1	37.3	47.6	61.4	62.4	60.2	73.8	72.6	65.3	67.6	62.8	62.8	62.8
Subtotal FSA	43.0	47.4	44.9	62.0	81.4	78.4	100.1	89.4	91.4	96.1	87.0	85.0	75.9	73.9	88.7
Extension Service (ES) conservation activities	15.9	16.0	16.4	16.3	15.7	18.1	19.8	23.5	29.4	31.1	31.1	32.2	32.2	31.7	31.7
Forest Service (FS)															
Forest Stewardship	10.3	6.9	6.9	6.7	7.1	6.8	6.8	15.2	22.6	23.9	23.3	25.8	25.9	23.4	30.0
Economic Action Programs	2.6	1.2	1.0	0.9	1.0	2.0	1.0	4.2	10.2	15.2	13.7	15.5	16.0	14.5	15.0
Forest Legacy Program	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.9	9.9	6.9	0.0	3.0	3.0
Pacific Northwest Assistance	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.4	17.1	16.0	13.0
Urban and Community Forestry	1.5	1.6	2.0	1.9	1.9	2.0	2.5	2.8	21.1	23.8	24.8	27.0	28.3	25.5	26.0
Subtotal Cooperative Forest Conservation	4.1	2.8	2.9	2.8	3.0	4.0	3.5	6.9	31.2	44.0	48.4	65.9	61.4	59.0	57.0
Subtotal FS	14.4	9.7	9.8	9.5	10.0	10.8	10.3	22.1	53.8	67.9	71.7	91.7	87.3	82.4	87.0
Subtotal Tech. asst., ext., and admin.	487.4	477.9	487.1	488.4	545.4	579.9	621.3	641.1	721.1	800.1	846.4	869.2	828.8	828.5	903.7
2. Cost-sharing for practice installation:															
FSA															
Agricultural Conservation Program (ACP)	176.5	174.5	179.2	129.7	172.6	186.6	174.0	187.8	171.6	179.1	182.8	183.0	94.0	70.5	70.5
Conservation Reserve Program (CRP)	0.0	0.0	0.0	12.4	245.6	284.8	182.3	118.1	40.9	39.3	32.0	14.5	3.7	25.1	66.1
Emergency Conservation Program (ECP)	13.9	16.4	4.9	6.6	5.3	5.7	6.1	17.9	8.8	10.3	42.0	24.0	21.2	0.0	0.0
Rural Clean Water Program (RCWP)	2.5	0.0	1.9	10.6	0.0	2.1	0.8	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Subtotal FSA	193.0	190.9	185.9	159.3	423.5	479.3	363.1	324.1	221.3	228.7	256.8	221.5	118.9	95.6	136.6

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Table 6.1.3—USDA conservation expenditures, by activity and program, fiscal years 1983-97[1], continued

Activity/program	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995 actual	1996 approp.	1997[2] request
								$ million[1]							
FS Stewardship Incentives Program (SIP)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.9	0.8	17.8	17.9	18.3	4.5	20.0
NRCS															
Colorado River Salinity Control Program	0.0	0.0	0.0	0.0	2.5	3.1	3.4	6.0	8.9	8.8	8.2	8.2	0.6	2.4	2.5
Forestry Incentives Program (FIP)	11.3	11.1	11.5	9.8	10.7	10.6	11.1	10.2	12.4	11.5	11.2	11.5	6.0	5.7	5.7
Great Plains Conservation Program (GPCP)	12.2	12.3	12.5	11.5	11.4	11.8	12.2	12.9	16.4	16.2	16.4	16.4	6.1	0.0	0.0
Wetland Reserve Program (WRP)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	7.4	9.9	8.0	20.6
Subtotal NRCS	23.6	23.4	24.0	21.4	24.6	25.5	26.7	29.1	37.6	36.5	35.8	43.5	22.5	16.1	28.7
Subtotal Cost-sharing	216.5	214.3	209.9	180.7	448.1	504.8	389.9	353.2	278.8	266.0	310.4	282.9	159.7	116.2	185.4
3. Public works project activities (NRCS):															
Emergency Watershed Protection	22.5	22.0	5.0	79.7	14.8	13.5	10.0	94.9	20.0	70.0	73.1	133.2	290.6	0.0	15.0
Flood Prevention (operations)	22.7	9.9	13.9	19.1	11.5	11.3	12.8	16.0	12.8	21.4	23.8	22.9	0.0	6.0	0.0
Resource Conservation and Development (RC&D)	14.4	9.7	8.5	7.7	7.2	7.06.7	4.2	5.7	6.5	2.6	4.6	2.5	0.0	0.0	
Small Watershed Program (operations)	160.6	87.6	88.0	80.8	82.7	83.4	83.7	81.7	82.6	89.6	101.3	106.9	0.0	34.0	40.0
Subtotal NRCS public works projects	220.3	129.1	115.4	187.3	116.2	115.2	113.2	196.8	121.1	187.5	200.8	267.6	293.1	40.0	55.0
4. Rental and easement payments (FSA & NRCS):															
Conservation Reserve Program (CRP)	0.0	0.0	0.0	0.0	410.0	760.1	1162.1	1393.7	1590.1	1612.5	1510.0	1728.8	1711.7	1750.0	1837.3
Water Bank Program (WBP)	8.8	8.8	8.8	8.4	8.4	8.4	9.0	12.2	13.1	17.1	17.1	7.4	0.9	0.0	0.0
Wetland Reserve Program (WRP)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.4	86.9	78.8	58.0	150.5
Subtotal rental and easement payments	8.8	8.8	8.8	8.4	418.4	768.5	1171.1	1406.0	1603.2	1629.6	1531.5	1823.0	1791.4	1808.0	1987.7
5. Conservation data and research:															
Agricultural Research Service	63.5	63.7	63.7	62.4	59.3	60.5	65.9	73.6	73.6	73.9	74.3	76.7	75.5	76.1	79.7
Cooperative State Research Service	27.9	29.6	32.8	31.3	31.0	33.1	34.5	40.6	50.6	53.9	49.8	48.0	50.1	48.2	45.6
Economic Research Service	5.0	7.7	5.4	4.0	4.0	3.1	3.0	4.6	5.5	5.8	6.3	5.0	5.0	5.0	5.0
Forest Service (forest research)	107.7	109.4	121.7	120.1	132.7	135.5	138.3	150.9	167.6	180.5	182.7	195.0	193.5	178.0	179.8
National Agricultural Library (water quality)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
NRCS programs															
River basin surveys	16.4	15.6	14.9	14.2	12.1	12.1	12.1	12.3	12.8	13.3	13.3	13.5	13.0	8.4	11.5
Soil surveys	51.4	53.5	54.8	54.3	58.2	67.7	68.2	68.1	69.8	72.6	72.6	73.9	72.6	76.6	77.7
Plant materials centers	3.8	4.0	4.1	3.9	4.6	4.9	5.0	7.2	7.9	8.1	8.1	8.9	8.1	8.9	9.0
Snow surveys	3.8	3.9	4.0	3.8	5.0	5.4	5.5	5.4	5.6	5.7	5.7	5.8	5.6	5.9	5.9
Subtotal NRCS	75.47	77.02	77.78	76.19	79.74	90.00	90.79	92.98	96.03	99.58	99.58	102.10	99.32	99.73	104.03
Subtotal conservation data and research	279.5	287.4	301.3	294.0	306.8	322.2	332.5	363.0	393.7	413.9	413.0	427.2	423.7	407.3	414.4
6. Conservation compliance and sodbuster (FSA & NRCS) (expenditures are included in other programs listed above):															
USDA total	1212.5	1117.5	1122.6	1158.7	1834.8	2290.5	2627.9	2960.0	3117.8	3297.2	3302.2	3669.9	3496.8	3200.0	3546.2

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[1] Derived from material provided by the Office of Budget and Program Analysis (OBPA) USDA. [2] Based on Administration's request prior to passage of the 1996 Farm Act. Does not inlcude new programs created by the 1996 Act.

(CSREES) provides information and recommendations on soil conservation and water quality practices to landowners and farm operators in cooperation with the State Extension Services and State and local offices of USDA agencies and Conservation Districts. In 1995, about 5 percent of extension education effort was directed to USDA's Water Quality Program activities, and 4 percent to sustainable agriculture (table 6.1.1).

Conservation Loans and Farm Debt Cancellation Easements. FSA provides loans to farmers for soil and water conservation, pollution abatement, and building or improving water systems. Loan activity dropped to zero in 1995, continuing a downward trend since 1990 (table 6.1.1). FSA may also acquire voluntary conservation easements as a means of helping farmers reduce outstanding loan amounts. Only 69 easements covering 5,700 acres were acquired in 1995, one-sixth the amount of 1990. FSA places conservation easements on foreclosed land being sold, or transfers environmentally sensitive lands to Federal and State agencies for conservation purposes. In 1995, FSA approved 56 property transfers for conservation purposes covering 13,351 acres.

Forestry Incentives Program (FIP). FIP was initiated in 1975 and provides cost-sharing up to 65 percent for tree planting and timber stand improvement for private forest lands of no more than 1,000 acres. Maximum payment per owner is $10,000 annually, but payments in 1995 averaged about $2,300 (table 6.1.1). More than 4,500 forest owners participated in the program in 1995, with 166,000 acres enrolled. NRCS administers the program and the Forest Service (FS) provides technical assistance.

Forest Stewardship Program (FSP). FSP was enacted in 1990 and is administered by the Forest Service. The program provides grants to State forestry agencies for expanding tree planting and improvement and for providing technical assistance to owners of nonindustrial private forest lands in developing and implementing forest stewardship plans to enhance multi-resource needs. A companion ***Stewardship Incentive Program (SIP)***, administered by the Forest Service through FSA, provides cost-sharing up to 75 percent for practices in the approved forest stewardship plans. Payments may not exceed $10,000 annually per landowner and practices must be maintained for at least 10 years.

Pesticide Record-Keeping. This provision established by the 1990 Farm Act requires private applicators of restricted-use pesticides to maintain records accessible to State and Federal agencies regarding products applied, amount, and date and location of application. The requirement became effective May 10, 1993, and is administered by the Agricultural Marketing Service.

Resource Conservation and Development Program (RC&D). RC&D was initiated in 1962. Through this program, NRCS assists multicounty areas in enhancing conservation, water quality, wildlife habitat, recreation, and rural development. The program provides technical and limited financial assistance for planning and installation of approved projects. In 1995, 277 active areas existed, up slightly from 1994 (table 6.1.1). During 1994-95, $13-$14 of State and local funds supplemented each dollar of Federal funding, up significantly from earlier years.

Small Watershed Program. Otherwise known as PL-566, this program was initiated in 1954. It assists State agencies and local units of government in flood prevention, watershed protection, and water management. Part of this effort involves establishment of measures to reduce erosion, sedimentation, and runoff. The program provides up to 100 percent of the construction costs for structural measures with flood prevention purposes and up to 50 percent of such costs for structural measures with other purposes. The program also provides 75 percent of the installation cost for nonstructural measures. Eligible watersheds must be 250,000 acres or less in size. In 1995, 34 local projects were authorized, down from earlier years (table 6.1.1). NRCS administers the program and provides technical assistance.

Data and Research Activities. The Agricultural Research Service (ARS) conducts research on new and alternative crops and agricultural technology to reduce agriculture's adverse impacts on soil and water resources. CSREES administers competitive grants and coordinates conservation and water quality research conducted by State Agricultural Experiment Stations and land-grant universities. The Economic Research Service (ERS) estimates economic impacts of existing and alternative policies, programs, and technology for preserving and improving soil and water quality; and with the National Agricultural Statistics Service (NASS), collects data on farm chemical use, agricultural practices, and costs and returns. The Forest Service (FS) conducts research on environmental and economic impacts of alternative forest management policies, programs, and practices. NRCS conducts river basin studies, soil surveys, snow surveys, and National Resource Inventories; it also supports plant materials centers.

Table 6.1.4—Resource conservation and related programs affecting agriculture, FY 1996 estimated expenditures

Agency and program	FY 1996 estimated expenditure
	$ Million
U.S. Department of Agriculture (USDA) programs:	
Conservation Reserve Program (CRP)	1,782
Wetlands programs	72
Water Quality Program	193
Other conservation	1,153
USDA total	3,200
U.S. Environmental Protection Agency (EPA) programs: [1]	
Water quality programs	526
Drinking water programs	184
Pesticide programs	109
EPA total	819
Army Corps of Engineers programs: [1]	
Dredge and Fill Permit Program (wetlands)	101
Flood control programs	1,252
Corps total	1,353
U.S. Department of the Interior (USDI) programs: [1]	
Range improvement	10
Water development and management	982
Water resources investigations	186
Wetlands conservation	7
Endangered species conservation	36
Natural resources research	148
USDI total	1,369
Federal total	6,741
State and local expenditures on USDA cooperative conservation programs	736

[1] Programs affect other resources as well as agriculture.

Sources: USDA, ERS, based on data from Office of Management and Budget; and USDA, Office of Budget and Program Analysis.

USDA Conservation Program Expenditures

Resource conservation and environmental programs or activities administered by USDA had estimated expenditures in FY 96 of $3.2 billion (table 6.1.4). USDA's expenditures represent 47 percent of Federal expenditures on resource efforts affecting agriculture, estimated to be $6.7 billion in FY 96. The other major Federal players are the U.S. Department of the Interior (USDI), the Army Corps of Engineers (Corps), and the U.S. Environmental Protection Agency (EPA). USDI and Corps programs affecting agriculture primarily deal with water resource conservation and management, including irrigation, flood control, and wetlands. EPA administers programs dealing with surface-water quality, drinking water and groundwater protection, and use of pesticides (for more details, see box, "Other Federal Conservation and Environmental Programs That Affect Agriculture," p. 268-269, and chapters 3.2, 6.2, and 6.5).

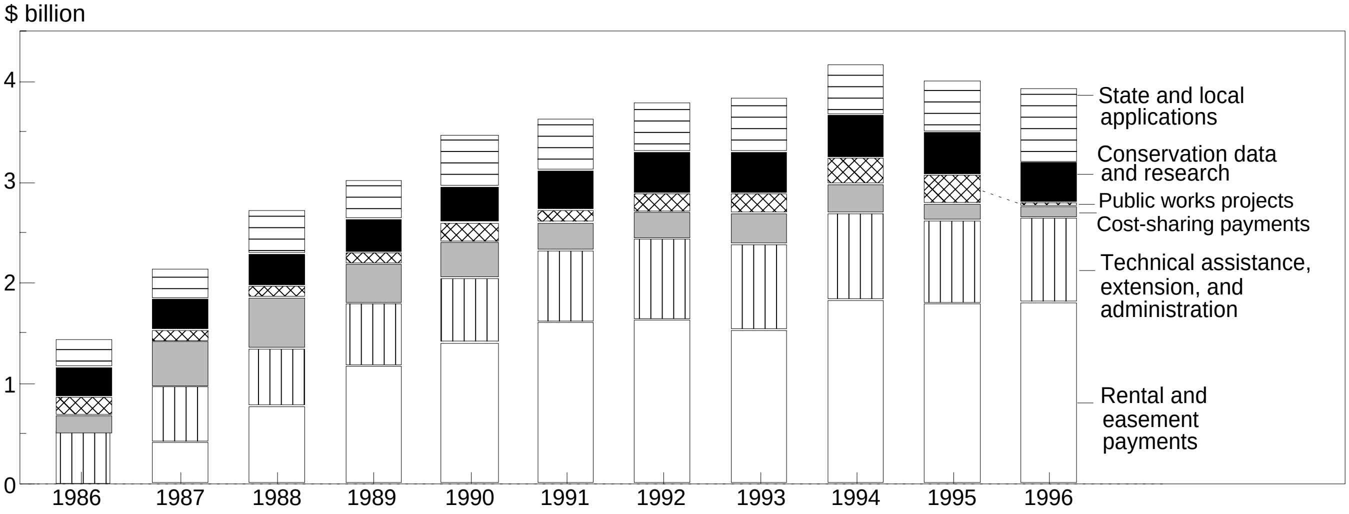
Programs administered at State and local levels also affect agriculture. All States support technical assistance for conservation and water quality through conservation or natural resource districts located at the county or multi-county level. In 1996, such support was $736 million. Also, all States fund cooperative extension education efforts and 44 States provide various incentives for farmers to use soil and water conservation and water quality practices. States and localities also provide support for cooperative regional water quality or estuary programs (see chapter 6.2, *Water Quality Programs*, for more details on State programs).

According to a Congressional Budget Office analysis, total funding committed to resource conservation under USDA conservation programs will grow by more than $2 billion over 1996-2002 ($300 million per year) as a result of the 1996 Farm Act. The 1996 Farm Act added conservation and environmental protection to the mission of the CCC charter, and provided for future funding of major conservation program such as the CRP, WRP, and EQIP through mandatory CCC allocations. For the first time, this places conservation funding on equal financial footing with commodity program funding. Although USDA must still submit an annual budget request that includes expected conservation and other spending, which is subject to an overall spending limit, funding these conservation programs through CCC should reduce the uncertainty associated with annual conservation program appropriations.

USDA Expenditures on Different Conservation Policy Approaches

Spending on conservation activities by USDA and State and local governments increased steadily until 1995 when budget tightening began occurring at all levels (fig. 6.1.1). At the Federal level, funding for ACP, GPCP, and watershed programs were cut significantly and funding was eliminated for the Water Bank Program. For 1996, USDA and related State and local government expenditures for conservation were nearly $4 billion, similar to 1995.

Figure 6.1.1--Conservation expenditures by USDA and related State and local programs, 1986-96



Source: USDA, ERS, based on Office of Budget and Program Analysis data.

Also changed has been the mix of USDA expenditures. Rental and easement payments accounted for over half of USDA conservation expenditures in 1995 (fig. 6.1.2, table 6.1.3). Since 1988, rental payments for land retired for conservation purposes have been the largest category of USDA conservation expense. The bulk of these were rental payments to participants in the Conservation Reserve Program (CRP) for land retired from production and placed into protective cover. Rental payments were also made for land enrolled in the Water Bank Program and easement payments for land accepted into the new Wetlands Reserve Program. Technical assistance and extension expenditures were $829 million in 1995 and accounted for almost 24 percent of the USDA total for conservation purposes. Only cost-sharing for practice installation, which accounted for less than 5 percent of USDA spending in 1995, was funded well below previous levels. High expenditures for public works projects reflected emergency measures required by the 1993 Midwest flood at over 8 percent of USDA spending.

The President's budget for 1997 shows declines from 1995 for public works project activities and conservation data and research but increases for technical assistance and extension, cost-sharing, and rental and easement payments. The budgeted increase in rental payments is for land expected to go into the Wetlands Reserve and re-enrollment of environmentally sensitive lands into the CRP as existing contracts expire.

Erosion and Pollutant Reductions from USDA Conservation Programs

USDA programs contribute to farmers' increasing use of management practices that reduce soil erosion and chemical applications or loads (table 6.1.5). The Water Quality Program (WQP) and the Agricultural Conservation Program (ACP) helped farmers implement integrated crop management (ICM), nutrient management, and pesticide management. According to a General Accounting Office report, during fiscal years 1992-94, USDA supported conservation measures on an average of 71 million acres under 565,000 agreements with land users annually under 10 cost-sharing programs and 7 land retirement programs. The 10 cost-sharing programs included ACP, CRSCP, ECP, FIP, GPCP, the Rural Clean Water Program, the Small Watershed Program, Soil and Water Conservation Loan Program, SIP, and WQIP. The seven land-retirement programs included CRP, the Emergency Wetland Reserve Program, conservation easements, Forest Legacy Program, Integrated Farm Management Program Option, WBP, and WRP.

USDA conservation programs have significantly reduced erosion from 1987 levels. For example, as of early 1995, the CRP had converted 36.4 million cropland acres to protective cover, reducing annual cropland erosion by an estimated 690 million tons (table 6.1.6). This was a drop of over one-fifth in annual cropland erosion from the 1987 level of 3 billion tons (see chapter 6.3, *Conservation Reserve Program*, for more detail). Compared with 1987,

Table 6.1.5—Major practices implemented under USDA conservation programs, fiscal 1988-95

Practice and program[1]	1988	1989	1990	1991	1992	1993	1994	1995
				Million acres treated				
Grass cover establishment:								
ACP	0.65	0.61	0.58	0.61	0.59	0.53	0.71	0.38
CRP	7.36	4.27	3.02	0.33	0.79	0.78	0	0
Grass cover improvement:								
ACP	1.37	1.17	0.96	1.00	1.00	1.12	1.25	0.88
CRP	0.47	0.29	0.17	0.04	0.09	0.11	0	0
Tree planting:								
ACP	0.16	0.13	0.12	0.13	0.12	0.13	0.13	0.20
CRP	0.50	0.41	0.19	0.09	0.10	0.12	0	0
FIP	0.16	0.16	0.15	0.18	0.16	0.18	0.19	0.14
Wildlife habitat establishment:								
ACP	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02
CRP	0.39	0.31	0.65	0.01	0.01	0.01	0	0
Cropland protective cover:								
ACP	0.75	0.64	0.58	0.61	0.65	0.48	0.41	0.02
Conservation tillage:								
ACP	0.45	0.33	0.43	0.41	0.56	0.60	0.53	0.21
WQP regional activities	NA	NA	NA	0.42	0.48	NA		
Strip cropping systems: ACP	0.14	0.12	0.15	0.12	0.10	0.08	0.07	0.05
Integrated crop management: ACP	--	--	0.03	0.20	0.28	0.32	0.38	0.34
Nitrogen management:[2]								
WQP Demo projects	0	0	NA	0.01	0.22	0.46	NA	NA
WQP HUA projects	0	0	NA	0.20	0.44	0.46	NA	NA
WQP regional activities	NA	NA	NA	0.13	0.19	NA	NA	NA
Phosphorus management:[2]								
WQP Demo projects	0	0	NA	0.01	0.13	0.25	NA	NA
WQP HUA projects	0	0	NA	0.07	0.43	0.25	NA	NA
Pesticide management:[2]								
WQP Demo projects	0	0	NA	0.04	0.08	0.18	NA	NA
WQP HUA projects	0	0	NA	0.13	0.58	0.18	NA	NA
WQP Chesapeake Bay	NA	NA	NA	0.22	0.25	NA	NA	NA
				Million acres served				
Grazing land protection: ACP	3.60	3.77	4.72	3.33	3.66	2.85	2.68	2.13
Irrigation water conservation: ACP	0.82	0.77	0.69	0.77	0.69	0.80	0.85	0.52
Terraces and diversions: ACP	1.07	0.93	0.62	0.70	0.75	0.62	0.80	0.65
Water impoundments: ACP	0.27	0.27	0.22	0.19	0.14	0.14	0.12	0.09
Sediment control structure: ACP	0.25	0.22	0.21	0.22	0.20	0.18	0.19	0.16
Sod waterways: ACP	0.22	0.17	0.18	0.26	0.20	0.16	0.26	0.16
				Number				
Agricultural waste systems:[2]								
ACP	1,947	1,753	2,348	2,912	3,844	4,108	4,116	3,132
WQP Demo projects	0	0	NA	123	162	NA	NA	NA
WQP HUA projects	0	0	NA	200	325	NA	NA	NA
WQP regional activities	NA	NA	NA	581	74	NA	NA	NA
Wellhead protection:								
WQP Demo projects	0	0	NA	62	463	NA	NA	NA
WQP HUA project	0	0	NA	2,304	1,553	NA	NA	NA

[1] ACP = Agricultural Conservation Program. CRP = Conservation Reserve Program. FIP = Forestry Incentives Program. HUA = Hydrologic Unit Area. WQP = Water Quality Program. No data available for programs or projects not listed.

[2] Some of the practices implemented in the WQP in 1991 and 1992 were cost-shared under ACP and are duplicative.

NA = Not available.

Source: USDA, ERS, based on annual reports of the various programs.

Table 6.1.6—Impacts of USDA conservation programs on erosion and chemicals, fiscal 1988-95[1]

Impact and program	1988	1989	1990	1991	1992	1993	1994	1995
				Million tons				
Erosion reduced/soil saved by:								
Conservation Reserve Program[2]	514	596	644	654	672	692	692	692
Conservation compliance[3]	0	0	0	NA	236	458	465	527
Agricultural Conservation Program[4]	40	34	33	34	30	29	29	18
Conservation Technical Assistance and GPCP[4, 5]	463	353	353	282	298	321	325	284
Annual Acreage Reduction Program[4, 6]	107	62	55	60	39	46	29	40
WQP regional activities	NA	NA	NA	2	NA	NA	NA	NA
				Million lbs.				
Nitrogen application reduced by:								
WQP Demo projects[4]	NA	NA	NA	0.9	8.9	NA	NA	NA
WQP HUA projects[4]	NA	NA	NA	1.7	38.5	NA	NA	NA
WQP regional activities[4]	NA	NA	NA	8.1	5.9	NA	NA	NA
Phosphorus application reduced by:								
WQP Demo projects[4]	NA	NA	NA	0.2	7.3	NA	NA	NA
WQP HUA projects[4]	NA	NA	NA	1.5	57.4	NA	NA	NA
WQP regional activities[4]	NA	NA	NA	4.4	5.8	NA	NA	NA
				1,000 tons				
Salt load reduced by:								
Colorado River Salinity Control Program[2]	62	75	92	105	127	163	191	212
				1,000 lbs. active ingredient				
Pesticide load reduced by:								
WQP Demo projects[4]	NA	NA	NA	48	66	NA	NA	NA
WQP HUA projects[4]	NA	NA	NA	191	462	NA	NA	NA

NA = Not available.

[1] No data or estimates available for programs not listed. The erosion reductions are estimates based on long-term national weather patterns, and do not reflect annual variations in weather.

[2] All lands treated by program, including those first treated in past years with practices that are still effective.

[3] Minimum estimate based on 18, 35, 46, and 54 million acres of additional lands with a conservation plan fully implemented for 1992-95 respectively, excluding land in the CRP or land eroding at or below the soil loss tolerance (T) level in 1987. The average erosion reduced was assumed to be approximately 10 tons/acre/year, based on SCS status reviews of HEL-determined fields with a fully implemented plan, excluding those in the CRP.

[4] Reduction on lands newly treated during year only. No estimates exist of continuing reductions on lands treated in prior years.

[5] Includes partial double counting with CRP, compliance, and ACP programs.

[6] Assumes average reduction of 2 tons/acre/year. While this is a commodity program, idling the land and reducing cultivation preserves soil that would otherwise erode.

Source: USDA, ERS, based on annual program reports of the various agencies.

Conservation Compliance (see chapter 6.4, *Conservation Compliance*) was estimated to reduce soil erosion an additional 18 percent or 572 million tons as of 1995 (excluding acreage going into the CRP or already eroding at or below the tolerance level).

USDA programs are also reducing and improving fertilizer and pesticide use, thereby reducing chemicals entering surface and ground waters. Lands in the CRP receive lower applications of fertilizer and pesticides than if they had remained active cropland. WQP participants who implement improved nutrient management use less nitrogen and less phosphorus (table 6.1.6). Pesticide applications have also fallen. These reductions, although insignificant compared with total use in the United States, can improve water quality in environmentally sensitive areas. The Colorado River Salinity Control Program reduced the salt load entering the river by an estimated 212,000 tons in 1995. The downstream benefits (reduction in damages caused by salinity) have been estimated to be at $38 - $70 annually per ton of salt reduction, or $8 - $15 million for 1995.

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Other Federal Conservation and Environmental Programs That Affect Agriculture

The Environmental Protection Agency (EPA), the U.S. Army Corps of Engineers, and the U.S. Department of the Interior administer programs that affect resource use in agriculture. In some cases, these programs limit farmers' management decisions by restricting land use, chemical use, water use, and cropping practices.

EPA-Administered Programs

Clean Water Act is the Nation's most important water quality protection law. Originally passed in 1972, the Act's goal is to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters." The Act contains a number of provisions that affect agriculture (see chapter 6.2, *Water Quality Programs*, for more detail on the following programs).

Clean Lakes Program, reauthorized by Section 314 of the Clean Water Act, authorizes EPA grants to States for lake classification surveys, diagnostic/feasibility studies, and for projects to restore and protect lakes.

Nonpoint Source Program, established by Section 319 of the Clean Water Act, requires States and U.S. territories to identify navigable waters that cannot attain water quality standards without reducing nonpoint source pollution and develop management plans to reduce nonpoint source pollution.

National Estuary Program, established by Section 320 of the Clean Water Act, provides for the identification of nationally significant estuaries that are threatened by pollution; for preparation of conservation and management plans; and for Federal grants to State, interstate, and regional water pollution control agencies to implement the plans.

National Pollutant Discharge Elimination System (NPDES) Permit Program, established by Section 402 of the Clean Water Act, controls point-source discharges from treatment plants and industrial facilities (including large animal and poultry confinement operations).

Coastal Nonpoint Pollution Control Programs. In 1990, amendments to the Coastal Zone Management Act, administered by the National Oceanic and Atmospheric Administration and EPA, required that States with coastal zone management programs develop and implement programs to control nonpoint sources of pollution.

Regional programs for addressing water quality problems exist as cooperative efforts among State agencies, EPA, and USDA.

Safe Drinking Water Act (SDWA) requires the EPA to set standards for drinking water quality and requirements for water treatment by public water systems. Also, SDWA requires States to establish a wellhead protection program to protect public water system wells from contamination by chemicals, including pesticides, nutrients, and other agricultural chemicals.

Pesticide programs, established by the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), provide the legal basis under which pesticides are regulated. A pesticide can be restricted or banned if it poses unacceptable risks to human health or the environment. The re-registration process, mandated in 1988 for all active ingredients then on the market, has resulted in manufacturers dropping many less profitable products rather than paying the registration fees. (See chapter 3.2, *Pesticides*, for more discussion.)

Comprehensive State Ground-Water Protection Program (CSGWPP), initiated by EPA in 1991, coordinates operation of all Federal, State, tribal, and local programs that address groundwater quality. States have the primary role in designing and implementing CSGWPP's in accordance with distinctive local needs and conditions.

Continued--

Other Federal Conservation and Environmental Programs That Affect Agriculture (cont.)

U.S. Army Corps of Engineers-Administered Programs

Dredge and Fill Permit Program, established by Section 404 of the Clean Water Act, regulates dredging, filling, and other alterations of waters and wetlands, including wetlands owned by farmers. USDA has authority to make wetland determinations on agricultural land. (Discussed more in chapter 6.5, *Wetlands Programs*.)

Flood control activities include the construction, rehabilitation, and operation of dams, levees, and other facilities for flood control. An emergency supplemental appropriation in 1994 provided funds to complete repair of non-Federal levees damaged by the Midwest floods of 1993. (Discussed more in chapter 6.5, *Wetlands Programs*.)

U.S. Department of the Interior-Administered Programs

Endangered Species Act is the Nation's chief statute to conserve endangered or threatened species and their ecosystems. When a species is designated as threatened with extinction, a recovery plan is developed to protect it from further population declines. The plan could include restrictions on cropping practices, water use, and pesticide use. (Discussed more in chapter 1.2, *Land Tenure*.)

Endangered Species Conservation provides State grants for the conservation of threatened and endangered species and for monitoring the status of candidate species.

Range Improvements, including rehabilitation and protection, are undertaken by the Bureau of Land Management with a percentage of receipts from grazing of livestock on the public lands.

Water Development and Management activities in the 17 Western States by the Bureau of Reclamation include construction, rehabilitation, and operation of dams and facilities for water conservation, irrigation, municipal and industrial use, flood control, recreation, and electric power generation. (Discussed more in chapter 2.1, *Water Use and Pricing*.)

Water Resources Investigations by the U.S. Geological Survey include monitoring and appraisals of the Nation's water resources to support Federal, State, and local government decisions on water development, management, and quality; and energy development.

Wetlands Conservation includes obtaining real property interest in lands or waters, the restoration or enhancement of habitat, and training and development for wetlands management. (Discussed more in chapter 6.5, *Wetlands Programs*.)

6.2 Water Quality Programs

Several approaches for protecting water quality have been developed at the Federal and State levels. These approaches use a variety of incentive mechanisms for reducing pollution discharges. Pollution from factories and other point sources is controlled through regulations and penalties. In contrast, policies and programs for reducing pollution from agriculture and other nonpoint sources are mostly based on voluntary approaches providing education, technical, and cost-sharing assistance.

Contents

Water quality protection has a been a major component of U.S. environmental policy since the passage of the Federal Water Pollution Control Act of 1972 (known since as the Clean Water Act). Most of the focus of clean water legislation has been on point sources, primarily the discharge from factories and municipal sewage treatment plants. A technology- and performance-based regulatory approach has achieved substantial reductions in point source pollution. In recent years, attention has turned to nonpoint sources, primarily runoff from agricultural operations. Federal and State programs have been implemented to address agricultural source pollution. Federal water quality programs are administered by EPA and by USDA (see box, p. 271). Some EPA and State-administered programs require mandatory actions, while USDA programs are voluntary. Even with these efforts, many water quality problems remain (see chapter 2.2, *Water Quality*, for a discussion of water quality status and trends, and pollution from agriculture).

EPA Programs Affecting Agriculture

While Federal water quality laws tend to focus on point sources, they do not ignore nonpoint sources. The primary Federal law, the ***Clean Water Act*** (CWA), addresses both point and nonpoint source pollution. Pollution from point sources is subject to both (1) technology-based controls, which consist of uniform, EPA-established standards of treatment that apply to certain industries and municipal sewage treatment facilities; and (2) water quality-based controls that invoke State water quality standards for receiving waters. These standards consist of designated uses to be made of the streams and the criteria necessary to protect those uses. Individual discharge requirements are based on the effluent quality needed to ensure compliance with the water quality standards. Most States are using the technology-based approach but some, such as Oregon, Idaho, and North Carolina, are trying the water-quality based approach in some watersheds. The individual effluent limits are enforced through the National Pollutant Discharge Elimination System (NPDES) permits. Large confined animal operations (over 1,000 animal units) fall under the NPDES

Federal Water Quality Programs Affecting Agriculture in 1996

EPA-Administered Programs

Clean Water Act Programs:
  Clean Lakes Program (Section 314)
  Nonpoint Source Program (Section 319)
  National Estuary Program (Section 320)
  National Pollutant Discharge Elimination System (Section 402)

Coastal Nonpoint Pollution Control Programs

Regional Programs

Safe Water Drinking Act

Pesticide Programs

Comprehensive State Ground-Water Protection Program

USDA-Administered Programs

Agricultural Conservation Program (ACP):
  Water Quality Incentives Projects (WQIP)
  Integrated Crop Management (ICM) Practice

Conservation Technical Assistance (CTA) Program

Colorado River Salinity Control Program (CRSCP)

Water Quality Program (WQP):
  Research and development
  Education, technical, and financial assistance
  Data base development and evaluation

Farm Bill Programs (1985 and 1990):
  Conservation Compliance
  Conservation Reserve Program (CRP)
  Wetland Reserve Program (WRT)
  Integrated Farm Management Program
  Pesticide Record-Keeping

Great Plains Conservation Program

Small Watershed Program

Resource Conservation and Development Program

system. Over 6,000 operations are large enough to require an NPDES permit. However, enforcement has been a problem, and many facilities lack permits (Westenbarger and Letson, 1995).

Section 319 of the CWA calls for controls on nonpoint sources of pollution, including agriculture, but does not provide direct authorities to regulate these sources. The NPDES permit system is unsuited for nonpoint source pollution because discrete discharge points cannot be observed. Because of the diverse and site-specific nature of nonpoint source pollution, States are given primary responsibility. State and local governments develop nonpoint source control plans that can include regulatory measures but mostly emphasize voluntary actions. The ***Nonpoint Source Program***, established by Section 319, authorizes grants to States for developing and promoting nonpoint source management plans. States have established a number of watershed projects under this program that involve many local, state, and Federal stakeholders. EPA's role is to provide program guidance, technical support, and limited funding. Through 1995, EPA has provided over $274 million in grants to such projects, of which $107 million was for agriculture.

The ***Coastal Zone Management Act Reauthorization Amendments*** (CZARA) added important nonpoint source (NPS) water pollution requirements to the Coastal Zone Management Act. This is the first federally mandated program requiring specific measures to deal with agricultural nonpoint sources. CZARA requires that each State with an approved coastal zone management program submit to EPA and to the National Oceanic and Atmospheric Administration a program to "implement management measures for nonpoint source pollution to restore and protect coastal waters." A list of economically achievable measures for controlling agricultural NPS pollution is part of each State's management plan. States can first try voluntary incentive mechanisms, but must be able to enforce management measures if voluntary approaches fail. Implementation of plans is not required until 1999. In general, annual costs of CZARA management measures are estimated to be less than $5,000 per farm for most farm sizes. Exceptions are grazing management measures for larger farms in the West, and manure management measures on larger dairy farms (Heimlich and Barnard, 1995).

The Safe Drinking Water Act (SDWA) requires the EPA to set standards for drinking-water quality and requirements for water treatment by public water systems. The SDWA authorized the ***Wellhead Protection Program*** in 1986 to protect supplies of ground water used as public drinking water from contamination by chemicals and other hazards, including pesticides, nutrients, and other agricultural chemicals. The program is based on the concept that land-use controls and other preventive measures can protect ground water. Currently, 43 States have an EPA-approved wellhead protection program.

The ***Comprehensive State Ground Water Protection Program (CSGWPP),*** established in 1991, coordinates all Federal, State, tribal, and local programs that address groundwater quality. States have the primary role in designing and implementing CSGWPP's in accordance with local needs and conditions. EPA has approved programs in 5 States, and plans from an additional 13 States are under review.

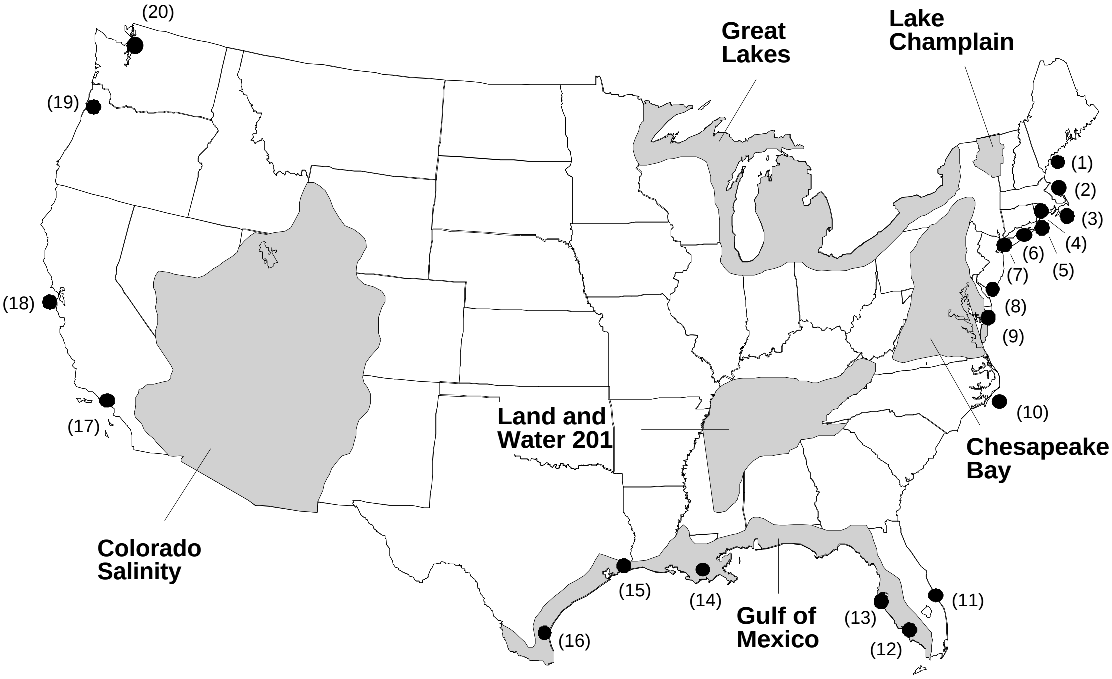
EPA also administers some multi-agency regional programs targeted at particular water bodies (fig. 6.2.1). EPA's ***National Estuary Program*** helps States to develop and carry out basin-side, comprehensive programs to conserve and manage their estuary resources (fig. 6.2.1). The ***Clean Lakes Program*** authorizes EPA grants to States for lake classification surveys, diagnostic/feasibility studies, and for projects to restore and protect lakes.

State Programs

Some 44 States have passed laws or instituted programs that either protect water quality directly, or indirectly by affecting some aspect of agricultural production that is associated with the generation of agricultural nonpoint source pollution (table 6.2.1). Some of these laws are in response to Federal laws such as the Clean Water Act. Others are in response to chronic problems such as nitrates or pesticides in ground water. States use a variety of approaches for addressing water quality problems: controls on inputs or practices, controls on land use, economic incentives, and education programs.

Input controls are primarily directed at pesticides and nutrients. Most States require certification of pesticide applicators. Some States restrict where particular chemicals can be used, usually in response to observed groundwater problems. Nutrient management plans are required in 16 States, usually in areas affected by groundwater contamination.

Figure 6.2.1--Estuary and regional programs for water quality, 1996



● Estuaries of national significance: (1) Casco Bay, (2) Massachusetts Bay, (3) Buzzards Bay, (4) Narragansett Bay, (5) Peconic Bay, (6) Long Island Sound, (7) New York-New Jersey Harbor, (8) Delaware Bay, (9) Delaware Inland Bays, (10) Albemarle-Pamlico Sound, (11) Indian River Lagoon, (12) Sarasota Bay, (13) Tampa Bay, (14) Barrataria-Terrebonne Estuary, (15) Galveston Bay, (16) Corpus Christi Bay, (17) Santa Monica Bay, (18) San Francisco Bay, (19) Tillamook Bay, (20) Puget Sound, (21) San Juan Bay (Puerto Rico, not pictured).

Technical assistance provided by the Natural Resources Conservation Service.
Source: USDA, ERS, based on Natural Resources Conservation Service information.

Table 6.2.1—Summary of State water quality mechanisms, 1996[1]

State	Nutrient plan requirement	Restrictions on			Cost-share	Farm*A*Syst[2]
		Pesticide	Chemigation	Sediment		
Alabama					X	
Arizona	X	X			X	
Arkansas						X
California		X				
Colorado	X		X			
Connecticut	X			X	X	
Delaware				X	X	
Florida	X	X	X	X	X	X
Georgia			X		X	
Hawaii			X	X		
Idaho	X		X	X	X	
Illinois			X	X	X	X
Indiana					X	
Iowa		X	X	X	X	
Kansas			X		X	X
Kentucky	X					X
Maine				X		
Maryland	X	X		X	X	
Michigan	X			X		X
Minnesota	X		X	X	X	X
Mississippi					X	
Missouri					X	X
Montana				X	X	X
Nebraska	X		X		X	
Nevada			X			
New Hampshire			X			
New Jersey		X			X	
New Mexico						X
New York			X			
North Carolina			X		X	
North Dakota			X			X
Ohio				X	X	
Oklahoma	X			X	X	
Oregon						X
Pennsylvania	X			X	X	
Rhode Island						
South Carolina			X		X	
South Dakota			X	X	X	X
Utah					X	
Vermont	X					
Virginia	X	X			X	X
Washington			X			
Wisconsin	X	X	X	X	X	X
Wyoming	X			X		

[1] Mechanisms may apply only under certain conditions or in certain localities.[2] Farmstead Assessment System helps farmers, ranchers, and rural residents to evaluate pollution risks on their properties and to identify remedial actions.
Sources: USDA, ERS, based on Ribaudo and Woo, 1991; Gadsby, 1996; Jackson, 1996.

Chemigation is banned or tightly controlled in 19 States.

Practices for controlling soil erosion to address water quality problems are required in 18 States. In most, best management practices (BMP's) are required if a complaint is filed by a citizen or government agency. Some States require erosion control plans on cropland, but actual implementation of BMP's is contingent on the availability of cost-share funds.

As animal operations become larger, more States are looking at ways of protecting environmental quality from animal waste. Large confined animal operations can present major water quality problems at the local level. Large operations (greater than 1,000 animal units) are subject to the NPDES point-source permits of the Clean Water Act. However, these permits address only storage of manure on the site, and not disposal. Pennsylvania is the first State to pass a comprehensive nutrient management law aimed at concentrated animal operations. Animal operations with over two animal units per acre of land available for spreading must have a farmlevel nutrient management plan that demonstrates that waste is being safely collected and disposed. An animal unit is defined as 1,000 pounds of live weight.

Land-use laws that affect agriculture are being used by municipalities, counties, and other local governments. Land-use controls include zoning, land acquisition, and easements targeted to areas deemed critical for protecting water resources. Zoning ordinances are used in many areas, especially around the rural-urban fringe, to ban confined animal operations.

Economic incentives for water quality primarily take the form of cost-sharing; 27 States have cost-share programs for soil conservation and other practices. Tax credits are used to a much lesser degree. (Many States have fertilizer taxes, which can be a negative incentive, but these are for revenue generation rather than environmental protection.)

State water quality laws are often driven by court decisions brought about by citizen suit. For example, in hearing a citizen suit brought against a dairy operation in New York, the Second Circuit Court of Appeals made a ruling that could expand the point-source designation of concentrated animal feeding operations to cover all associated lands used for manure disposal (Martin, 1996).

A national voluntary program that originated from local needs is Farm*A*Syst, developed in Wisconsin by state Extension staff, with support from USDA and EPA, to protect farm water supplies. Farm*A*Syst helps farmers, ranchers, and rural residents identify and reduce agricultural and household sources of pollution. Using assessment worksheets, farmers and other rural landowners evaluate structures and management practices for their pollution risks. Once aware of potential problems, landowners can take appropriate action. All 50 States have expressed some interest in the program, and it is being implemented in 15. Farm*A*Syst is also being integrated into USDA and EPA water quality programs.

USDA Programs

In FY 1995, the USDA spent an estimated $3.5 billion on voluntary resource conservation and other environmental programs and activities, many of which addressed water quality (see chapter 6.1, *Conservation and Environmental Programs Overview*). USDA uses six broad approaches to achieve conservation and environmental goals, including: (1) technical assistance and education, (2) financial assistance (cost-sharing and incentive payments), (3) public works projects, (4) rental and easement programs, (5) data and research programs, and (6) compliance programs “linked” to commodity and other USDA program benefits. Typically one or two of these approaches are evident in the many programs and activities USDA has used to address water quality and pollution prevention. For example, the Agricultural Conservation Program (ACP) and the Colorado Salinity Control Program (CRSCP) provided technical assistance (by the Natural Resources Conservation Service) and cost-sharing (by the Farm Service Agency) for installation of BMP’s. Rental and easement programs (primarily land retirement programs) pay farmers to take land out of production and place it in conservation uses and provide technical assistance to help manage retired land. Technical assistance plays a crucial role in programs that are linked to commodity programs, such as Conservation Compliance.

USDA research programs complement the other five approaches. Activities include: (1) research on new and alternative crops and agricultural technologies to reduce agriculture’s harmful impacts on water resources; (2) research that estimates the economic impacts of policies, programs, and technologies designed to improve water quality and prevent pollution; and (3) environmental and conservation data collection. USDA also administers competitive grants and coordinates conservation and water quality research conducted by State Agricultural Experiment Stations and land grant universities.

The 1996 Federal Agriculture Improvement and Reform Act (1996 Farm Act) continues the same approaches but, beginning in 1997, consolidates some

Addressing Water Quality in the 1996 Farm Act

The Federal Agriculture Improvement and Reform Act of 1996 (the 1996 Farm Act) made significant changes in how USDA provides support to landowners for adopting conservation practices. The Act combined the functions of the Agricultural Conservation Program (ACP), Great Plains Conservation Program (GPCP), Water Quality Incentives Projects, and Colorado River Salinity Control Program into a single program, the ***Environmental Quality Incentives Program (EQIP)***. EQIP is to provide financial assistance to farmers and ranchers such that environmental benefits per dollar expended are maximized. Whereas previous USDA conservation assistance was often available on a first-come, first-serve basis to farmers and ranchers, EQIP will be targeted to priority conservation areas and identified problems outside of priority areas. Assistance will be provided only to those farmers and ranchers facing the most serious threats to soil, water, and related natural resources, including grazing lands, wetlands, and wildlife habitat. Contracts will be for 5 to 10 years, giving farmers the chance to learn to use new practices successfully. Cost-sharing may pay up to 75 percent of the costs of installing approved practices. The annual payment limit is $10,000, with a maximum of $50,000 per contract. Half of the appropriated funding for the program is targeted at practices or systems relating to livestock production. However, owners of large confined livestock operations (generally over 1,000 animal units, but States may request another definition based on environmental circumstances) are not eligible for cost-share asistance for installing animal waste storage or treatment facilities.

The ***Conservation Farm Option*** of the 1996 Farm Act is a pilot program that will provide producers of wheat, feed grains, cotton, and rice who have acres enrolled in production flexibility contracts the opportunity to receive one consolidated payment for implementing a 10-year conservation plan in lieu of separate payments from CRP, WRP, and EQIP (see chapter 6.1, *Conservation and Environmental Programs Overview*).

Table 6.2.2—Summary of ACP expenditures and acres treated for water quality purposes, FY 1991-95

Item	1991	1992	1993	1994	1995
Expenditures, by category:			*$ million*		
Integrated crop management	0.8	1.3	1.4	1.7	1.8
Water Quality Incentive Project	NA	0.3	1.9	4.3	6.5
Animal waste structures	15.9	18.2	19.0	21.9	16.4
Other	13.8	16.9	15.7	16.4	11.9
Total	30.5	36.7	38.0	44.2	36.6
Percent of expenditures, by purpose:			*Percent of water quality expenditures*		
Sediment	15.9	16.0	14.9	13.4	13.2
Animal waste	60.4	56.0	55.1	56.3	56.4
Nutrients	15.7	15.7	15.8	18.4	17.6
Pesticides	1.9	3.1	3.0	3.9	4.9
Salinity	2.6	2.4	2.6	2.4	3.1
Other	3.5	6.8	8.6	5.6	4.7
Total	100.0	100.0	100.0	100.0	100.0
Acres treated, by major practice:			*1,000 acres treated*		
Water quality incentive practice	NA	47.6	250.9	551.7	822.1
Integrated crop management	137.7	221.0	237.1	345.7	284.7
Cropland protective cover	225.8	257.1	189.2	163.9	9.2
Grazing land protection	46.2	88.5	123.0	89.2	73.6
No-till	57.6	74.9	69.8	92.9	54.2
Permanent vegetative cover	60.3	64.2	67.7	85.1	43.8
Irrigation water conservation	66.1	76.4	59.6	105.0	44.1

NA - WQIP not in effect
Source: USDA, ERS, based on Farm Service Agency data.

programs and increases the targeting of conservation and water quality efforts to priority problem areas (see box, "Addressing Water Quality in the 1996 Farm Act" for more detail). USDA programs that addressed water quality in 1995-96 are described below.

Agricultural Conservation Program (ACP)

The ACP provided financial assistance to agricultural producers to help solve a wide range of agricultural conservation and environmental problems, including water quality. Program activities included prevention of soil loss, water conservation, improvement of water quality, conservation of forest and wildlife resources, and pollution abatement. With several important exceptions, ACP funds were not targeted to specific geographic areas. About 100 technical practices were eligible for ACP cost-share funds. Up to 75 percent of the total cost of implementing the practice could be payed by ACP, with a maximum of $3,500 per recipient per year. ACP also reimbursed the Natural Resources Conservation Service (NRCS) for technical assistance in planning and implementing technical practices.

ACP was traditionally used to address soil erosion and water conservation issues. In recent years, as concern over water quality grew, more ACP resources were devoted to water quality practices. Cost-share expenditures on practices whose primary purpose was water quality rose from $13.4 million in 1988 to $44.2 million in 1994 (table 6.2.2), or from 7.1 percent of ACP expenditures to 23.1 percent (USDA, CFSA, 1995a). By 1994, almost all of USDA's water quality cost-share funds came from ACP.

Evidence suggests that profitability is the primary factor for farmers adopting new practices (Logan, 1990; Camboni and Napier, 1994; Magleby and others, 1989). Practices most frequently cost-shared by ACP included conservation tillage, irrigation water management, and nutrient management. All have been shown to increase net returns in many parts of the country.

Conservation Technical Assistance (CTA)

Conservation Technical Assistance provides technical assistance to farmers for soil and water conservation and water quality practices, and is administered by NRCS. CTA provides technical assistance to farmers adopting practices cost-shared under ACP, and to other producers who ask for assistance in adopting approved NRCS practices. In 1995, the CTA program spent $7.6 million on water quality-related assistance, apart from those activities directly related to the Water Quality Program (see below). This includes assistance provided to programs run by agencies other than USDA (see below).

Water Quality Incentive Projects (WQIP)

The Water Quality Incentives Projects was created by the 1990 Food, Agriculture, Conservation and Trade Act, and was administered as an ACP practice. The goal of WQIP was to reduce agricultural pollutants through sound farm management practices that restore or enhance water resources compromised by agricultural nonpoint source pollution. Areas eligible for WQIP included: watersheds identified by States as being impaired by nonpoint source pollution under Section 319 of the Clean Water Act; areas identified by State agencies for environmental protection and so designated by the Governor; and areas where sinkholes conveyed runoff directly into ground water. A total of 242 projects were started during FY 1993-95.

Eligible producers entered into 3- to 5-year agreements with USDA to implement approved management practices on their farms, as part of an overall water quality plan, in return for an incentive payment. The WQIP supported 39 different practices for protecting water quality (table 6.2.3). Consistent with practices funded under ACP, these were the conservation practices most likely to increase net farm returns.

Table 6.2.3—Major practices installed under WQIP, FY 1992-95

Practice	Acres
	1,000 acres
Conservation Cropping Sequence	181.1
Conservation Tillage	140.4
Crop Residue Use	78.6
Integrated Crop Management	305.6
Irrigation Water Management	152.4
Nutrient Management	349.5
Pasture and Hayland Management	123.0
Pest Management	273.7
Waste Utilization	124.2

Note - one acre treated in two different years with the same practice is counted as two acres treated.
Source: USDA, ERS, based on FSA program data.

Integrated Crop Management (ICM)

Integrated crop management was instituted in 1990 on a trial basis as part of the ACP. ICM promoted the efficient use of pesticides and fertilizers in an environmentally sound and economical manner. ICM provided 75-percent cost sharing, not exceeding $7 per acre for most field crops or $14 per acre for horticultural and specialty crops. Cost sharing was made available for up to 3 years for practices including pest scouting services, soil testing, or the rental of specialized machinery. In 1992, ICM was included as an eligible practice under WQIP, where it received a flat incentive payment of up to $10 per acre for field crops and $20 per acre for specialty crops. From 1990 to 1993, ICM was implemented on about 830,000 acres.

An analysis of the first year of ICM on four crops grown in four States indicated limited success (Osborn and others, 1994): nitrogen fertilizer reductions of 16 to 32 percent per acre on corn, wheat, and cotton were found. Use of other fertilizers (phosphorus and potassium) were largely unaffected. ICM's effect on herbicide use varied by crop. ICM resulted in a net increase in total herbicide use on corn, no significant effect on soybeans, and a decrease on wheat.

Health and environmental risks from pesticide applications were apparently reduced by ICM in some instances, while in others they were increased. An index that accounts for risks to farmworkers, consumers, and the environment from pesticide applications indicated that ICM generally reduced risks in its first year (Dicks and others, 1991). However, ICM impacts were not uniform. About 40 percent of the sampled farms demonstrated a net increase in the index or a negative environmental impact, often due to a change in the mix of chemicals used. Producers switched to chemicals that can be applied at lower rates but leach more easily or are more toxic. Simply reducing chemical applications may not provide adequate environmental protection from pesticides. The toxicity or leaching characteristics of new chemicals must be considered, as well as changes in application strategies.

Colorado River Salinity Control Program (CRSCP)

The Colorado River Salinity Control Program was started in 1984 to identify salt source areas in the Basin; assist landowners and operators in installing practices to reduce salinity in the Colorado River; carry out research, education, and demonstration activities; and monitor and evaluate the activities being performed. The Colorado River is the primary source of water for over 18 million people in Arizona, California, Colorado, Nevada, New Mexico, Utah, Wyoming, and Mexico. Water is used for irrigated agriculture, generating hydroelectric power, and municipal and industrial purposes. CRSCP was jointly administered by USDA and the U.S. Department of the Interior. The Bureau of Reclamation constructed salinity control structures for water distribution systems, and USDA provided technical and financial assistance to help irrigators implement improved irrigation systems.

The improved irrigation systems were designed to increase irrigation efficiency and to reduce the movement of salt into the ground water. Efforts included installing more efficient sprinklers, installing pipe, and lining delivery canals. Landowners who wish to participate, once their application was approved, submitted to a contract of 3 to 10 years. Besides agreeing to build and install the salinity control project, the landowner agreed to operate and maintain the project for as long as 25 years. The cost-shares mitigated the upfront costs of more efficient systems, which might otherwise have discouraged landowners.

Through 1994, 150,000 acres had been treated, out of 360,000 acres originally identified as needing treatment (U.S. GAO, 1995b). The program has conserved about 300,000 acre-feet of water (USDA, CFSA, 1995b). Salt loadings are down 191,223 tons per year (U.S. GAO, 1995b), 38 percent of the total reduction believed possible. The cost-effectiveness of the project ranges from $38 to $70 per ton of salt removed (U.S. GAO, 1995). Salt levels at the three monitoring stations have remained below the limits instituted under the Clean Water Act, thus satisfying the program's goal.

USDA's Water Quality Program

In 1990, USDA made a commitment to protect the Nation's waters from contamination by agricultural chemicals and waste products by establishing the Water Quality Program (WQP). The WQP was in response to a Presidential initiative in the 1990 budget for enhancing water quality. The initiative integrates the combined expertise of four Federal departments (USDA, EPA, Interior, and Commerce) to promote the use of environmentally and economically sound farm production practices, and to develop improved chemical and biological pest controls. The WQP in 1996 was in its seventh year, with annual expenditures ranging from $83 to $116 million (table 6.2.4).

The WQP strives to (1) determine the precise nature of the relationship between agricultural activities and water quality; and (2) develop, and induce the adoption of, technically and economically effective agrichemical management and agricultural production strategies that protect surface- and groundwater quality (USDA, 1993). The WQP contains three major components: (1) research and development; (2) education, technical, and financial assistance; and (3) database development and evaluation. The scale of the program, and the integration of research and database development with the traditional education, technical, and financial assistance projects, makes this program unique to USDA. Originally intended as 5-year program, USDA funding for limited program activities is projected beyond 1999 (USDA, ERS, 1994).

WQP research has improved our understanding of the relationship between water quality and production practices in the Midwest. In particular, the Management System Evaluation Area (MSEA) efforts have resulted in a number of improvements in nitrogen management, herbicide management, crop management, and irrigation water management. The MSEA findings are improving USDA's ability to provide farmers with information on practices that are sound economically, agronomically, and environmentally.

The Hydrologic Unit Area (HUA) and Demonstration Projects (DP), which target education, technical, and financial assistance in areas with known agricultural pollution problems, have shown progress in:

- *Nitrogen management*. Through 1993, nitrogen management practices (including cover and green manure crops) have been implemented on 1 million acres, about 46 percent of the 5-year goal for the 90

Table 6.2.4—Status of Water Quality Program (WQP) and associated activities, FY 1991-95

Activity	Unit	1991	1992	1993	1994	1995
Educational, technical, and financial assistance activities:						
Demonstration Projects:						
Number of active projects	Number	16	16	16	16	15
Demonstration farms	Number	135	135	NA	NA	NA
Total USDA funding[1]	Mil. dol.	8.5	8.5	7.7	5.8	5.7
Ratio education/technical/financial	Percent	25/54/21	25/54/21	29/60/11	36/64/0	37/63/0
Hydrologic Unit Area projects:						
Number of active projects	Number	74	74	74	74	68
Total USDA funding	Mil. dol.	31.5	28.1	17.3	15.0	14.7
Ratio education/technical/financial	Percent	12/50/38	14/43/43	20/60/11	27/73/0	28/72/0
Water Quality Special Projects:						
Number of annual projects	Number	35	35	2	0	0
Total USDA funding	Mil. dol.	9.1	9.1	1.1	0	0
Ratio education/technical/financial	Percent	0/5/95	0/5/95	0/5/95	NA	NA
Water Quality Incentive Projects:						
Number of projects started	Number	0	0[2]	106	71	65
Project acres	Mil. acre	0	0[2]	4.8	3.8	8.4
Total USDA funding	Mil. dol.	0	6.8	15.0	15.0	15.0
Regional activities:						
Regional continuing projects	Number	5	5	6	6	6
Estuaries of National Significance	Number	17	21	21	21	21
Total USDA funding	Mil. dol.	22.7	23.1	22.1	25.2	15.1
Ratio education/technical/financial	Percent	0/61/39	0/58/42	0/63/37	0/67/33	0/96/4
Improved program support:						
CSREES	Mil. dol.	3.9	5.0	5.0	4.6	4.6
NRCS	Mil. dol.	7.5	7.6	7.6	8.1	7.9
ERS	Mil. dol.	0.5	0.5	0.5	0.4	0.4
Research and development activities:						
Management System Evaluation Areas	Number	5	5	5	5	6
ARS expenditures	Mil. dol.	12.9	15.3	15.3	15.3	15.3
CSREES research grants	Mil. dol.	9.0	9.0	9.0	4.2	2.8
ERS collaboration	Mil. dol.	0.5	0.5	0.5	0.4	0.4
Database development and evaluation activities:						
ERS for agricultural chemical database	Mil. dol.	1.9	1.9	2.3	1.0	1.0
CSREES for chemical database support	Mil. dol.	0.3	0.3	0.3	0.4	0.4
National Agricultural Library for information center	Mil. dol.	0.3	0.3	0.3	0.3	0.3
Total USDA funding for WQP and associated activities	Mil. dol.	108.6	116.0	104.0	95.7	83.6

[1] Excludes funds to ERS, which are included under improved program support.
[2] Funds distributed to 49 existing HUA's.
NA = Not available.
Source: USDA, ERS, based on Office of Budget and Program Analysis data.

DP and HUA projects (USDA, NRCS, 1995). Annual nitrogen reductions averaged almost 42 pounds per acre on land receiving treatments.

- *Phosphorus management*. Phosphorus management practices, including those for managing field applications of animal waste, had been implemented on about 850,000 acres by 1993, which is nearly 100 percent of the 5-year goal (USDA, NRCS, 1995). Annual phosphorus reductions averaged about 40 pounds per acre. Predominant phosphorus management practices include nutrient management, use of cover and green manure crops, and conservation tillage.
- *Pesticide management*. Through 1993, 501,000 acres had been treated with pesticide management practices (USDA, NRCS, 1995), nearly 43 percent of the 5-year goal of the 90 projects. Practices include scouting, improved application/timing, mechanical control of pests, use of host crops and predators for pest control, and crop rotations. Pesticide reductions averaged nearly 0.6 pound per acre active ingredient (AI) in 1993. The significance of the chemical reductions in many projects is limited by inadequate knowledge of pre-project application rates (USDA, SCS, 1993).
- *Erosion and sediment control*. Erosion and sediment control practices have been installed on over 1 million acres (USDA, NRCS, 1995). Over 50 different conservation practices are being used to abate erosion and sediment delivery in the project areas, some of which are innovative and not included in the SCS technical manual. Practices include rotations, crop residue use, conservation tillage, cover and green manure crops, and pasture and hayland planting.
- *Water management*. In 1993, the HUA's and DP's implemented irrigation water management practices on 119,000 acres, reducing average annual application of irrigation water by 11 inches per acre (USDA, NRCS, 1995). Irrigation application efficiency on treated fields increased by 18 percent.

The practices successfully promoted are those known to increase net returns, consistent with ACP and WQIP. Targeted financial assistance ended as of 1993. An assessment of HUA's found that acreage goals for a number of practices have not yet been achieved (USDA, NRCS, 1996). Previous experience with USDA voluntary programs has indicated that financial assistance is often critical in getting farmers to try new practices; education and technical assistance alone are not enough (Magleby and others, 1989).

Conservation Compliance

Conservation Compliance provisions were enacted in the Food Security Act of 1985 to reduce soil erosion. Producers who farmed highly erodible land (HEL) were required to implement a soil conservation plan, including prescribed or alternative technical practices, to remain eligible for programs such as price support, loan rate, crop insurance, disaster relief, CRP, and FmHA loans (see chapter 6.4, *Conservation Compliance*). NRCS provides technical assistance for planning and implementing the practices, and some-cost share assistance may be available through ACP or other programs. The magnitude of erosion reductions will result in sizable water quality benefits. ERS has estimated that the average annual water quality benefits from Conservation Compliance are about $13.80 per acre (USDA, ERS, 1994). Conservation compliance results in a large social dividend, primarily due to offsite benefits. An evaluation using 1994 data on HEL fields indicates that the national benefit/cost ratio for Compliance is greater than 2, based on reported changes in tillage practices and expected changes in water quality. In other words, the monetary benefits associated with water quality, air quality, and productivity outweigh the costs to government and producers (USDA, ERS, 1994).

Conservation Reserve Program

The Conservation Reserve Program was established in Title XII of the Food Security Act of 1985 as a voluntary long-term cropland retirement program. USDA provides CRP participants with an annual per-acre rent and half the cost of establishing a permanent land cover (usually grass or trees) in exchange for retiring highly erodible or other environmentally sensitive cropland for 10-15 years. CRP enrollment reached 36.4 million acres in 1993. At its peak, the CRP reduced soil erosion by nearly 700 million tons per year, or 19 tons per acre. This was a 22-percent reduction in U.S. cropland erosion (USDA, ERS, 1994). (For more on the CRP, see chapter 6.3).

Erosion from cropland has been estimated to cause between $2 and $8 billion in damages each year (Ribaudo, 1989; Clark, Haverkamp, and Chapman, 1985). These damages include reduced recreation opportunities, increased water treatment costs, sedimentation of reservoirs, increased dredging of navigation channels, and silting up of drainage and irrigation channels. The erosion reductions estimated for the 36.4 million acres enrolled in the CRP are estimated to generate about $437 million annually in benefits to water users. These estimates do not include the water quality benefits from reduced use of nutrients and pesticides on the land removed from production.

As a general approach for improving water quality, retiring cropland can be very expensive. Even though the water quality benefits are "guaranteed" as long as the land is retired, land retirement probably cannot be economically justified on the basis of water quality benefits alone. However, there are areas where the benefits of retiring cropland outweigh the costs. These could include riparian areas, wellhead recharge areas, and drainage areas around particularly valuable reservoirs.

Wetland Reserve Program

The Wetland Reserve Program was authorized in 1990 as part of the Food, Agriculture, Conservation and Trade Act of 1990. Administered by NRCS, the WRP provides easement payments and restoration cost-shares to landowners who permanently return prior converted or farmed wetlands to wetland condition. Easement payments cannot exceed the fair market value of the land, less the value of permitted uses, such as hunting or fishing leases or managed timber harvest. An enrollment goal of 975,000 acres by the year 2000 was set.

The Wetland Reserve Program is primarily a habitat protection program, but retiring cropland and converting back to wetlands also has water quality benefits. Some benefits arise from reduced chemical use on former cropland, but the greatest potential benefits come from the ability of the wetland to filter sediment and agricultural chemicals from runoff and to stabilize stream banks. The value of wetlands and other riparian vegetation as water purification systems has been well documented (Cooper and others, 1987; Cooper and Gilliam, 1987). Artificial wetlands are currently used to treat runoff from animal facilities.

The degree to which created wetlands will improve water quality has not been estimated. One study put the water quality benefits of converting cropland to streamside vegetative buffers at about $95 per acre (Ogg and others, 1989). Creation of a wetland as opposed to a filter strip would likely generate greater water quality benefits.

The Wetland Reserve Program is not targeted on a watershed basis. Water quality benefits would be enhanced by targeting enrollment to watersheds in greatest need of protection from agricultural runoff. Research in Illinois indicates that adequate flood control and water quality improvements in a watershed can be achieved with as little as 2 to 5 percent of the watershed acreage in strategically located wetlands (Stevens, 1995).

USDA Support of Non-USDA Programs

USDA is supporting several water quality projects sponsored under non-USDA programs (see fig. 6.2.1). USDA provides accelerated technical and financial assistance to farmers in the upland areas of the 21 National Estuary Program projects through CTA and ACP. USDA provides the same support to several multi-agency regional programs to manage and protect water resources. These include the ***Chesapeake Bay Program**, **Great Lakes National Program**, **Gulf of Mexico Program**, **Lake Champlain Program**, and **Land and Water 201 Program**.* USDA support for the Estuary Program and regional programs totaled $15.1 million in 1995.

USDA is assisting EPA’s Clean Lakes Program by targeting some of the Small Watershed Program flood control and land treatment projects to Clean Lakes Program projects. USDA is providing program support in many of EPA’s Section 319 watershed projects. Some of the HUA and WQIP projects have been targeted to watersheds identified under Section 319. Technical assistance from NRCS for Section 319 projects totaled $300,000 in 1995.

Successful Water Quality Projects

Besides the programs currently being administered, USDA has gained experience from previous efforts targeting agricultural nonpoint source reductions (see box, “Past USDA Water Quality Efforts”). Improvements in water quality from nonpoint source pollution reductions often take years to detect because of the store of pollutants already in the water resources, pollutants already in the soil profile, and other factors such as weather variations and changes in crops grown. While improvements to water quality from most current USDA programs are not yet apparent, the sizable reductions in pollutants entering water resources because of these programs suggest that water quality improvements will follow.

Several completed watershed projects have documented improvements in water quality from activities undertaken in the watershed. Animal waste management greatly improved water quality in Rural Clean Water Program (RCWP) projects in Snake Creek, Utah, and the Tillamook Bay, Oregon (U.S. EPA, 1990). Implementation of BMP’s reduced

Past USDA Water Quality Targeted Efforts

Model Implementation Program (MIP) 1978-82. The Model Implementation Program was an experimental program designed to demonstrate and study a concerted attempt by USDA and EPA to address agricultural nonpoint source water quality problems by using existing program authorities. The MIP consisted of seven projects. USDA offered education, technical, and financial assistance to help farmers adopt best management practices. The project resulted in a number of recommendations for improving future agricultural water quality programs (National Water Quality Evaluation Project, 1983).

Rural Clean Water Program (RCWP) 1980-86. RCWP was initiated in 1980 as an experimental effort to address agricultural nonpoint source pollution in watersheds across the country. Twenty-one projects were funded, representing a wide range of pollution problems and impaired water uses. Farmer participants received technical and financial assistance to implement best management practices to reduce polluted runoff or infiltration. Monitoring and evaluation were conducted to document water quality improvement and economic benefits and costs. Funding for practices ended in 1986, but monitoring continued until 1995. Results of the program were mixed. Some projects documented water quality improvements. Economic benefits from actual or expected water quality improvements were estimated to exceed costs in about half the projects studied (Magleby and others, 1989).

Water Quality Special Projects (WQSP) 1991-92. Water Quality Special Projects extended cost-share assistance to farmers and ranchers for installing approved water quality practices in small watersheds with identified agricultural nonpoint-source problems. Funding was through ACP. Limited technical assistance was available from the Soil Conservation Service. WQSP's were annual projects, although landowners could enter into multiyear agreements. No new projects were funded after 1992.

phosphorus and fecal coliform from animal waste by substantial amounts. Keeping animals out of streams in the Taylor Creek-Nubbin Slough Basin, Florida RCWP project cut phosphorus concentrations in some Lake Okeechobee tributaries by 50 percent. Irrigation water management and other BMP's in the Rock Creek, Idaho RCWP project reduced suspended sediment concentrations in the watershed. These projects were able to document water quality improvements only after many years of implementation activity and extensive monitoring.

In the Ketch Brook Watershed Section 319 project in Connecticut, agricultural and other BMP's reduced sediment in roadside ditches and a wetland (U.S. EPA 1994). Nolichucky River Watershed in Tennessee had a significant pollution problem from animal wastes. One year after animal waste BMP's were installed on the majority of animal operations as part of a Section 319 project, statistically significant improvements in benthic habitat in two subwatersheds were observed (U.S. EPA, 1994). Battle Branch Watershed in Oklahoma, a Section 319 project, suffered elevated nutrient loadings from poultry and dairy operations. Structural and nonstructural BMP's for managing nutrients reduced nitrate levels during runoff as much as 72 percent, and total phosphorus levels as much as 35 percent (U.S. EPA, 1994).

West Lake Reservoir, a Section 319 project in Iowa, was being hurt by sediment and atrazine. Half the watershed for the reservoir was in corn-soybean rotation. Sediment was rapidly reducing reservoir capacity, damaging filtration systems, and increasing operation and maintenance costs. Atrazine levels were above the maximum contaminant levels specified under the Safe Drinking Water Act. As part of the project, no-till and ICM were promoted to producers in the watershed. Atrazine use in the watershed was cut in half and there were significant reductions in soil erosion (U.S. EPA, 1994). As a result of these reductions, atrazine concentrations in the reservoir have dropped below the maximum contaminant level. The concentrations of another pesticide, cyanazine, have also decreased.

Lessons Learned From Water Quality Programs

Experience with past and present water quality programs suggests several recommendations for the success of voluntary water quality programs:

- ***Voluntary programs are likely to be most successful in areas where farmers recognize that agriculture contributes to severe local pollution problems such as groundwater impairment***. A survey of producers in some Water Quality Program projects indicated that farmers believe they have a responsibility to protect water quality if they are causing a problem (Nowak and O'Keefe, 1995). The lack of such a belief has been attributed to slow progress in the Darby Creek HUA project in Ohio (Camboni and Napier, 1994). On the other hand, the immediate threat to West Lake Reservoir in Iowa apparently spurred quick action by the farm community (U.S. EPA, 1994).

One of the roles of education is to increase problem awareness. Educating producers about the potential impacts of poor water quality on personal health, the health of neighbors, and the health of the environment may speed up the adoption process. Farm*A*Syst has been successful in getting farmers to reduce risks to water supplies by raising their awareness of activities around the farm that pose risks to them and their families. Assessments of the program in Arkansas, Minnesota, and Wisconsin found that those who participated in the risk-assessment activities were more likely to implement groundwater protection practices (Jackson, Knox, and Nevers, 1995).

- ***Voluntary programs are likely to be successful when the alternative practices recommended generate higher returns.*** The long-term success of voluntary programs depends on farmers continuing to use new practices after assistance ends. Continued use is more likely if practices are profitable. The practices being adopted under ACP and the Water Quality Program are those known to increase net returns, namely conservation tillage, nutrient management, and irrigation water management. Some practices being promoted in the Water Quality Program Demonstration Projects (Rockwell and others, 1991) were not adopted by farmers because they were not profitable. Research can help identify those practices that protect water quality and are also profitable.

- ***Cost-effectiveness is enhanced when program activities are targeted to watersheds—and to critical areas within watersheds—where agriculture is the primary source of a water quality impairment.*** Watersheds with identifiable problems may differ greatly in the water quality improvement that can be achieved and in the economic and social benefits and costs of that achievement. The success of some RCWP projects was limited because agriculture turned out not to be the primary source of water quality impairment (Magleby and others, 1989). In addition, identifying critical areas for priority treatment within watersheds, as well as the set of management practices that are best suited for addressing the particular problem, increases the cost-effectiveness of assistance.

- ***Flexible cost-share programs for practice adoption are more efficient than those with fixed rates and limited lists of supported practices.*** Improvements in current cost-share programs can be made by increasing the maximum amount of incentive payment and quickly approving the financial support of innovative practices. A study by the Sustainable Agriculture Coalition found that per-acre incentive payments for WQIP were not enough to interest some producers to implement management changes identified as necessary for meeting individual project goals (Higgins, 1995). The study concluded that the payments for the following practices were too low in some regions: Waste Management System, Conservation Cover, Conservation Tillage, Critical Area Planting, Filter Strip, Pasture and Hayland Management, Pasture and Hayland Planting, Planned Grazing System, Stripcropping, Nutrient Management, Pest Management, and Record Keeping (Higgins, 1995).

These conclusions are supported by ERS research findings. Feather and Cooper (1995) found that incentive payments were insufficient for adopting and maintaining some practices beyond 3 years. A survey of farmers in four regions was used to estimate farmers' willingness to adopt conservation tillage, split fertilizer applications, integrated pest management, legume crediting, manure crediting, and soil moisture testing given different incentive payment levels. The results indicated that 8 to 73 percent of the producers were willing to adopt certain practices without incentive payments because of the profitability of the practice (depending on the practices), provided that they are given sufficient information on the practice. Practices such as nutrient management, rotations, and conservation tillage have been shown to increase net returns in many areas, and these practices were the most popular in the WQIP. However, the study also found that at program payment levels, only conservation tillage and split applications were attractive to at least 50 percent of producers. Fifty-percent adoption for the other practices would require a substantial increase in the WQIP incentive payment, unless farmer concern over the impacts of farming operations on water quality can be increased through education.

Lack of financial assistance may have slowed practice adoption in some Demonstration Projects. In the Wisconsin Demonstration Project, cost-share funds were available for less than half the farmers wanting to adopt ICM (Finlayson and Erb, 1995). In addition, a lack of flexibility may be hindering the promotion and adoption of innovative practices. For example, the length of time required for an innovative practice with no national standards to be approved for financial assistance could have slowed project implementation (Rockwell and others, 1991).

- ***Local research on the economic and physical performance of recommended practices can improve practice adoption.*** Farmers are skeptical of practices with "national" standards when there is no local history of use to readily observe. Project managers in eight USDA Demonstration Projects evaluated by the University of Wisconsin indicated the lack of data to support claims that certain BMP's are effective and economically advantageous (Rockwell and others, 1991). A number of projects diverted considerable resources to applied research to investigate the economic, environmental, and agronomic features of promoted practices (Nowak and O'Keefe, 1995). A research component to watershed projects for testing alternative management practices would accelerate the adoption process.

- ***Interaction with non-USDA agencies, organizations, and local businesses within a watershed is important.*** Local districts such as soil and water conservation districts, drainage districts, irrigation districts, and natural resource districts may be operating in project areas. Local business and environmental groups may have some interest in water quality issues. Involving these stakeholders early in project planning would minimize future conflicts, and may bring in additional resources. Seeking and obtaining local cooperation has been identified as a strength of USDA Water Quality Program projects (Rockwell and others, 1991; Nowak and O'Keefe, 1995).

- ***More attention to and resources for water quality monitoring and project evaluation could help determine the cost-effectiveness of alternative practices and assist in the development of targeting strategies for program improvement.*** Standardized reporting mechanisms that include economic information and water quality monitoring data provide the information necessary to understand both producer behavior and the efficacy of new practices. Lack of water quality monitoring in USDA Water Quality Program and Water Quality Incentive Projects has been cited as a reason why the ultimate impacts on water quality of many watershed projects may never be known (USDA, NRCS, 1996). Likewise, the lack of data on the economic impacts of the practices adopted with incentives provided by USDA limits the degree to which the effectiveness of implementation strategies can be evaluated.

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Recent ERS Reports Related to Water Quality Programs

The Conservation Reserve Program: Enrollment Statistics for Signup Periods 1-12 and Fiscal Years 1986-93, SB-925, November 1995 (C. Tim Osborn, Felix Llacuna, Michael Linsenbigler). The U.S. Department of Agriculture accepted about 33.9 million acres of cropland into the CRP during 1986-89. An additional 2.5 million acres were enrolled in 1991 and 1992 under significantly revised program rules.

Soil Erosion and Conservation in the Unites States: An Overview, AIB-718, Oct. 1995 (Richard Magleby, Carmen Sandretto, William Crosswhite, C. Tim Osborn). Soil erosion in the United States does not pose an immediate threat to the Nation's ability to produce food and fiber, but it does reduce the productivity of some soils, and it also causes water quality damage. USDA has initiated a number of programs for promoting soil conservation measures to farmers.

USDA's Water Quality Program Enters its 6th Year, AREI Update, 1995 No. 11 (Marc Ribaudo). Sixty-five water quality projects were started in 1995, and 6 projects were completed at the end of 1994. Over 400 water quality projects have been started since 1990.

Voluntary Incentives for Reducing Agricultural Nonpoint Source Water Pollution, AIB-716, May 1995 (Peter Feather and Joe Cooper). Data from the Area Studies are used to evaluate the success of existing incentive programs to control agricultural nonpoint source pollution. Because profitability drives production decisions, these programs tend to be most successful when they promote inexpensive changes in existing practices.

A Preliminary Assessment of the Integrated Crop Management Practices, ERS Staff Report AGES-9402, Feb. 1994 (C. Tim Osborn, D. Hellerstein, C. Matthew Rendelman, Marc Ribaudo, and Russ Keim). Analysis of the first year of ICM, based on a sample of four crops grown in four States, indicates limited success. The primary effect of ICM appears to have been reduced nitrogen fertilizer use.

Water Quality Benefits from the Conservation Reserve Program, AER-606, Feb. 1989 (Marc Ribaudo). The Conservation Reserve Program is estimated to generate between $3.5 and $4 billion in water quality benefits if it achieves its original enrollment goal of 40-45 million acres. Potential benefits include lower water treatment costs, lower sediment removal costs, less flood damage, less damage to equipment that uses water, and increased recreational fishing.

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6.3 Conservation Reserve Program

After several years without new signups or significant new program activity, the Conservation Reserve Program (CRP) became active on multiple fronts in 1995 and 1996. In 1995, USDA allowed early release from CRP contracts, permitted 1-year extensions of contracts scheduled to expire in 1995, and held a 13th signup to replace early-out acres with more environmentally sensitive cropland. In 1996, USDA allowed a second early-out opportunity and another 1-year extension of expiring contracts. Also in 1996, the Federal Agriculture Improvement and Reform Act continued the CRP at a maximum of 36.4 million acres through the year 2002. In March 1997, USDA held a major signup based on new program rules that expanded land eligibility conditions, and revised rental payment limits and the environmental ranking acceptance process. Of 23.3 million acres offered, USDA accepted 16.1 million at an average rental fee of $39 an acre.

Contents

The Conservation Reserve Program (CRP), USDA's most ambitious conservation effort, was initiated by Congress in Title XII of the Food Security Act of 1985. As a voluntary long-term cropland retirement program, CRP provides participants (farm owners or operators) with an annual per-acre rent and half the cost of establishing a permanent land cover (usually grass or trees) in exchange for retiring highly erodible and/or environmentally sensitive cropland from production for 10-15 years. Although the enrollment mandate established in the 1985 Act was 40-45 million acres by the end of the 1990 crop year, by that point 33.9 million acres had been enrolled. The primary goal of the CRP during 1986-89 was to reduce soil erosion on highly erodible cropland. Secondary objectives included protecting the Nation's longrun capability to produce food and fiber, reducing sedimentation, improving water quality, fostering wildlife habitat, curbing the production of surplus commodities, and providing income support for farmers.

The Food, Agriculture, Conservation, and Trade Act of 1990 (1990 Farm Act) extended the CRP enrollment period through 1995, and redirected the goals of the CRP toward improving water quality and other environmental concerns. Under the 1990 Act, an additional 2.5 million acres were enrolled, bringing total enrollment to 36.4 million acres as of 1993. Subsequent appropriations legislation capped CRP enrollment at 38 million acres. In April 1996, President Clinton signed the Federal Agricultural Improvement and Reform Act (1996 Farm Act), continuing the CRP through 2002. Under this legislation, USDA was given authority to re-enroll existing CRP contracts, as well as enroll new acres, subject to a maximum annual enrollment of 36.4 million acres.

Table 6.3.1—Conservation Reserve Program activity, 1986-96

Event	Number of acres	Average rental payment when in CRP	Average erosion reduction when in CRP
	Million acres	*$/acre/year*	*Tons/acre/year*
Signup #1, March 1986[1]	0.75	42.06	26
Signup #2, May 1986	2.77	44.05	27
Signup #3, August 1986[2]	4.70	46.96	25
Signup #4, February 1987[3]	9.48	51.19	19
Signup #5, July 1987	4.44	48.03	17
Signup #6, February[4]	3.38	47.90	18
Signup #7, July 1988	2.60	49.71	17
Signup #8, February 1989[5]	2.46	51.04	14
Signup #9, July-August 1989	3.33	50.99	14
Signup #10, March 1991[6]	0.48	53.66	17
Signup #11, July 1991	1.00	59.37	15
Signup #12, June 1992	1.03	62.98	16
Early-out #1, May 1995	-0.70	58.51	20
Signup #13, September 1995[7]	0.62	53.93	10
1995 expirations	-0.13	46.36	26
Early-out #2, 1996	-0.77	57.41	17
1996 expirations	-0.96	60.51	22
Net enrollment, Dec. 1996[8]	32.96	49.20	19

[1] Eligible acres included cropland in land capability classes II-V eroding at least three times greater than the tolerance rate, or any cropland in land capability classes VI-VIII. [2] Eligible acres expanded to include cropland in land capability classes II-V eroding at least two time the tolerance rate and having gully erosion.
[3] Eligible acres expanded to include cropland eroding above the tolerance rate with an erodibility index of 8 or greater.
[4] Eligible acres expanded to include cropland in land capability classes II-V eroding at least two times the tolerance rate if planted in trees. Eligibility also extended to cropland areas 66-99 feet wide adjacent to permanent water bodies for placement in filter strips. [5] Eligible acres expanded to include cropped wetlands and cropland areas subject to scour erosion. [6] Eligible acres expanded to include cropland devoted to easement practices, cropland in State water quality areas, cropland in conservation priority areas, and cropland within established wellhead protection areas. Farmed wetlands, even if otherwise eligible, were ineligible for enrollment. [7] Eligible acres included fields with an average erodibility index greater than or equal to 8, cropland areas with evidence of scour erosion caused by out-of-bank water flows and floods occurring in at least one out of 10 years, wellhead protection areas identified by the Environmental Protection Agency, any cropland determined suitable for riparian buffer/filterstrips by NRCS, small farmed wetlands contained in and part of a field that were otherwise eligible, or any cropland located in the Chesapeake Bay region watershed, the Great region watershed, the Long Island Sound watershed, other areas designated as conservation priority areas in CRP signup 12, and newly approved State priority areas. [8] Net after subtracting 1.5 million acres terminated by producers prior to 1995 early-out.

Source: USDA, ERS, based on CRP contract data.

Program Status Up to the 1996 Farm Act

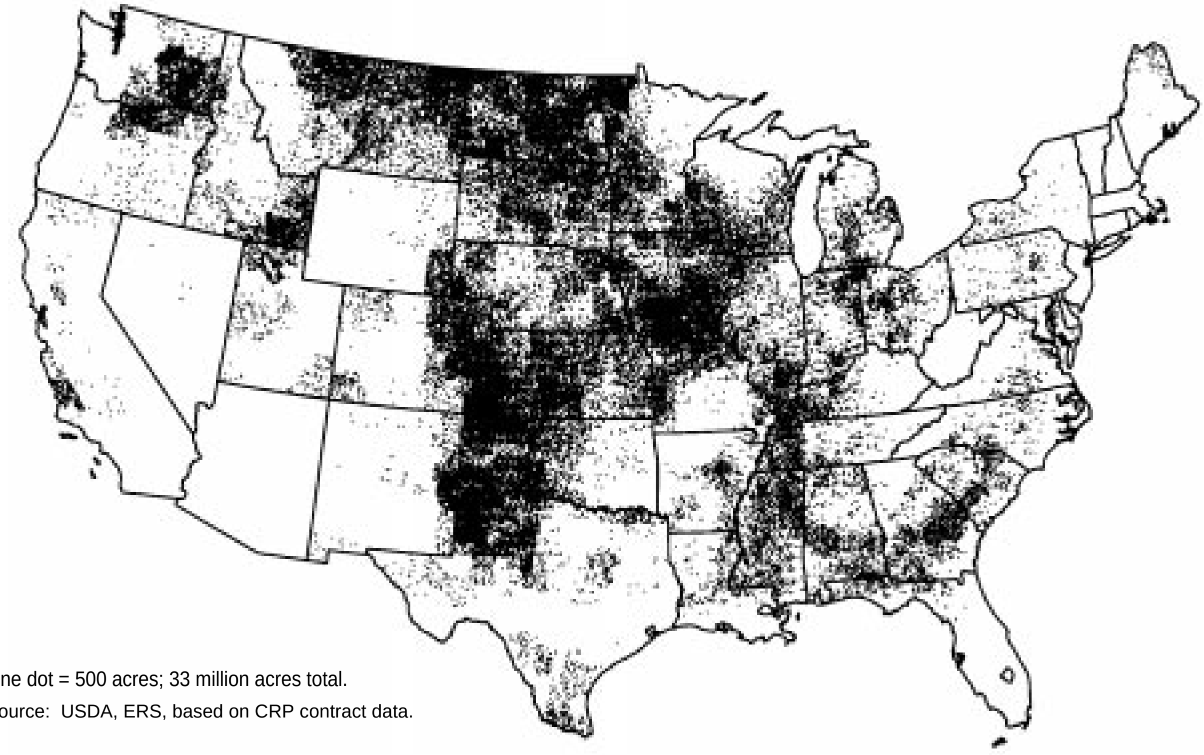
After 12 years, as of December 1996, the CRP contained approximately 33 million acres of idled cropland (table 6.3.1). This is less than the 37.0 million acres enrolled in signups 1-13 due to 704,000 acres removed in the May 1995 early-out, 1.5 million acres from contracts previously terminated by producers, 126,000 acres scheduled to expire in 1995 and not extended by producers, 768,000 acres removed under 1996 early-out authority, and 956,000 acres scheduled to expire in 1996 and not extended (table 6.3.2).

CRP acres (December 1996) were concentrated in the Great Plains and western Corn Belt (table 6.3.2, fig. 6.3.1). Annual CRP rental payments averaged about $49 per acre. Annual erosion reductions for the acreage in the program as of December 1996 totaled 626 million tons, or about 19 tons per acre. This is a 20-percent reduction in cropland erosion compared with conditions prior to the CRP. Most CRP acres were planted to grass, but the CRP also included 2.4 million acres of trees, 1.6 million acres of special wildlife practices (e.g. habitat, shallow water area), and 8,100 miles of filter strips along waterways.

Early-Outs and Contract Extensions in 1995

On December 14, 1994, the Secretary of Agriculture announced that, under authority of the 1985 and 1990 Farm Acts, USDA would (1) allow participants to be released early from contracts (or to reduce the number of acres under contract), and (2) allow producers with contracts expiring in 1995 to extend their contracts 1 year.

Figure 6.3.1--Acres under CRP contract, December 1996



One dot = 500 acres; 33 million acres total.

Source: USDA, ERS, based on CRP contract data.

Table 6.3.2—Remaining regional CRP enrollment, December 1996

Region	Enrolled in signups 1-12	Terminated by producers prior to early-out opportunity	Terminated by producers in early-out opportunity, May 1995	Enrolled in replacement signup 13, Sept. 1995	Unextended contracts that expired in 1995	Terminated by producers in 1996 early-out	Unextended contracts that expired in 1996[2]	Remaining enroll-ment[1]
				1,000 acres				
Appalachian	1,158	-54	-66	19	-20	-19	-97	922
Corn Belt	5,603	-126	-245	193	-23	-198	-383	4,821
Delta	1,248	-48	-18	47	-12	-9	-31	1,177
Lake States	3,008	-142	-96	68	-11	-185	-84	2,559
Mountain	6,687	-137	-62	76	-14	-100	-84	6,365
Northeast	226	-17	-9	10	-3	-5	-9	194
Northern Plains	9,664	-732	-96	100	-14	-144	-142	8,635
Pacific	1,791	-27	-14	18	-5	-27	-27	1,708
Southeast	1,693	-130	-22	28	-14	-10	-32	1,512
Southern Plains	5,343	-116	-75	58	-11	-71	-65	5,064
U.S.[1]	36,423	-1,528	-704	616	-126	-768	-956	32,956

[1] May not add across or down because of rounding.

[2] Includes acres terminated during Oct.-Dec. 1996 (FY 1997).

Source: USDA, ERS, based on FSA data on CRP contracts.

During May 15-June 2, 1995, CRP participants were permitted to request early contract releases without penalty or obligation to refund previous payments issued under the CRP. Prior to this opportunity, participants had been required to refund past CRP rental payments plus interest, liquidated damages, and, in many cases, cost-share payments previously paid under the contract. The early release was designed to replace these acres with more environmentally sensitive cropland under new CRP contracts, and to allow the released acres to produce additional grain given low stocks.

A number of conditions were in effect for the early release opportunity. First, certain environmentally sensitive CRP acres were ineligible. These included acres within 100 feet of a stream or other water body, acres covered by a CRP easement, and acres containing grass waterways, filter strips, shallow water areas for wildlife, bottomland timber on wetlands, field windbreaks, and shelterbelts established by the CRP. If the released CRP acres were to be cropped, eligibility for certain USDA benefits required they be farmed according to a Basic Conservation System (BCS), at least until the date the CRP contract would have expired. A BCS reduces soil erosion to the soil-loss tolerance level—the rate of soil erosion above which long-term soil productivity may be depleted. This is a higher, and potentially more costly, level of erosion control, than an Alternative Conservation System (ACS) which is required of highly erodible cropland and CRP acres after contracts expire. If the released CRP acres were to be hayed or grazed, they had to be managed in accordance with an approved haying or grazing plan determined by the Natural Resource Conservation Service (NRCS). Crop acreage bases, allotments, and quotas associated with the released CRP acres could not be reinstated until the 1996 crop year, making deficiency payments unavailable for 1995 even if released acres were planted that crop year. Finally, the effective date of the release could not exceed September 30, 1995.

It had been estimated that CRP participants could potentially opt to end contracts early on as many as 4.5 million acres. However, perhaps due to the lateness of the early-out opportunity in the crop year and the conditions listed above, producers requested early release on just 704,000 acres. Iowa had the most acres removed, followed by Texas and Minnesota. Regionally, early-out acres were greatest in the Corn Belt (245,000), followed by the Lake States (96,000) and the Northern Plains (96,000) (table 6.3.2).

Also, during May 15-June 2, 1995, CRP participants with contracts expiring September 30, 1995 (approximately 2 million acres) were allowed to submit requests to extend their contracts for 1 additional year. This opportunity was to help these participants whose contracts were expected to expire before passage of the farm bill make informed decisions about the use of their CRP acres in light of changes to conservation and commodity programs contained in new farm legislation. Of the acres scheduled to expire in 1995, 25,000 elected early-out in May, 1.7 million were extended for 1 year, and 126,000 expired on schedule. The additional government cost of extending the 1.7 million acres for 1 year was approximately $70 million.

Targeted 1995 Replacement Signup

To replace the acres granted early release in June 1995, USDA held a 13th CRP signup during September 11-22, 1995 to accept bids for new 10-15 year contracts. This was the first signup since June 1992. To enroll acres with the highest environmental benefits relative to government cost, bids were ranked by an environmental benefits index, much as in signups 10-12. However, substantial changes were made, among them:

- Cropland eligibility criteria were modified from past signups.
- Producers were given open access to information on how the environmental benefits index was calculated and on the maximum rental payment the Government would accept for their cropland based on their soil's productivity.
- States could develop their own bid-ranking process to be used in place of the national process. Colorado, Missouri, Nebraska, and Oregon developed their own processes.
- Environmental Priority (EP) bids, such as filter strips along waterways, were eligible for a 10-percent rental bonus to promote their enrollment.

Cropland eligible for enrollment included fields with an average erodibility index greater than or equal to 8. This criteria removed land capability class as a definition for highly erodible acres under CRP and replaced the two-thirds field predominance requirement used in previous signups. Eligibility also included cropland with evidence of scour erosion caused by out-of-bank water flows and floods occurring in at least 1 out of 10 years; wellhead protection areas identified by the Environmental Protection Agency; any cropland determined suitable

Table 6.3.3—Results of the 13th CRP signup, September 1995

Region	Acres bid	Acres accepted and contracted	Acres with trees	Average rental rate	Average erosion reduction
	1,000 acres			*$/acre/yr*	*tons/acre/yr*
Appalachian	29	19	4	54.92	11
Corn Belt	423	193	8	80.93	9
Delta	71	47	40	40.53	10
Lake States	144	68	8	59.13	6
Mountain	139	76	0	30.76	8
Northeast	16	10	0	43.95	5
Northern Plains	179	100	0	39.71	7
Pacific	30	18	0	49.00	8
Southeast	42	28	20	38.52	9
Southern Plains	101	58	0	32.45	25
U.S.	1,174	616	80	53.79	10

Source: USDA, ERS, based on FSA data on CRP contracts.

for riparian buffer/filterstrips by NRCS; small farmed wetlands contained in and part of a field that was otherwise eligible; and any cropland located in the Chesapeake Bay region watershed, the Great Lakes region watershed, the Long Island Sound watershed, other areas designated as conservation priority areas in CRP signup 12, and newly approved State priority areas.

A national ranking process was used to determine the amount of acreage to be approved in each State and to determine the actual acceptance of bids in States that did not develop their own process. The environmental benefits index used in the national ranking process was comprised of five factors, four characterizing the environmental contributions of each parcel offered and one characterizing the government cost of enrolling each parcel. The environmental factors included water quality protection (both ground water and surface water; a maximum of 20 points), creation of wildlife habitat (a maximum of 20 points), control of soil erodibility (a maximum of 20 points), and tree planting (a maximum of 10 points). The cost factor was based on the annual rental rate requested by the producer. For two bids with the same environmental score, the bid with the lower per-acre cost received a higher ranking in both the national and State ranking plans. In addition, certain acres categorized as EP bids (partial-field bids devoted exclusively to filter strips, shallow water areas for wildlife, field windbreaks, shelter belts, etc.) automatically received maximum environmental factor scores under both national and State ranking plans.

During the signup, USDA informed each applicant of the maximum annual per-acre rental payment the Government would accept (bid cap) for the cropland offered based on the soil's productivity. Applicants were free to request any rental amount, but bids that exceeded the bid cap were rejected at the county level. Applicants could increase their likelihood of bid acceptance by bidding less than the cap.

In total, 1.17 million acres were offered for enrollment by landowners and operators in the 13th signup (table 6.3.3). Of these, 683,000 were accepted to replace the acres removed in the May 1995 early-out opportunity, and of these, producers entered into contracts on 616,000 acres. The average annual rental cost for land accepted in the 13th signup was $53.79 per acre, significantly less than recent signups. The average erosion reduction for accepted acres was lower than under previous signups at 10 tons per acre per year. Thirty-one percent of accepted acres were located in the Corn Belt region, while 38 percent were from the Great Plains States (Northern Plains, Southern Plains, and Mountain regions). Most acres (80 percent) were planted with grass, but tree planting accounted for 80,000 acres (13 percent) and filter strips accounted for 31,000 acres (5 percent). The filter strip enrollment from the 13th signup represented a 58-percent increase in total CRP filter strip acres.

Early-Outs and Contract Extensions in 1996

On March 14, 1996, the Secretary of Agriculture announced a second early-out opportunity for March 20-April 26, 1996. This opportunity pertained to

CRP contracts scheduled to expire in September 1996, covering more than 14 million acres. As with the 1995 early-out opportunity, certain environmentally sensitive acres such as filter strips, acres within 100 feet of a stream or other water body, and grass waterways were not eligible. In addition, CRP acres with an erodibility index greater than 15 were ineligible. Unlike the 1995 early-out, producers that returned their released acres to crop production needed only adopt an Approved Conservation System to be eligible for USDA program benefits; and acreage bases, allotments, and quotas were restored for the 1996 crop year. USDA took this action to allow farmers to take advantage of high grain prices, to ensure higher production to meet demand, and meet the administration's commitment to an environmentally sound and cost-effective CRP. This early-out opportunity was later eclipsed by the passage of the 1996 Farm Act, which provided authority for producers to withdraw most lands from the CRP at any time, subject to 60-day notice to USDA. As of December 1996, nearly 768,000 acres were removed from the CRP under the 1996 early-out authority (table 6.3.2).

In addition to the early-out option, producers were allowed to extend their expiring 1996 contracts 1 year at existing rental rates during March 20-April 26, 1996. In announcing the signup period, the Secretary said, "A 1-year extension is the most prudent option until a new farm bill is enacted giving USDA enrollment authority and establishing a longer-term policy for the CRP." Operators chose to extend contracts on all but 956,000 acres (table 6.3.2).

Program Changes and Status Under the 1996 Farm Act

The new Federal Agricultural Improvement and Reform Act (1996 Farm Act), signed into law in April 1996, continued the CRP at a maximum of 36.4 million acres through the year 2002, and allowed USDA to enroll new acres in addition to re-enrolling existing CRP acres. The Act also provided authority for producers with contracts established before January 1, 1995, that have been in effect for at least 5 years, to withdraw from the CRP at any time subject to 60 days notice to USDA. However, CRP acres with filterstrips, grass waterways, riparian areas, windbreaks, shelterbelts, acres having an erodibility index greater than 15, and other lands with high environmental benefits as determined by the Secretary (including wetlands) are ineligible for early withdrawal. Producers will receive prorated rental payments for contracts that are withdrawn before the end of a fiscal year. The 1996 Act further stipulated that early withdrawal of a CRP contract shall not affect the ability of the owner or operator to submit a bid to re-enroll the land in the CRP at a future date. Finally, conservation requirements under conservation compliance, sodbuster, and swampbuster for CRP lands returned to production must be no more onerous than those required for similar lands in the area.

Continuous 14th Signup

Under the authority of the 1996 Farm Act, on September 4, 1996, USDA began a continuous CRP signup (referred to as the 14th signup) for filter strips, riparian buffers, grassed waterways, field windbreaks, shelterbelts, living snow fences, salt-tolerant vegetation, shallow water areas for wildlife, and wellhead protection areas designated by EPA. These partial-field practices involve a small amount of acreage, but provide disproportionately large environmental benefits. Producers wishing to enroll acres devoted to these practices may do so at any time, avoiding the need to wait for a discrete CRP signup period. If the producer is willing to accept no more than a maximum productivity-adjusted payment rate calculated by FSA, these acres will be automatically accepted. In addition, special bonus payments may also be available to attract certain high-priority practices.

15th Signup in March 1997

In early 1997, CRP acreage acceptance rules were finalized for a 15th signup opportunity March 3-28, 1997. The new rules expanded the base of eligible lands to more than 240 million acres, including about 65 percent of U.S. cultivated cropland, compared with around 100 million acres of highly erodible cropland eligible when the CRP was first initiated (table 6.3.4).

Table 6.3.4—Lands eligible for CRP signup, based on the 1996 Farm Act

Category	Million acres
Highly erodible cropland	142
Cropland in national priority areas	86
Cropland in State priority areas	24
Cropland adjacent to water bodies	13
Cropped wetlands and adjacent upland	8
Pastureland adjacent to water bodies	na
Total CRP land eligibility[1]	240

na = Not available.

[1] Excludes minor categories of eligible land and double-counting of acres falling into more than one category.

Source: USDA, ERS, based on FSA analysis.

Table 6.3.5—Results of the 15th CRP signup, March 1997

Region	Acres offered for enrollment	Acres accepted	Accepted acres formerly in CRP	Average rental rate	Existing or new tree acres accepted	Wetland restoration acres accepted	Average erodibility index
	1,000 acres		*Percent*	*$/acre/yr*		*1,000 acres*	
Appalachian	498.9	348.6	89.9	55	56.3	0.0	32
Corn Belt	2,787.0	1,670.4	81.2	70	40.0	7.1	27
Delta	674.8	613.5	80.9	37	442.7	9.2	24
Lake States	1,490.4	637.1	74.5	52	55.2	39.9	13
Mountain	5,443.1	4,132.1	71.7	32	3.6	1.6	15
Northeast	99.9	90.4	70.8	43	3.3	0.1	23
Northern Plains	6,026.1	5,050.3	67.6	36	5.3	724.3	10
Pacific	1,322.2	606.9	84.6	40	3.7	5.2	15
Southeast	781.8	584.7	86.2	37	440.9	0.5	15
Southern Plains	4,144.8	2,413.0	68.2	33	6.4	1.5	16
U.S.	23,269.1	16,147.0	72.7	39	1,057.5	790.3	16

Source: USDA, ERS, based on FSA CRP summary tables.

The additional eligible lands were mostly cropland in national and State environmental priority areas, cropland adjacent to water bodies, and cropped wetlands and adjacent upland.

Producers that wished to enroll eligible land with practices not covered by the continuous signup, including eligible acres from the 21.5 million acres with CRP contracts then scheduled to expire in 1997, had to submit bids for their land and compete with other bids for acceptance. Offers of eligible land were ranked using an environmental benefits index (EBI). The EBI for the 15th signup was composed of the sum of 6 environmental factors and a cost factor: wildlife habitat benefits (100 points maximum); water quality benefits from reduced water erosion, runoff, and leaching (100 points maximum); onfarm benefits of reduced wind or water erosion (100 points maximum); long-term benefits of cover beyond the contract period (50 points maximum); air quality benefits from reduced wind erosion (25 points maximum); benefits from enrollment in conservation priority areas (25 points maximum); and cost (200 points maximum).

On May 22, 1997, USDA accepted 16.1 million acres for enrollment in the CRP from the 15th signup period. Approximately 23.3 million acres had been offered by producers. Of the acres accepted, 4.4 million represented new acres not formerly enrolled in the program. The regional distribution of accepted acres was similar to the historic CRP except for small reductions in the Lake States and Pacific Regions, and a small increase in the Mountain Region (table 6.3.5).

The average environmental index (EBI) score for the acres enrolled in the 15th signup (307) was 46 percent greater than the average EBI of the historic CRP (210) owing mainly to improved wildlife habitat benefits, water quality benefits, and decreased rental costs. Approximately 84 percent of accepted acres were highly erodible, and nearly half of these acres had an erodibility index greater than 15. The average erodibility index for accepted acres was 16. Approximatley 1.1 million of the accepted acres were devoted to new or existing trees, while most of the remainder will be covered with various grasses. Included in the acres accepted in the 15th signup were over 790,000 acres of cropped wetland and associated acreage that will be restored and over 652,000 acres that were enrolled in State water quality areas.

Due to revised soil bid caps and enhanced program competition, annual rental costs were reduced from an average of $50 per acre under the historic CRP to $39 on the 15th signup accepted acres. In addition, over 60 percent of rental payments requested by producers were below established USDA soil bid caps. Based on the improved EBI and the lower rental cost, USDA announced that the newly accepted acreage

Wildlife Benefits of the Conservation Reserve Program

The CRP provides exceptional opportunities to enhance habitat for grassland-dependent birds and other wildlife. Lands enrolled in the CRP are extensive enough that they can have large-scale effects on populations of both game and nongame species. In some areas, CRP lands now represent the majority of available grassland habitat for wildlife. The CRP has created new grassland habitat for wildlife on an area twice the size of all national wildlife refuges and all State wildlife areas within the contiguous 48 States (Wildlife Management Institute, 1994).

Numerous studies have documented increased reproduction and diversity of game and nongame species in areas where CRP land is present. The CRP has been beneficial to many grassland wildlife species, including regular game birds (pheasants and ducks) and other species (lesser prairie chicken and the formerly endangered greater prairie chicken). Big-game wildlife such as elk, mule deer, white-tailed deer, and pronghorn antelope have also responded favorably to habitat improvement on CRP land in Western States.

CRP also improves aquatic habitats by reducing discharge of soil sediment and agricultural chemicals. Impacts would be most noticeable in rural watersheds dominated by agricultural activity. Improved aquatic habitat implies healthier and more diverse fish populations and enhanced recreational fishing opportunities.

Beneficial impacts on wildlife populations generate welfare benefits for those who participate in consumptive (hunting) and non-consumptive (observing) recreation activities. Even though no cash transactions may be involved, participants place a value on an increase in the quality of the recreation activity.

Estimating the environmental economic benefits of the CRP is difficult and imprecise due to the nonmarket nature of these effects. One study has estimated that benefits for small game hunting total about $3 billion for acres enrolled in the CRP (total over life of current contracts, not annual) (Ribaudo and others, 1990). Economic benefits from improved waterfowl hunting because of CRP are estimated to total $1.4 billion (Johnson and others, 1994). An estimate of benefits for nonconsumptive wildlife use (birdwatching, etc) totals $4.1 billion (Johnson and others, 1994). Freshwater fishing benefits are estimated to total $310 million (Ribaudo, 1989).

represented an 85 percent increase in the CRP's environmental cost-effectiveness (USDA, 1997).

Another CRP signup is planned for the fall of 1997.

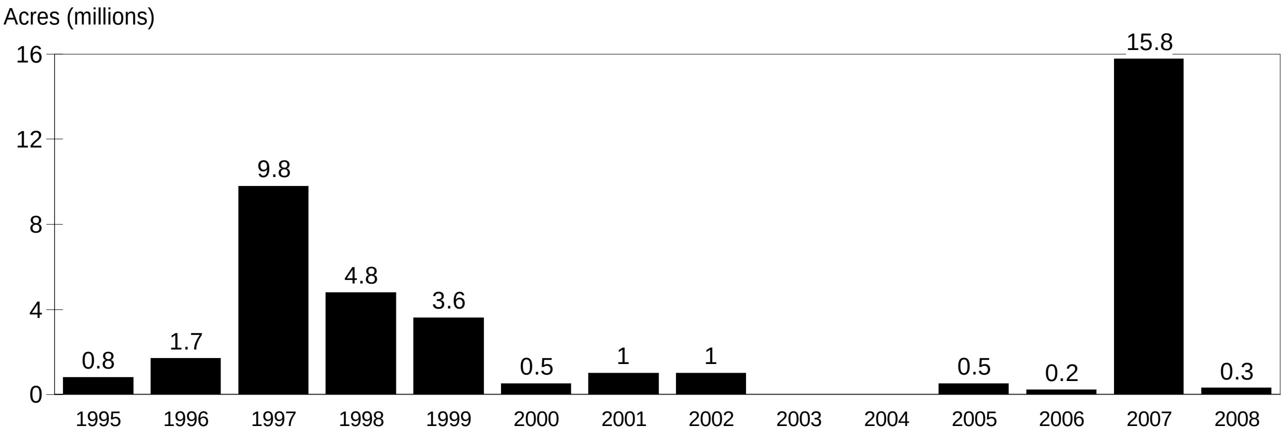
Scheduled Contract Expirations

At the end of the CRP contract period, annual rental payments made by USDA to CRP contract-holders cease, and producers may decide the next use of their land. If the land is returned to crop production and it is highly erodible, producers must adopt an approved alternative conservation system to meet Conservation Compliance requirements for retaining eligibility for USDA farm program benefits. CRP contract expirations in 1995 and 1996 were small due to the 1-year contract extension options granted producers in these years (fig. 6.3.2). However, combining extended contract acres with acres from contracts scheduled to expire on September 30, 1997, brought anticipated 1997 contract expirations to 21.5 million acres. However, 11.7 million of these acres were accepted for new contracts in the 15th signup, leaving 9.8 million expected to expire in 1997. Approximately 4.8 million acres are scheduled to expire in 1998, and 3.6 million acres in 1999.

Program Cost, Benefits, and Effectiveness

By idling highly erodible or other environmentally sensitive cropland, the CRP produces a wide range of physical and economic effects. Some effects, such as improved environmental quality and higher food costs, represent changes in the quantity or quality of real goods and services valued by society. These are the social benefits and costs. Other effects, including the disbursement of annual CRP rental payments and reduced outlays for USDA commodity programs, are not changes to real goods or services but to transfer payments between regions or sectors of the economy. Due to this fundamental difference, the overall effect of the CRP cannot be determined by simply adding up all the individual effects without regard to whether they represent real changes to social welfare or are merely transfer payments. Two separate accounting frameworks are necessary. The first focuses on CRP's net effect on social welfare, while the second

Figure 6.3.2--Schedule of CRP contract expirations, May 1997



1997 is net after subtracting 11.7 million acres scheduled to expire in 1997 but accepted for new contracts in the 15th signup.

Source: USDA, ERS, based on FSA data on CRP contracts.

summarizes the program's net effect on government spending.

For social welfare, it is necessary to estimate product and service value changes that occur with and without the CRP. In 1990, when the CRP stood at 33.9 million acres, ERS estimated net social benefits of \$4.2-\$9 billion in present value over the life of the program (Osborn and Konyar, 1990). This is the extent to which the social benefits of the CRP exceeded its social costs. Social benefits included increases in net farm income (\$2.1-\$6.3 billion), the value of future timber (\$3.3 billion), preservation of soil productivity (\$0.6-\$1.7 billion), improved surface-water quality (\$1.3-\$4.2 billion), lower damages due to windblown dust (\$0.3-\$0.9 billion), and enhanced small-game hunting (\$1.9-\$3.1 billion). Social costs included higher food costs to consumers (\$2.9-\$7.8 billion), costs of establishing vegetative cover on CRP acres (\$2.4 billion), and USDA technical assistance (\$0.1 billion). Since then, the U.S. Fish and Wildlife Service has estimated additional wildlife benefits of \$1.4 billion for waterfowl hunting, and \$4.1 billion for nonconsumptive wildlife benefits, making wildlife the largest benefit category for the CRP and bringing overall net benefits of the CRP to \$9.7-\$14.5 billion (see box, "Wildlife Benefits of the Conservation Reserve Program").

In 1990, ERS also estimated the net government cost (the second evaluation framework) of the CRP at \$6.6-\$9.3 billion in present value over the life of the program. Program expenses were estimated at \$14.6 billion in present value, of which \$13 billion represented annual rental payments. Commodity program cost savings were estimated at \$5.3-\$8 billion. However, estimates of commodity program savings are very sensitive to assumptions about annual acreage reduction programs that would exist in the absence of the CRP. Estimates of commodity program savings, for example, would be much smaller if it were assumed that annual acreage reduction programs in the absence of the CRP would be larger.

While the CRP has provided significant conservation and environmental benefits, especially for wildlife, most agree that the overall program could have been structured to provide even greater benefits. In addition, the government cost of enrolling some CRP acres could have been lower, particularly in the Great Plains. Experience of program implementation before and after passage of the 1990 Farm Act shows that (1) active targeting of bids based on relative comparisons of environmental benefits and contract costs improves program cost-effectiveness, and (2) consideration of the productivity of the acres offered in each bid can reduce the likelihood of overpayment.

Signups 1-9, conducted under authority of the 1985 Farm Act, were subject to mandatory minimum annual enrollment levels as established in the Act. In an effort to meet these enrollment levels, USDA did

Recent ERS Reports on the Conservation Reserve Program

The Conservation Reserve Program: Enrollment Statistics for Signup Periods 1-12 and Fiscal Years 1986-93, SB-925, Nov. 1995 (C. Tim Osborn, Felix Llacuna, and Michael Linsenbigler). Through the 12th signup, 36.4 million acres had been enrolled in the CRP with an average annual rental cost of $49.67 per acre and an average annual erosion reduction of 19 tons per acre.

"Changes in Store for CRP," *Agricultural Outlook*, Sept. 1995 (C. Tim Osborn). Administration actions on the CRP as of 1995 are reviewed as are proposals for the future of the CRP, including legislative proposals by members of Congress, the Senate Agriculture Committee's early version of the conservation title, and the administration's farm policy guidelines.

Expiration of Conservation Reserve Program Contracts, AIB-664-2, April 1993 (C. Tim Osborn and Ralph E. Heimlich). Outlines the imminent expiration of CRP contracts, what is at stake, and alternative policy options.

"A Fresh Look at the CRP," *Agricultural Outlook*, Aug. 1990 (C. Tim Osborn and Kazim Konyar). Based on the 33.9 million acres enrolled in signup periods 1-9, net economic benefits of the CRP were estimated to be $4.2-$9 billion in present value over the life of the program. This included benefits to farm income, timber production, soil productivity, water quality, wildlife, and air quality.

The Conservation Reserve Program: An Economic Assessment, AER-626, Feb. 1990 (C. Edwin Young and C. Tim Osborn). The net economic benefits of a 45-million acre CRP were estimated to be $3.4-$11 billion in present value over the life of the program (1986-1999). Effects of placing less emphasis on soil erosion control and more emphasis on forestry and environmental benefits were also examined.

Natural Resources and Users Benefit from the Conservation Reserve Program, AER-627, Jan. 1990 (Marc O. Ribaudo, Daniel Colacicco, Linda L. Langner, Steven Piper, and Glenn D. Schiable). This report provides detailed natural resource benefit estimates resulting from the CRP, including soil productivity, water quality, air quality, wildlife habitat, and groundwater supply.

(Contact to obtain reports: C. Tim Osborn, (202) 219-1030 [tosborn@econ.ag.gov])

not rank bids in signups 1-9. Rather, bids were accepted as long as (1) ownership and land eligibility criteria were met, and (2) the rental rate requested by the producer did not exceed a USDA maximum acceptable rental rate (MARR) established for a multicounty area or State. Therefore, an eligible parcel with twice the erodibility of another eligible parcel had no greater priority for enrollment. In addition, USDA established only one MARR for each area and this amount eventually became known to producers. As a result, producers could receive rental payments in excess of prevailing cash rents for enrolling less productive land. Also, MARR's were sometimes set too high in relation to average cash rents, primarily in the Great Plains, also contributing to overpayment.

Based on the need to enroll only a limited amount of additional acreage during 1990-95, under authority of the 1990 Farm Act, USDA actively ranked bids for acceptance in CRP signups 10-13. The ranking processes were designed to select acreage that provided the greatest conservation and environmental benefits relative to the government cost of enrollment. In addition, to reduce overpayment, new rental rate screening processes were instituted.

In signups 10-12, the rental payment requested by a producer was screened against a soil productivity-adjusted estimate of the rent that could be earned on comparable local cropland. Bids that exceeded this amount, adjusted for other costs incurred by producers due to CRP participation, were rejected. The bid screen amounts used in these signups were not related to the MARR's in signup periods 1-9. Next, eligible easement bids, primarily filterstrips, and wellhead protection bids that survived the rental rate screen were automatically approved for CRP enrollment. These bids typically involve a limited number of acres and a small government cost, but provide significant conservation and environmental benefits. Finally, standard bids that survived the rental rate screen were ranked for acceptance based on the ratio of an environmental benefits index (EBI) to the government cost of the contract. In signups 10-12, the EBI was comprised of seven coequal indicators (surface-water quality, groundwater quality, soil productivity, conservation compliance assistance, tree planting, Hydrologic Unit Areas identified by the USDA Water Quality Initiative, and conservation priority areas). When submitting a bid, producers were not informed of the rental rate screen amount for their soil or how the EBI was calculated. Approximately 2.5 million acres were enrolled in signups 10-12. As discussed earlier, in signups 13 and 15, revised EBI's were used to rank bids and rental rate requests were screened against productivity-based soil rental rates that were announced during the signups.

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6.4 Conservation Compliance

The 1985 Food Security Act introduced the Conservation Compliance and Sodbuster programs to combat soil erosion. These programs require farmers to implement approved soil conservation systems on highly erodible land (HEL) in order to receive certain USDA program benefits. These programs, along with other measures, have significantly reduced erosion on U.S. cropland. In 1995, approved conservation plans were being applied to nearly 90 million acres of cropped HEL, while an additional 30 million acres of HEL were enrolled in the Conservation Reserve Program. Major soil conservation practices implemented include conservation cropping sequences, crop residue use, and conservation tillage.

Contents

The Food Security Act of 1985 (1985 Farm Act) was drafted during a period of high agricultural support payments and growing concern about the environmental and productivity consequences of soil erosion. In 1982, cultivated HEL[1] accounted for nearly 60 percent of total erosion on U.S. cropland (USDA, NRI, 1994). The 1985 Farm Act introduced two new programs affecting farmers who cultivate crops on HEL: the Conservation Compliance Program and the Sodbuster Program.[2] Both programs required farmers to implement approved soil conservation systems on cultivated HEL in order to receive certain USDA program benefits. Conservation Compliance applied to HEL previously cultivated in any year between 1981 and 1985. It required farmers producing crops on HEL to implement and maintain a soil conservation system approved by the Natural Resources Conservation Service (NRCS) on that land by 1995. These conservation systems achieve a substantial reduction in soil erosion on a field or group of fields containing HEL. HEL placed into the Conservation Reserve Program (CRP) is also considered to be in compliance. The stricter Sodbuster Program applied to HEL not cultivated during 1981-85. Sodbuster required farm program participants bringing HEL under cultivation to apply basic soil conservation systems. Basic systems are intended to reduce soil erosion to the soil tolerance level (T): the rate above which long-term soil productivity may be depleted. This is a higher level of erosion control than often required under

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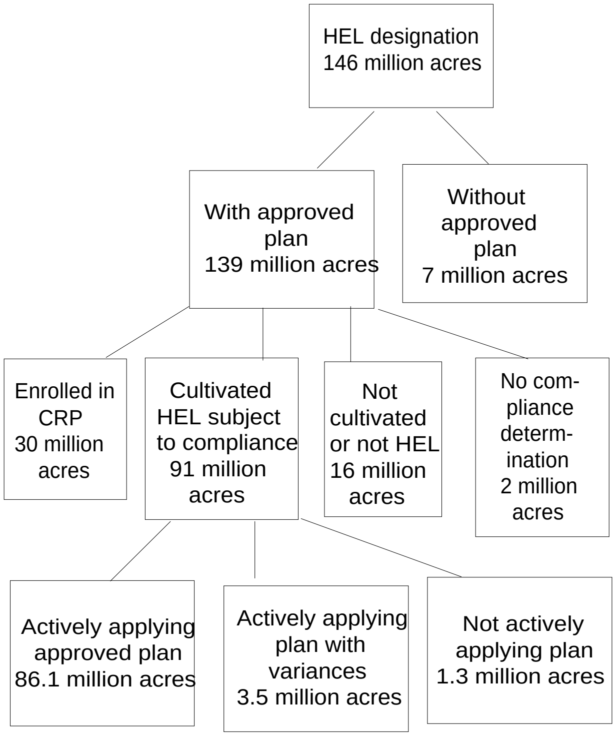
[1] HEL cropland was estimated using NRI points with an erodibility index greater than or equal to 8. In practice, HEL cropland is a field, not a point determination.

[2] The Conservation Reserve Program was a third major program introduced in the 1985 Farm Act to control soil erosion (see chapter 6.3).

Figure 6.4.1--Status of highly erodible land, 1995



Source: USDA, ERS, based on NRCS 1995 Status Review.

Conservation Compliance. Under both programs, farmers who continued to cultivate HEL without implementing an approved conservation system would be ineligible to receive Commodity Credit Corporation price supports or payments, CRP payments, farm storage facility loans, disaster payments, Consolidated Farm and Rural Development or Farmers Home Administration loans, or Federal Crop Insurance. However, this provision was modified under the Food, Agriculture, Conservation and Trade Act of 1990, giving the Secretary of Agriculture discretion to determine that a person, although in violation, acted “in good faith” without the intent to violate Conservation Compliance requirements. In such cases, the person’s payments may be reduced by not less than $500 nor more than $5,000, but the person would remain eligible to participate in USDA programs if the violation were corrected.

The Federal Agricultural Improvement and Reform Act (1996 Farm Act) made further changes in provisions governing cultivation on HEL. First, the 1996 Act made compliance no longer a requirement for Federal Crop Insurance. Second, the Act eliminated distinction between HEL cultivated from 1981 to 1985 and HEL brought under cultivation after 1985, doing away with the Sodbuster Program. Newly cultivated HEL may use conservation systems other than the basic systems previously required under Sodbuster. Alternative systems can be applied where they do not result in substantially higher soil erosion. However, alternative conservations systems may not always adequately prevent a substantial increase in soil erosion when converting HEL fields from native vegetation. In these cases, basic conservation systems may still be required.

The 1996 Farm Act also included several modifications to reduce compliance and monitoring costs. These include: (1) expedited variances for timely responses to producer requests for relief from climatic or economic hardship; (2) grace periods for good-faith violations to provide producers with unintended violations to come into compliance without penalty; (3) onfarm conservation research authority to examine innovative conservation systems; and (4) provisions to allow farmers to report residue measurements.

Status of Conservation Compliance: 1995

About 146 million acres, roughly one-third of total U.S. cropland, had been designated as HEL and potentially subject to Conservation Compliance.[3] In 1995, the first year conservation systems were to be fully applied and maintained, conservation plans had been approved for 139 million HEL acres (USDA, NRCS, 1996b). Of those acres with approved plans, 91 million were cultivated non-CRP HEL subject to compliance, while another 16 million acres were either not under cultivation in 1995 or were subsequently determined not to be HEL (USDA, NRCS, 1996a).[4] These acreage estimates can fluctuate with year-to-year changes in cultivated acreage. An estimated 30 million acres were enrolled in CRP and considered in compliance (USDA, FSA, 1997).[5] A remaining 2 million acres had not had compliance determinations. NRCS determined that approved conservation practices and systems were actively applied on over 86 million (95 percent) of the 91 million acres of non-CRP HEL subject to compliance (USDA, NRCS, 1996a). The proportion of HEL units determined as subject to compliance and

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[3] This includes some non-HEL soils that are in fields that are predominantly HEL.

[4] Land not currently in cultivation could be planted in cover crops or be in other conserving uses.

[5] Acreage of HEL enrollled in CRP could not be estimated directly from the NRCS 1995 Status Review and had to be derived from other sources.

Table 6.4.1—Conservation compliance status, 1995

Region	Designated HEL in cultivated cropland subject to compliance[1]	Actively applying approved plan	Actively applying plan with variances	Not actively applying plan (violations)
	Acres	*Percent of operating units*[2]		
Northeast	2,457,859	93.9	2.8	2.4
Appalachian	4,719,538	96.5	2.4	1.1
Southeast	1,021,934	98.3	0.7	0.5
Lake States	4,004,279	95.7	2.3	1.5
Corn Belt	18,662,889	90.3	7.6	2.0
Delta States	758,134	98.1	0.0	0.6
Northern Plains	23,683,540	94.3	4.2	1.5
Southern Plains	11,934,394	97.8	1.5	0.7
Mountain States	19,417,899	98.3	0.7	0.5
Pacific	4,306,341	92.4	5.5	2.0
Total/average	90,987,369	94.6	3.8	1.4

[1] Acreage total excludes HEL in the CRP.

[2] The percentage of acres in each compliance status determination is not known because the determination was made on an operating unit basis. However, the percentage of units in each status designation is an indicator of the relative acreage. The rows may not sum to 100 percent due to rounding, and because HEL cropland falling in "other" (includes, for example, wetlands on HEL or acres not required to apply plans) has been omitted.

Source: USDA, ERS, based on NRCS 1995 Status Review of Conservation Compliance.

not actively applying an approved conservation plan declined from 2.9 to 1.4 percent between 1994 and 1995 (USDA, 1994b and 1996a).

Only a small proportion of HEL cropland is not in compliance, although variances can be important in some regions. Based on survey estimates, about 1.3 million acres of HEL were estimated to be in violation (not actively applying an approved plan) in 1995. This represents just 1.4 percent of the 91 million acres of HEL cropland subject to compliance (USDA, 1996a). The Northeast had the highest percentage of units estimated to be in violation, while the Southeast had the lowest percentage (table 6.4.1). In 1995, the Corn Belt and Pacific regions had the highest percentages of units receiving climatic and hardship variances. Variances are offered to producers when climatic conditions prevent implementation of the full conservation plan, as when a drought prevents the establishment of a cover crop. Hardship variances are offered when circumstances such as family illness or crop failure prevent a farm from implementing the conservation plan. Because drought or floods can be widespread, variances can be important, not only for individual farmers, but also for broader production regions. The Northern and Southern Plains, Mountain States, and Corn Belt accounted for 80 percent of HEL acreage subject to conservation compliance in 1995 (table 6.4.1). In all regions, more than 90 percent of operating units with HEL subject to compliance were actively applying and maintaining an approved conservation system.

Since 1986, violations of the HEL conservation subtitle have resulted in $13.6 million in denied benefits on over 200,000 acres of cropland (table

Table 6.4.2—Benefits denied under the conservation compliance and sodbuster programs, 1986-95

Year	Producers found in violation	Land in violation	Value of benefits denied	Producers with all benefits denied
	Number	*Acres*	*Dollars*	*Number*
1986	2	10	10,834	2
1987	66	3,289	224,328	66
1988	174	3,745	530,974	174
1989	83	2,957	238,239	83
1990	342	60,295	1,555,209	342
1991	584	42,675	2,928,188	nd
1992	693	38,503	1,803,250	nd
1993	859	36,252	3,232,378	341
1994[1]	632	25,933	2,087,251	261
1995[2]	118	3,266	955,215	40
Total	3,553	216,925	13,565,866	1,309[3]

nd = no data available. [1] Preliminary. [2] As of December 11, 1995. [3] Number is incomplete because no information is available for 1991 and 1992.

Source: USDA, ERS, based on USDA, FSA, 1996.

Table 6.4.3—Conservation management systems and technical practices being applied on cultivated HEL subject to compliance (excluding CRP), 1995

Item	Acreage	Percent of cultivated HEL[1]
Management systems		
Conservation cropping sequence/crop residue use	27,443,973	30.2
Conservation cropping sequence/conservation tillage	9,081,148	10.0
Conservation cropping sequence only	6,249,209	6.9
Crop residue use only	4,041,388	4.4
Conservation cropping sequence/conservation tillage/grassed waterways	2,027,771	2.2
Conservation cropping sequence/conservation tillage/contour farming/grassed waterways/terrace	1,958,476	2.2
Conservation cropping sequence/contour farming/crop residue use/terrace	1,896,080	2.1
Conservation cropping sequence/crop residue use/wind stripcropping	1,768,605	1.9
Conservation cropping sequence/contour farming/crop residue use/grassed waterways/terrace	1,665,697	1.8
Conservation cropping sequence/conservation tillage/crop residue use	1,602,604	1.8
Total, 10 most frequently used systems	57,734,951	63.5
Technical practices[2]		
Conservation cropping sequence	75,632,767	83.1
Crop residue use[3]	48,294,496	53.1
Conservation tillage[3]	28,477,584	31.3
Contour farming	18,046,999	19.8
Terrace	12,868,684	14.1
Grassed waterway	10,842,932	11.9
Field border	4,442,198	4.9
Wind stripcropping	3,508,340	3.9
Cover and green manure	3,169,983	3.5
Surface roughing	3,018,871	3.3
Grasses and legumes in rotation	2,424,281	2.7
Stripcropping-contour	1,699,477	1.9
Critical area planting	1,545,287	1.7
Pasture and hay land management	1,126,426	1.2

[1] Based on 91 million acres of cultivated HEL subject to compliance.
[2] Because many conservation systems include multiple technical practices, percentages will sum to more than 100.
[3] Conservation tillage and residue mangement are often combined and reported as a single practice, conservation tillage.
Source: USDA, ERS, compiled from NRCS data, 1996.

6.4.2) (USDA, FSA 1996). Violations prior to 1990 were Sodbuster violations that occurred when HEL was brought into production without an approved conservation management plan, causing farmers to be ineligible for USDA benefits. After 1990, all farmers participating in USDA programs were to have approved conservation plans on HEL cropland. Persons without approved conservation plans or who were not implementing them on schedule could be found in violation of the conservation compliance provision.

Conservation Plans and Systems

Conservation plans specify economically viable conservation systems which substantially reduce erosion. Conservation systems are composed of one or more conservation practices. The 1995 status review provides the first assessment of fully implemented conservation systems under Conservation Compliance. Although the 1995 status review found over 4,000 different conservation systems (combinations of practices) applied nationwide, four conservation systems involving conservation cropping sequences, crop residue use, or a combination of these practices with conservation

Table 6.4.4—Technical practices included in conservation plans in Iowa, North Carolina, North Dakota, and Oklahoma, 1995

Technical practice	Iowa	North Carolina	North Dakota	Oklahoma
	Percent of conservation plans[1]			
Conservation crop rotation	87.1	82.0	99.0	9.9
Conservation tillage	79.2	30.6	0.4	3.5
Residue management	.7	50.5	98.4	92.3
Contour farming	44.4	24.3	--	5.4
Strip cropping field border	32.3	15.0	--	--
Strip cropping - contour	2.3	0.0	--	--
Strip cropping field	--	5.0	--	--
Strip cropping wind	--	--	0.6	0.3
Grassed waterway - retired[2]	24.9	21.9	0.7	8.2
Grasses & legumes in rotation	1.0	7.2	0.0	--
Cover and green manure crop	0.0	5.1	1.5	.3
Conservation cover - retired[2]	0.0	13.6	3.0	0.5
Critical area planting - retired[2]	0.8	4.3	0.1	0.6
Terrace	13.4	1.2	0.0	0.2
Pasture & hay land management	13.7	5.9	0.2	22.5
Pasture & hay land planting	1.3	6.3	0.4	0.3

-- indicates less than 0.1 percent.

[1] Because many conservation systems include multiple practices, percentages will sum to more than 100.

[2] Retired indicates land taken out of production.

Source: USDA, ERS, based on NRCS 1995 Status Review.

tillage covered half of HEL cropland (table 6.4.3). Conservation cropping sequences were included in the conservation systems applied to 83 percent of non-CRP HEL, and either conservation tillage or crop residue use was applied to 84 percent. Terraces, which require a significant capital investment, were used in 14 percent of conservation systems. Practices taking land out of crop production—such as grassed waterways, field borders, and critical areas plantings—are included in 12, 5, and 2 percent of the plans.

Adoption of particular conservation systems varies with climate, topography, soils, predominant crops, and pre-existing production practices. A system or practice acceptable in one location may not be feasible in another. The effectiveness of a system in controlling erosion depends on several factors, including the frequency, timing, or severity of wind and precipitation; the exposure of land forms to weather; the ability of exposed soil to withstand erosive forces; the plant material available to shelter soils; and the propensity of production practices to reduce or extenuate erosive forces.

A comparison of Iowa, North Carolina, North Dakota, and Oklahoma illustrates how local environmental conditions affect farmers' adoption of particular conservation systems. In the relatively homogeneous Northern Plains, there are few economically viable alternatives to a wheat/fallow rotation. Thus, in North Dakota, the conservation crop sequence/crop residue management system was part of nearly all conservation systems on cropped HEL (table 6.4.4; USDA, NRCS, 1996a). Similarly, in the Southern Plains, wheat is the predominant crop, with few economically viable alternatives. In Oklahoma, most conservation systems consist of a single technical practice—crop residue management. Both the number of feasible conservation systems and the number of systems required to control erosion are greater in areas with greater climatic and geographic variability. Iowa produces predominantly corn and soybeans, and has a higher average rainfall and a more varied topography than North Dakota and

Table 6.4.5—Land use and erosion changes on cultivated HEL and non-HEL, 1982-92

Region	Land use change				Erosion change[2]		
	Small grains	Row crops	CRP land[1]	Other ag.	Wind	Water	Total
HEL cropland[3]	*1,000 acres*				*Tons/acre/year*		
Northeast	-20.7	-391.1	95.7	-212.7	-2.01	0.00	-2.01
Appalachian	-530.1	-1,782.6	784.8	86.7	-5.30	-0.06	-5.36
Southeast	-192.3	-793.3	501.3	112.2	-5.82	0.00	-5.82
Lake States	-372.6	20.8	893.2	-244.3	-4.05	-0.71	-4.76
Corn Belt	-1,693.4	-1,818.5	2,996.9	-110.6	-8.53	-0.57	-9.11
Delta States	-86.7	-1,186.4	537.0	-135.4	-8.04	0.00	-8.04
Northern Plains	-2,081.6	-1,760.7	4,615.5	-890.3	-1.60	-2.61	-4.21
Southern Plains	-380.2	-1,939.3	3,265.4	-407.1	-0.49	-9.91	-10.00
Mountain States	-1,990.5	-1,084.5	5,225.3	-433.5	-0.75	-2.82	-3.57
Pacific	-527.1	-78.5	881.1	238.2	-4.20	-0.74	-4.94
Total HEL	-7,898.6	-10829.5	19,796.2	-2,001.7	-3.18	-2.69	-5.87
Non-HEL cropland							
Northeast	-94.1	-764.1	109.3	438.6	0.57	-0.00	0.57
Appalachian	-33.6	-1,454.5	291.4	726.7	0.39	0.01	0.40
Southeast	-676.3	-2,879.2	1,020.8	513.9	-0.31	0.00	-0.31
Lake States	-2,421.7	167.0	1,837.1	79.9	-0.15	0.05	-0.06
Corn Belt	-1,731.3	-183.2	2,139.0	1,017.0	-0.52	-0.52	-1.04
Delta States	156.3	-2,586.1	616.7	1,339.1	-0.45	0.00	-0.45
Northern Plains	-4,854.5	3,791.9	4,268.9	-601.5	-0.18	-1.60	-1.77
Southern Plains	-3,399.5	-1,733.8	1,870.7	314.5	0.06	-1.59	-1.53
Mountain States	-1,923.3	142.0	1,252.0	-505.0	-0.18	0.49	0.31
Pacific	-1,955.1	-520.5	837.9	693.7	-0.15	0.20	0.05
Total Non HEL	-16,008.1	-5,967.7	14,243.8	4,016.9	-0.20	-0.61	-0.82

[1] CRP in 1992, but cropland in 1982.
[2] Average erosion change on cultivated and CRP lands in 1992.
[3] HEL cropland refers to NRI points with an EI of 8 or greater.
Source: USDA, ERS, based on Kellogg and Wallace, 1995.

Oklahoma. Thus, in Iowa, a larger number of conservation systems are used, most frequently conservation cropping sequences and conservation tillage. North Carolina has a variable topography with diverse soils and precipitation patterns, and produces sizable quantities of wheat, corn, soybeans, cotton, sorghum, and tobacco. Here, the conservation systems are even more varied.

Erosion Reduction on HEL

Evidence from the National Resources Inventory (NRI) suggests that focusing conservation efforts on HEL was effective in reducing soil erosion on HEL. Between 1982 and 1992, estimated rates of soil erosion on U.S. cropland declined an average of 2.8 tons per acre per year (tay) (USDA, 1994).[6]

Estimated erosion on cropped HEL declined at an even higher rate, 5.9 tay on average (USDA, 1994a, table 6.4.5). Since 1985, Conservation Compliance, Conservation Reserve, and Sodbuster all worked to reduce soil erosion on HEL directly. Other changes in commodity programs affected soil erosion indirectly by altering producer returns, changing

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[6] The rate of soil erosion is estimated using the Universal Soil Loss Equation and the Wind Erosion Equation. Both consider factors such as the erodibility of the soil material, the slope and slope length, climatic conditions, land use, vegetative cover, and conservation practices. The factors that producers can reasonably change to alter soil erosion are land use, vegetative cover, and conservation practices.

relative profitability between commodities, and changing land use and production practices.

With more complete implementation of conservation systems since 1992, the erosion on cultivated HEL has declined further. In 1995, the implemented conservation systems reduced average soil erosion to less than the soil tolerance level (T) on 44 million acres, nearly half of HEL cropland subject to compliance (USDA, NRCS, 1996a). On most of the balance, average erosion was less than 2T. In 1995, erosion on HEL averaged 9.2 tay less than it did prior to installing and maintaining approved conservation systems. Not all of this reduction can be attributed to Conservation Compliance. Changes in market and program prices and technological innovations also affect the adoption of conservation systems. Some conservation practices now in place on HEL would have been applied even without the program and some were in place before the program.

Costs and Benefits of Conservation Compliance

While fully implemented conservation plans provide erosion control benefits, reducing soil erosion has a cost shared by farmers, consumers, and taxpayers. These costs and benefits can vary widely across individuals and regions. Conservation compliance requirements can increase production costs for farmers by idling or retiring cropland, substituting more expensive production practices, or requiring the purchase of new equipment. Consumers can be affected by changing market prices, as competitive commodity markets transmit changes in the cost of production. Other costs include the administrative costs of the compliance programs, which are borne by taxpayers (see box, "Summary of Reports Assessing Conservation Compliance," p. 309).

Benefits

Erosion control provides both onsite productivity benefits to farmers and off-site benefits from lower environmental damages. Reducing soil erosion helps maintain soil quality and land productivity. Erosion control reduces the water pollution associated with sediment, attached nutrients, and pesticides deposited into rivers, lakes, and streams. It also lowers maintenance costs for irrigation facilities and waterways and increases the service life for dams by reducing the amount of storage area lost to sedimentation. Reducing wind erosion lowers costs of cleaning wind-blown soil from machinery and household items.

Water and air quality benefits of erosion control are uncertain because of the difficulties in predicting weather patterns and other physical processes such as runoff and leaching. However, Ribaudo and Young (1989) estimated the national off-site benefits from controlling soil erosion to be 56 cents per ton, or $9 billion dollars per year. This includes commercial and recreational uses, water storage, and reduced flood damage, but ignores health and aesthetic benefits, as well as any interactions between changes in soil erosion and chemical leaching effects. Piper and Lee (1989) estimated the benefits of reduced damage from wind erosion at $0.30-$1.96 per ton abated.

Costs

The costs of Conservation Compliance in a given region or to individual producers within a region depend on several factors. These include the distribution of HEL cropland, the resource attributes of operations, and the production alternatives available to producers. In some cases, implementation of a Conservation Compliance plan entails little or no additional production costs. For example, conservation tillage and residue management systems reduce fuel, labor, and/or machinery costs (Bull, 1996; Fox, et al., 1991; Miller, 1996). These systems are being adopted not only on HEL subject to compliance, but on other lands as well. In other cases, compliance requires farmers to take acreage out of production or to make significant capital investments. As shown earlier, Iowa and North Carolina have a much higher percentage of plans with higher cost practices—such as terraces, critical area plantings, grassed waterways, border strips, and filter strips—than do North Dakota and Oklahoma (table 6.5.4). Even within States, there can be considerable variation in the reliance on higher cost practices.

The net costs of individual cropping practices may also vary across different physical settings. Some practices will entail little or no cost in some areas, but be costly in others. For example, conservation cropping rotations can entail only minor changes (or no changes) from pre-existing crop rotations, such as reduced grazing of winter wheat to maintain sufficient residue cover. In other cases, conservation rotations may require farmers to establish non-revenue producing winter cover crops or to add a year to a rotation, reducing producer returns. These more costly practices are often required for crops that leave little crop residue or that require substantial soil disturbance such as sugar beets, potatoes, or peanuts. Terracing is another practice with net returns sensitive

Table 6.4.6—Benefits and costs of conservation compliance, regional estimates[1]

Region	Per-acre benefits from-- Water quality	Air quality	Productivity	Per-acre costs to-- Producers	Federal Government	Net economic benefits	Benfit/cost ratio
	Annual 1993 dollars per acre						
Northeast	35.63	0	0.16	3.57	3.43	28.80	5.12
Lake States	21.99	0	0.12	0.32	3.43	18.37	5.90
Corn Belt	15.61	0	0.25	8.90	3.43	3.53	1.29
Northern Plains	3.47	3.00	0.19	3.35	3.43	-0.11	0.98
Appalachia	23.58	0	0.24	3.51	3.43	16.89	3.43
Southeast	25.63	0	0.12	8.18	3.43	14.15	2.22
Delta	35.50	0	0.12	1.97	3.43	30.22	6.60
Southern Plains	5.26	4.63	0.33	2.34	3.43	4.45	1.77
Mountain	5.10	4.01	0.15	0.20	3.43	5.63	2.55
Pacific	31.83	1.09	0.14	2.23	3.43	27.40	5.85
United States	13.81	1.93	0.21	3.78	3.43	8.74	2.21

[1] For procedures used, see box "Measuring the Benefits and Costs of Conservation Compliance." Onsite benefits based on USDA (1986) and SCS March 1994 status review. Offsite benefits are based on Ribaudo (1989), Huszar (1989), and SCS status review. Costs are based on Barbarika and Dicks (1988), SCS status review, and SCS staff-year projection. U.S. figures are weighted means of regional numbers, based on HEL acreage by region.

Source: USDA, ERS, based on Canning, 1994.

to local conditions. The capital expenditure, maintenance cost, and opportunity cost of land taken out of production associated with installing terraces generally exceeds the discounted benefits. However, in drier environments, the increased yield from moisture conservation can result in the discounted benefits exceeding costs (Clark, et al., 1985).

In North Dakota, Iowa, and Oklahoma, pasture and hay land management includes periodic cropping of pasture land to improve ground cover, control weeds and address problems on root-bound lands. These conservation measures, which provide more productive pasture and hay land, tend to increase net farm revenues. However, in some States, pasture and hay land management reflects a shift from cropping to a less intensive and less profitable use.

Conservation Compliance also has administrative costs, ideally measured as the difference between costs with and without the program. NRCS estimated that 6,000 staff-years would be required to administer the Conservation Compliance program in 1994, with staff-year requirements declining by one-half in 1995, and further in later years. Two important figures are absent from these data: (1) how the conservation provision influenced the total size of NRCS staff years, and (2) whether any services previously provided by existing staff were phased out due to compliance duties (Canning, 1994).

Comparing Costs and Benefits

Canning (1994) estimated the national benefits of Conservation Compliance (table 6.4.6) to be $15.95 per acre, with water quality improvements the largest source of benefits ($13.81 per acre). The estimated national cost was $7.21 per acre, shared fairly evenly by producers and government. Costs borne by farmers/landowners are offset by improvements in long-term soil productivity. Taxpayers pay the administrative costs of the program, including cost-share assistance, in return for the public benefits from improved air and water quality. These estimates lead to a benefit/cost ratio of 2.2, indicating that, on average, over two dollars of benefits are being obtained for each dollar of cost.

Benefit/cost ratios range from 0.98 in the Northern Plains States, the region with the greatest amount of HEL, to 6.60 in the Delta States (table 6.4.6). Four regions—the Northeastern, Lake States, Delta States, and Pacific—had benefits exceeding costs by a ratio of more than 5 to 1.[7] The Delta States region was the only region with both a large reduction (8 tons per acre per year) in the estimated rate of soil erosion and a high benefit/cost ratio. The Corn Belt and the

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[7] The Corn Belt includes Illinois, Indiana, Iowa, Missouri, and Ohio; the Delta States includes Arkansas, Louisiana, and Mississippi; and the Southern Plains is composed of Oklahoma and Texas.

Measuring the Benefits and Costs of Conservation Compliance

The benefit and cost estimates presented in table 6.3.3 are based on a combination of sources. A March 1994 status review provides detailed information related to the goals and accomplishments of the conservation compliance provision. This information is translated into monetary estimates of annual benefits and costs using studies that estimate the economic impacts of soil erosion to households, firms, and municipalities.

Water Quality

Several studies have looked at the relationship between water quality and soil erosion from farmland. Ribaudo (1989) estimated the value of total annual damage caused by soil erosion from all sources to the quality of water used by households, industry, and municipalities in the 10 farm production regions. The damages from cropland erosion per ton can be estimated by multiplying Ribaudo's regional damage estimate by cropland's percentage of total sediment delivery, and dividing the result by the region's total annual erosion from cropland. Multiplying the water quality damages per ton of soil erosion for each region times the erosion reduced by compliance in that region provides an estimate of compliance's water quality benefits in that region.

Air Quality

Air quality is affected by wind-blown soil, which accounts for much of the erosion west of the Mississippi River. Like water-based erosion, a damage function for wind erosion depends on the use value of the damaged good and on the total volume of wind erosion. Huszar (1989) uses contingent valuation techniques to determine the annual damage per household per ton of wind-blown dust in New Mexico. As with water-based soil erosion, marginal wind-blown soil abatement benefits are smaller in sparsely populated areas, and where the total volume of wind erosion is large relative to the reduction achieved by compliance. Huszar's damage function is applied to estimate county-level impacts of a reduction in wind erosion from conservation compliance in all regions west of the Mississippi River. These estimates are then aggregated to farm production regions. In eastern regions, wind erosion damage is not estimated, although it is a problem in some areas. The estimates include only household-related damage. Inclusion of dust damage to firms, health, and recreation would increase the damage values.

Productivity

Onfarm benefits of soil conservation have been estimated by USDA (1986) as the net current value of future productivity gains to soil per ton of erosion abatement. Weighting the USDA value per ton of soil conservation for each soil group by the percentage of acreage in each soil group for each county with significant HEL acreage provides estimates of the onfarm net present value per ton of soil conservation. Multiplying this value by soil savings from conservation compliance and annualizing these benefits (based on a 4-percent discount rate) gives estimates of annual productivity gains.

Producer and Government Costs

Conservation compliance costs of producers are estimated at the field level. For HEL fields that need only conservation tillage, crop rotation, or other residue management (no structures), compliance cost is assumed to be zero. Barbarika and Dicks (1989) assumed a no-cost transition to conservation tillage when this was all that was required for full compliance. In a national survey reported by Esseks and Kraft (1993), 1 in 5 producers subject to compliance expected to incur costs, and under 1 in 20 expected significant costs. Where structures are prescribed by SCS, one of two equations (depending on whether or not conservation tillage is already applied to the field), estimated by Barbarika and Dicks, is used to relate annual installation and maintenance costs per acre to the level of soil erosion and the size of the treated field. Since the Barbarika and Dicks equations include the value of SCS technical assistance, this value is deducted from annual costs to avoid double-counting government costs.

Government costs of carrying out compliance are based on the value of continuing staff time per acre. USDA's budgeted annual staff years devoted to compliance duties are projected to level off at just under 2,000 by 1996. To be consistent with Barbarika and Dicks, opportunity costs are set at $82 per staff hour ($62.50 per staff hour in 1985 dollars converted to 1993 dollars). Compliance acres are estimated at 100 million, 86 percent of total HEL acreage (Esseks and Kraft,1993), less 28 million acres enrolled in the CRP. The startup costs of compliance, such as the staff years devoted to HEL determinations and development of conservation plans, are not included since they would amount to very little on an annualized basis.

Southern Plains had comparable reductions but lower per-acre benefits and higher costs.

Changes in Commodity Programs Affect Incentives for Compliance

The Conservation Compliance Program requires farmers growing crops on HEL cropland to implement an approved soil conservation plan in order to participate in commodity programs. This requirement directly links incentives offered by commodity programs with soil conservation goals. Prior to the FSA of 1985, commodity programs provided farmers with incentives to bring land into production and encouraged cultivation of erosive crops (Reichelderfer, 1985). In some cases, land brought into production was vulnerable to soil erosion. Cultivating lands vulnerable to erosion need not in itself be a problem if farmers adopt appropriate soil conservation measures. However, in many cases farmers may not have had a private incentive to do so. Conservation Compliance attempts to use commodity programs benefits to encourage farmers to adopt soil conservation practices.

Linking program benefits to conservation efforts also means that the *size* of the commodity program benefits can affect farmers' incentives to adopt soil conservation practices. Conservation Compliance requirements do not apply to producers not participating in programs. Changes in program benefits and compliance costs can influence program participation and the effectiveness of the Conservation Compliance Program. Between 1986 and 1995, commodity corporation outlays to the seven major program crops have decreased from $18.6 billion to $4.1 billion. Over this period, program participation also declined. Large changes in benefits are more likely to affect farmer incentives to participate in programs where costly conservation systems are required. Farmers using conservation systems that are cost-saving or cost-neutral will be more likely to retain these systems even if benefits decrease.

Changes in the *design* of commodity programs can also affect farmer incentives to participate in programs and to meet Conservation Compliance requirements. The 1996 Farm Act replaces the previous target price-deficiency payment system with a system of fixed annual payments. Under the previous system, farmers received payments based on the difference between the market price and a pre-determined target price for a portion of their production. Deficiency payments would rise when prices were low, but decline in years when prices were high. Farmers' program payments and their incentives to participate in programs would decline in high-price years. Under the 1996 Farm Act, payments to producers do not automatically decline in years when commodity prices are relatively high, so higher prices are less likely to reduce incentives to meet Conservation Compliance. The 1996 Farm Act also expands planting flexibility, increasing the attractiveness of program participation. It allows producers to make more market-based planting decisions by eliminating Acreage Reduction Programs that required farmers to take acreage out of production in some years as a condition of receiving program payments. It also eliminated many planting restrictions for producers of grains and upland cotton.

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Glossary

Approved conservation system—A set of field-specific cropping and managerial soil conservation practices designed in cooperation with local NRCS agents to reduce soil erosion. Basic conservation systems, which pertained to Sodbuster lands until 1996 and may be applied to other HEL, reduce erosion to the soil tolerance level (see definition below). Alternative conservation systems provide a significant level of erosion reduction without excessive economic burden on producers for land subject to conservation compliance.

Applied conservation system—An approved conservation system that has been applied and is being maintained, based on standards contained in the NRCS field-office technical guide.

Conservation Compliance provision—Since 1985, the conservation provision requires all farmers producing on HEL who receive or request certain USDA benefits to have an approved conservation system applied on those lands. Violations may result in disqualification from USDA programs or reduction of benefits.

Conservation cropping sequence—A crop rotation (multi-year sequence of crops) designed to improve or maintain good physical, chemical, and biological conditions of the soil; help reduce soil erosion; improve water use efficiency and water quality; improve wildlife habitat; or break reproduction cycles of plant pests.

Erodibility index (EI)—The natural erosion potential of a soil divided by the soil's tolerance level.

Field—A contiguous tract of land under a single farm operation and isolated by permanent barriers, such as fences, waterways, or woodland.

Highly erodible land (HEL)—Designations made by NRCS field staff include cropland in fields that have at least one-third or 50 acres (whichever is less) of highly erodible soils. HEL soils were defined as those soils with an erodibility index (EI) greater or equal to eight. An EI of 8 indicates that without any cover or conservation practices, the soil will erode at a rate 8 times the soil tolerance level. HEL designations currently total 146 million acres. This number has changed over time as more producers apply for benefits and more determinations are made.

Soil tolerance level (T)—The rate of soil erosion that can continually occur without reducing that soil's productivity.

Tract or operating unit—All fields farmed by a single operator. The entire unit is subject to the penalties of noncompliance, provided any field in the unit is determined to be highly erodible and the operator of that field has not applied or maintained the approved conservation system before receiving certain USDA program benefits.

Variances—Variances are offered to producers when **climatic** conditions such as flood or drought prevent implementation of the full conservation plan. One example would be where a drought prevented the establishment of a cover crop. **Hardship** variances are offered when circumstances such as family illness or crop failure prevent a farm from implementing the conservation plan. Because drought or floods can be widespread, variances can be important for not only individual farmers but also production regions.

Violations/disqualifications—Determined by FSA on recommendations of NRCS field staff, based on the guidelines of the approved conservation system. Before January 1, 1995, they occurred when an HEL field failed to have a partially applied conservation system by specified interim deadlines. After January 1, 1995, they occur when an operator requests or receives certain USDA program benefits without fully applying or maintaining an approved conservation system on HEL. Operators can request the development of a new plan or may be granted a temporary variance.

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Summary of Reports Assessing Conservation Compliance

USDA Natural Resource Conservation Service Status Reviews

Each year, NRCS randomly selects 5 percent of all HEL tracts nationally to conduct a status review. Tracts receiving variances are visited each year, as are tracts referred to NRCS by other agencies or whistle blowers. For each review, an NRCS soil conservationist visits the fields to determine if a developed conservation system is being implemented properly. Erosion rates are estimated, then inadequacies are either reported to agencies administering Federal farm programs or farmers are granted a variance. NRCS provides farmers with specific instructions to bring the tract into compliance. Recent changes in the review process now target HEL that is enrolled in Federal farm programs, and thus subject to compliance. A detailed evaluation of program implementation in several States serves as an internal quality control of program administration.

U.S. General Accounting Office (1994)

GAO evaluated progress made by NRCS in implementing the Conservation Compliance and Swampbuster programs established in 1985. A previous GAO evaluation (1990) had indicated that NRCS needed to improve the quality of the farmers' conservation plans and improve enforcement activities. GAO examined whether recent NRCS reforms addressing the concerns of the previous evaluations had resulted in improvements in the management and effectiveness of Conservation Compliance and Swampbuster. GAO concluded that while there were positive aspects of the reforms, NRCS still needed to improve its enforcement activities through better managed status reviews and by establishing clearer authority of State and county offices over conservation plans and wetland identifications. GAO also recognized that effective enforcement of conservation plans and swampbuster requires a change in the "culture" of NRCS, a change that acknowledges NRCS' newer, more regulatory role rather than its traditional role of advising farmers.

USDA Office of Inspector General (1995)

The Office of Inspector General (OIG) audited the Conservation Compliance Provisions to determine if producers complied with conservation requirements on HEL and whether the provision was effective in reducing erosion. In the 30 counties audited, OIG found that management practices reduced erosion from 9.5 tons per acre per year (tay) to 5.1 tay. They found that the plans tended to overestimate the rate of erosion associated with the conservation plans. Forty-seven percent of the tracts audited had rates of erosion at or below their soil loss tolerance. OIG concluded that the tolerance level can be achieved on all HEL fields. Despite the low level of erosion, 21 percent of the sampled tracts were not in full compliance. Forty percent of the tracts received a total of $212,000 in government benefits while having an erosion rate in excess of the minimum acceptable level of 7.2 tay. To provide a more accurate picture of the state of erosion control, OIG recommended that NRCS: (1) develop better measures of progress in reducing erosion and include these in the status review; (2) develop measures to evaluate relationships between soil loss levels—before, planned, alternative conservation plans, current—and tolerance; (3) provide more specific guidance to state and local administrators on identifying and treating ephemeral gully erosion, and (4) provide a consistent set of factors in estimating wind and other erosion.

U.S. General Accounting Office (1995)

GAO evaluated three aspects of Conservation Compliance: implementation flexibility in USDA across different regions of the country, differences in farming practices and the associated cost of compliance, and benefits and drawbacks of the program. Flexibility has been increased by allowing state offices to develop alternative conservation practices to satisfy regional standards for erosion. GAO found that: (1) three quarters of farmer conservation plans specified residue management as the primary control technique; (2) use of reduced tillage increased 30 percent between 1990 and 1994, and (3) no comprehensive data were available on the effect of conservation plans on production costs. A review of studies on compliance costs found mixed results. Factors leading to these mixed results include crop characteristics, soil type, climate, and farming practices. Studies of conservation tillage methods have shown both higher and lower returns to farmers, depending upon yield effects and changes in pesticide applications. GAO identified reduced soil erosion and improved surface water quality as environmental benefits that were potentially offset by increased pesticide and herbicide applications.

6.5 Wetland Programs

Wetlands are important to the Nation's environment. Wetlands can store floodwater, trap nutrients and sediment, help recharge ground water, provide habitat for fish and wildlife, and buffer shorelines from wave damage. Wetlands can also provide outdoor recreation, produce timber, provide grazing for livestock, and support educational and scientific activities. Despite these public values, conserving land as wetland forecloses more intensive economic uses for landowners. Differences between public and private interests in wetlands provoke controversy over wetland programs and policies.

Contents

Wetland status involves both the extent or quantity of wetlands and the functions or quality of wetlands. Most policy interest has been focused on the extent of wetlands remaining and the rate of conversion from wetlands to other uses. However, as wetland loss rates decline, quality aspects are receiving increasing attention.

Wetland Status and Trends

Almost half of U.S. wetland acreage has been converted to other uses since colonial times. Current policy is attempting to balance wetland losses and wetland restoration, with the long-term goal of achieving a net gain in wetlands that would partly reverse the historic decline.

Wetland Extent

Estimated wetland extent in 1992 was almost 124 million acres in the contiguous 48 States (including an estimated 12 million acres of Federal wetlands), just over half of the wetlands present in 1780 (table 6.5.1). An additional 170 million acres of wetlands exist in Alaska and Hawaii, down slightly from colonial times. Absolute losses of wetlands since 1780 have been greatest in Texas, Florida, Minnesota, Illinois, Arkansas, North Carolina, and Louisiana, ranging from 5 to 10 million acres each. Nine States experienced a 70-percent or greater loss in wetland extent since 1780, and 9 more lost more than 50 percent of original wetlands. Net gains posted for some States may be due to underestimates of original wetlands, or represent real gains through incidental or intentional wetland creation or restoration associated with water impoundments and other projects. Remaining wetlands are concentrated in Florida, along the southeastern and gulf coasts, and in the northern Lake and Plain States (fig. 6.5.1).

The greatest loss of wetlands occurred between colonial times and the early decades of this century, with most occuring since 1885 (Pavelis, 1987). Average annual rates of wetland conversion have generally been falling since the first reliable scientific inventories were taken in the mid-1950's.[1] Between 1954 and 1974, the net rate of wetland conversion averaged 457,600 acres per year, with 81 percent of gross wetlands conversion to agricultural uses and 8 percent to urban (table 6.5.2, fig. 6.5.2). Between 1974 and 1983, net wetland conversion dropped to 290,200 acres per year; gross conversions to agricultural use accounted for 53 percent and urban

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[1] Available data on wetland conversion are from three studies using different statistical sampling techniques on slightly different wetland universes.

Table 6.5.1—U.S. wetlands extent and losses, by States 1780's-1992[1]

State[1]	1780's extent[2]	1992 extent[3]	1780-92 losses[4]	
	Thousand acres			%
Texas	16,000	5,656	10,344	65
Florida	20,325	11,251	9,074	45
Minnesota	20,135	11,738	8,397	42
Illinois	8,212	1,361	6,851	83
Arkansas	9,849	3,140	6,708	68
North Carolina	11,090	5,259	5,830	53
Louisiana	16,195	11,195	5,000	31
Indiana	5,600	769	4,831	86
Mississippi	9,872	5,675	4,197	43
Ohio	5,000	937	4,063	81
Missouri	4,844	985	3,849	80
Alabama	7,568	3,737	3,830	51
Michigan	11,200	7,454	3,746	33
Wisconsin	9,800	6,546	3,254	33
California	5,000	1,901	3,099	62
Iowa	4,000	1,183	2,817	70
South Carolina	6,414	3,878	2,536	40
Oklahoma	2,843	497	2,345	83
Nebraska	2,910	1,206	1,705	59
Colorado	2,000	691	1,309	65
Tennessee	1,937	806	1,131	58
Kentucky	1,566	447	1,119	71
North Dakota	4,928	3,825	1,103	22
Wyoming	2,000	932	1,068	53
Maine	6,460	5,522	938	15
Oregon	2,262	1,430	832	37
New Jersey	1,500	700	800	53
Arizona	931	231	700	75
New Mexico	720	84	636	88
Maryland	1,650	1,028	622	38
South Dakota	2,735	2,144	591	22
Washington	1,350	1,012	338	25
Connecticut	670	361	309	46
Massachusetts	818	594	224	27
Delaware	480	263	217	45
Pennsylvania	1,127	948	179	16
Nevada	487	326	161	33
Virginia	1,849	1,727	122	7
West Virginia	134	99	35	26
Rhode Island	103	96	7	6
Idaho	877	926	(49)	(6)
Kansas	841	915	(74)	(9)
Georgia	6,843	6,956	(113)	(2)
Montana	1,147	1,363	(216)	(19)
New Hampshire	220	476	(256)	(116)
Vermont	341	710	(369)	(108)
Utah	802	1,247	(445)	(56)
New York	2,562	3,718	(1,156)	(45)
48-State total	221,130	123,945	97,184	44
Hawaii	59	52	7	12
Alaska	170,200	170,000	200	0
U.S. total	391,389	293,997	97,391	24

[1]Ranked in order of absolute loss. [2]Based on estimates by Dahl, 1990. [3]Based on 1992 National Resources Inventory estimates totaling 111.4 million wetland acres on nonfederal land in the 48 States, adjusted upward to include an estimated 12.5 million acres of wetlands in Federal ownership derived from the locations of U.S. Fish and Wildlife Service National Wetland Status and Trends Analysis samples. Estimates for Hawaii are 1992 NRI and estimated Federal wetlands. Alaskan estimate is for 1980 from Dahl, 1990. [4] Wetland gains in eight States may be due to low estimates of 1780's wetland extent or real wetland gains since 1780. Source: USDA, ERS estimates based on Dahl, 1990 and 1992 National Resources Inventory data (see footnotes).

What is a Wetland?

Since 1977, the Federal Government has used a three-part wetland definition involving soils, vegetation, and hydrology. According to the U.S. Army Corps of Engineers (ACE), wetlands are "areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions." While the definition of wetlands has not changed over time, the precise guidelines for deciding what land meets that definition, called delineation criteria, have been controversial because of conflicts between landowners who want to use and develop wetland areas and environmentalists who want to preserve them.

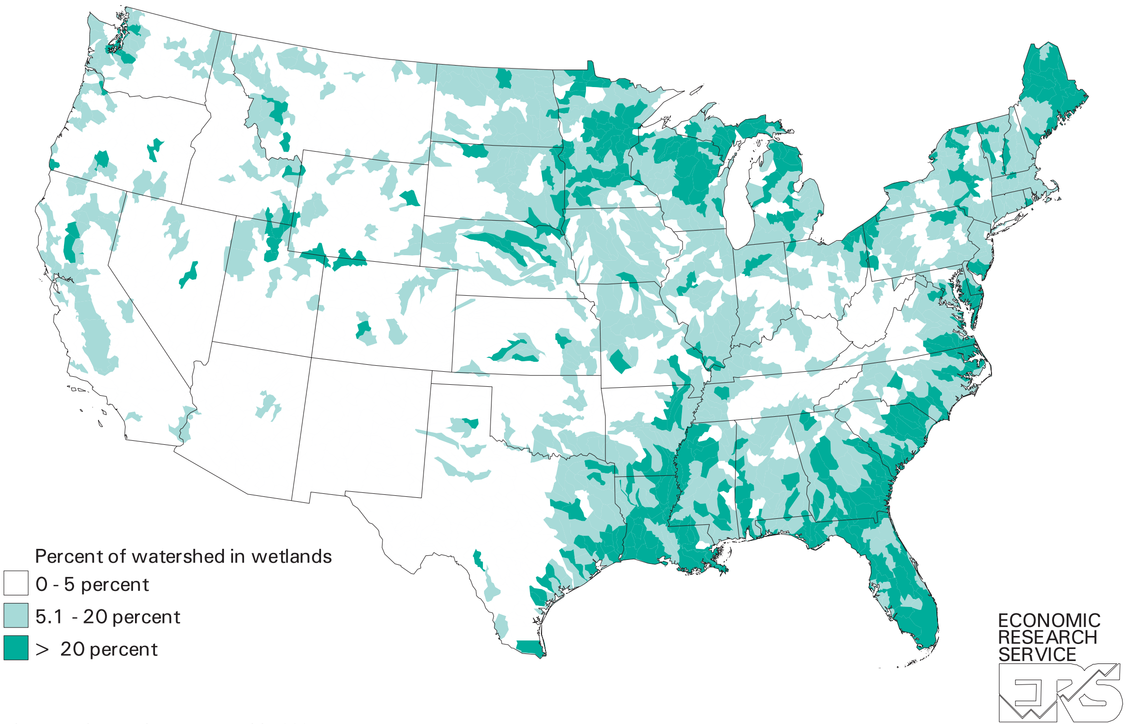
After interagency attempts to develop a manual for delineating wetlands in 1979, 1987, 1989, and 1991, a National Research Council committee was convened in 1994. Its report rejected the idea that all three indicators (soil, water, and vegetation) must be present and defended the use of one or two of the indicators to infer the presence of the third (NRC, 1995). It urged development of regional standards and protocols for delineation that recognize the diversity of wetlands and stressed the need for functional assessment in regulatory delineation.

Field tests of the latest manuals indicated that 30 to 80 percent of wetlands delineated in the 1989 manual would be excluded by the 1991 manual. Field evaluations in the fall of 1995 indicated that wetlands would be reduced 60 to 75 percent if proposed congressional revisions to wetland delineation are enacted.

uses for 3 percent (38 percent converted to other uses was cleared and drained, possibly intended for agricultural use). Between 1982 and 1992, the net rate of wetland conversion further dropped to 79,300 acres per year, with agriculture accounting for only 20 percent of gross wetland conversions and urban uses for 57 percent. Over half of all wetland losses between 1982 and 1992 were from forested wetlands or wetlands on forest land.

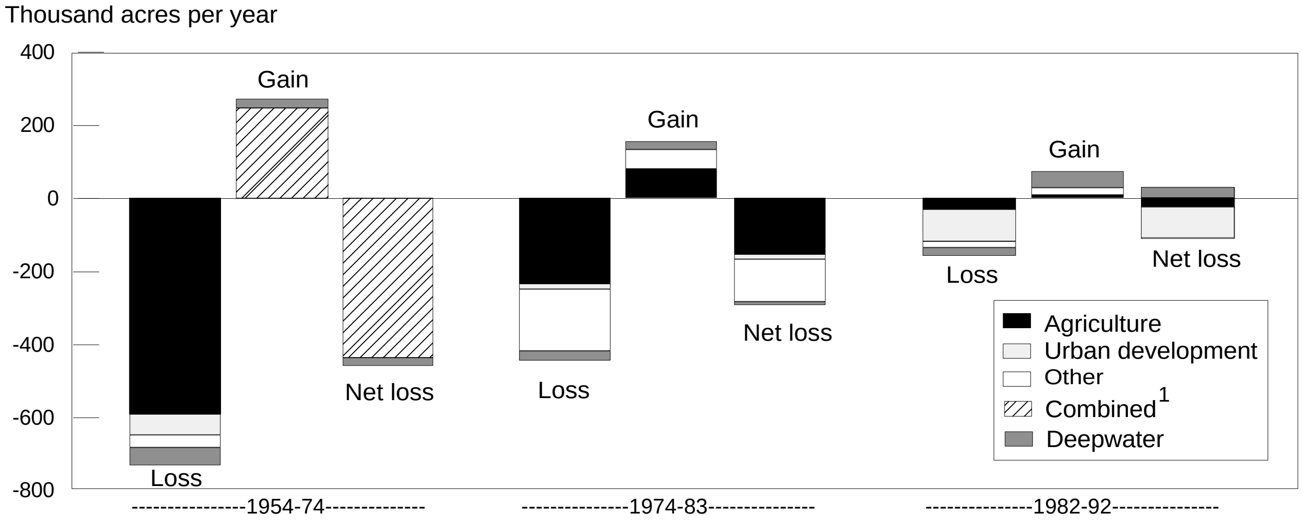
Conversion back to wetlands has increased from 1 acre for every 3 lost in 1954-74 to 1 acre for every 2 in 1982-92. Deepwater (permanently flooded lands) provided two-thirds of wetland gains in 1982-92 and former agricultural land provided 10 percent. In addition to abandonment, natural reversion, and

Figure 6.5.1--Distribution of wetlands on rural nonfederal land, 1992



Source: USDA, ERS, based on NRCS 1992 National Resources Inventory data.

Figure 6.5.2--Change in wetland acreage by use, 1954-1992



[1] Combined agriculture, urban development, and other. Separate data not available.

Source: USDA, ERS, based on (for 1954-84) USDI, National Wetland Status and Trend Analysis; and (for 1982-92) NRCS, National Resources Inventory data.

Table 6.5.2—Average annual wetland conversion, contiguous States, 1954 to 1992

Item	USDI, Fish and Wildlife Service estimates[1] (Includes Federal lands)				USDA, NRCS estimates[2] (Excludes Federal and urban lands)	
	1954-74 change		1974-83 change		1982-92 change	
	1,000 acres/yr.	*Percent*	*1,000 acres/yr.*	*Percent*	*1,000 acres/yr.*	*Percent*
Wetlands converted to:						
Agriculture	592.8	81	234.8	53	30.9	20
Urban development	54.4	8	14.0	3	88.6	57
Other	35.3	5	168.1	38	16.4	10
Deepwater	47.6	6	29.0	6	20.2	13
Total	730.1	100	445.9	100	156.1	100
Converted to wetlands from:						
Agriculture	247.8[3]	913	81.5	53	41.8	54
Urban development			.4	0	1.5	2
Other			53.4	34	28.8	38
Deepwater	24.7	9	20.4	13	4.8	6
Total	272.5	100	155.7	100	76.9	100
Net change in wetlands[4]:						
Agriculture	434.7[3]	953	153.3	53	-10.9	-14
Urban development			13.6	5	87.1	110
Other			114.7	40	-12.4	-16
Deepwater	22.9	5	8.6	2	15.4	20
Total	457.6	100	290.2	100	79.3	100

na = not available. [1] U.S. Fish and Wildlife Service, National Wetland Status and Trends Analysis, mid-1950's to mid-1970's and mid-1970's to mid-1980's. Excludes Alaska and Hawaii. [2] Soil Conservation Service, USDA, National Resources Inventories, 1982 and 1992. Includes only nonfederal land. Excludes Alaska; includes Hawaii and Caribbean. Wetlands exclude deepwater habitats. [3] Includes agriculture, urban development, and other. Separate estimates not available. [4] Conversion of wetland to nonwetland uses, plus increases in wetlands due to restoration, abandonment, and flooding. Excludes change to or from Federal ownership. Source: USDA, ERS compilation of available data, see footnotes.

private activity, wetland gains resulted from restoration programs such as the joint ventures sponsored under the North American Waterfowl Management Plan, Fish and Wildlife Service's Partners for Wildlife program, mitigation required under Section 404 of the Clean Water Act, and the efforts of private groups such as Ducks Unlimited.

Wetland losses vary throughout the country. Gross wetland losses were greatest along the east coast, Great Lakes, and Gulf Atlantic States, especially Louisiana, Florida, and North Carolina (fig. 6.5.3). Losses were more moderate in the Pacific Northwest. Thus, while net losses of wetlands are greatly reduced, certain areas of the country and certain wetland types are still experiencing significant losses.

Wetland Quality

With wetland losses stemmed, wetland quality is now receiving greater attention. Wetland quality or function is determined by hydrologic functions (such as groundwater recharge, shoreline stabilization, flood peak reduction, tidal flows, and sediment accretion), nutrient supply functions (such as organic matter, nutrient concentrations, and toxic metal concentrations), plant community characteristics and dynamics (dominant and sensitive species), and faunal community characteristics (arthropods, fish, aquatic invertebrates, birds, and mammals) relative to optimal levels in a fully functioning wetland of each type (NRC, 1992).

Methods have been developed to analyze wetland function, but they have not been systematically employed to indicate trends in wetland quality (Brinson, 1996; Adamus and Stockwell, 1983). However, changes in four factors—soil erosion, irrigation, forest cover, and urbanization—have potentially affected wetland quality and serve as indicators. In 1982-92, net reductions in erosion and irrigation in wetland watersheds probably had positive effects on wetland quality, while deforestation and urbanization likely had negative effects (table 6.5.3).[2]

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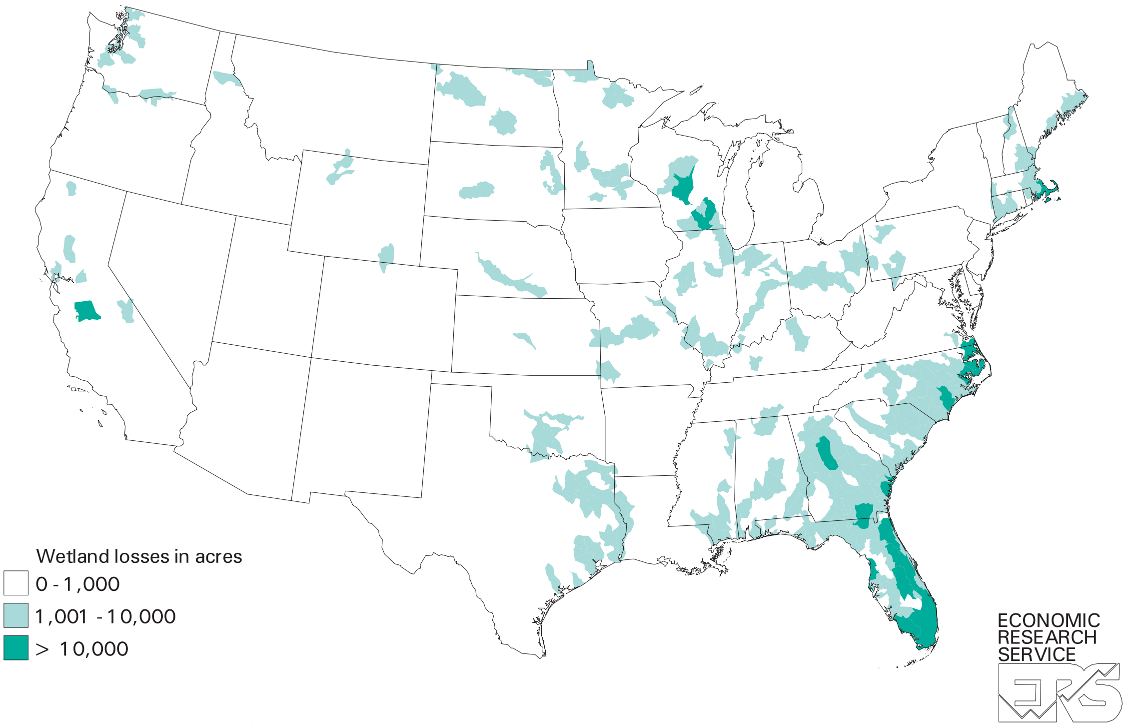
[2] Gross changes at the watershed level have not been validated as indicators of actual change in wetland quality and cannot reflect subtleties of landscape position and hydrology that would increase or mitigate wetland degradation.

Figure 6.5.3--Gross wetland losses, 1982-92



Source: USDA, ERS, based on NRCS 1992 National Resources Inventory data.

Sediment from soil erosion can clog wetland vegetation and impair water holding capacity. In 1982-92, decreases in all sources of water-caused erosion were widespread, occurring in 63 percent of the 677 wetland watersheds (watersheds with at least 5 percent of area in wetlands). Watersheds with erosion decreases contained 61 million wetland acres in 1992, while those with erosion increases contained 14.4 million wetland acres. Land retired from production in the Conservation Reserve Program—along with widespread changes in agricultural production practices caused by less intensive rotations, adoption of conservation tillage, and implementation of conservation compliance provisions in the 1985 Food Security Act—accounted for the erosion reductions.

Increases in irrigation can degrade wetlands where diversions from natural watercourses rob wetlands and other instream uses of water or where groundwater pumping lowers water tables and dries out wetlands. Similarly, decreases in irrigated area or in diverted water could improve wetlands. More wetland watersheds experienced net decreases in irrigated acreage between 1982 and 1992 than had net increases, but the majority had no change. Some 23 million acres of wetlands occurred in watersheds that had decreases in irrigated acres, and 15.8 million acres of wetlands were in watersheds where irrigated acreage increased. Watersheds with increases in irrigated acres are largely in humid areas where irrigation supplements natural precipitation. Supplemental irrigation may cause short-term stress on affected wetlands, but long-term damage is less likely.

Loss of tree cover, both from permanent land-use change and from normal harvesting of mature tree crops, can stress wetlands. Tree canopy protects watersheds from runoff and erosion and shades watercourses, lowering water temperatures for sensitive aquatic species. While some areas were planted to trees in 1982-92, development of tree canopy in a decade is usually insufficient to replace loss of mature tree cover. Nine out of 10 wetland watersheds lost forested acres between 1982 and 1992. The loss of tree cover reflects both purposeful harvest and incidental clearing of trees associated with changes such as urban and agricultural development. Forest harvest is likely the major cause of deforestation in the Southeast, northern New England, Minnesota and Wisconsin, and the Pacific. Tree clearing for urban development is likely a major

Table 6.5.3—Indicators of potential change in wetland quality, contiguous States, 1982-92

Indicator	Wetland watersheds[1]		Wetland area		Change in			
					Erosion	Irrigated area	Forest cover	Urbanization
	Number	*Percent*	*1,000 acres*	*Percent*	*Million tons*	*Million acres*		
Water erosion								
Increased erosion may have degraded wetlands	88	13	14.4	15	3.8	0.1	-1.0	-1.0
Decreased erosion may have improved wetlands	429	63	61.0	64	-98.0	0.3	-3.1	-4.9
No change	160	24	20.1	21	0.0	0.1	-1.2	-1.1
Irrigated area								
Increased irrigation may have degraded wetlands	93	14	15.8	17	-17.6	1.3	-1.0	-1.4
Decreased irrigation may have improved wetlands	149	22	23.0	24	-21.4	-0.8	-1.3	-2.4
No change	435	64	56.7	59	-55.2	0.0	-2.9	-3.1
Forest cover								
Decreased cover may have degraded wetlands	587	87	87.1	91	-86.9	0.5	-5.3	-6.7
No change	90	13	8.4	9	-7.3	0.0	0.0	-0.3
Urbanization								
Increased urban area may have degraded wetlands	647	96	92.3	97	-92.8	0.4	-5.2	-7.0
No change	30	4	3.2	3	-1.4	0.0	0.0	0.0
Summary of the four indicators								
All indicate degraded wetland quality	19	3	3.6	4	0.6	0.2	-0.3	-0.4
Three indicate degraded, one no change	187	8	25.0	26	2.1	0.2	-1.5	-1.2
Three indicate degraded, one improved quality	300	44	42.8	45	-68.8	0.7	-2.5	-3.3
All indicators made no change	9	1	1.0	1	0.0	0.0	0.0	0.0
Two indicate degraded, two indicate improved	142	21	21.1	22	-25.5	-0.6	-0.9	-2.0
Three indicate improved, one degraded quality	18	3	1.8	2	-2.5	-0.1	0.0	-0.1
All indicate improved wetland quality	2	0	0.1	0	-0.1	0.0	0.0	0.0
Total wetland watersheds	677	100	95.5	100	-94.1	0.5	-5.3	-7.0

[1] Watersheds with 5 percent or more of total area in wetlands.

Source: USDA, ERS, based on 1992 National Resources Inventory data.

cause in southern New England, the mid-Atlantic, and Florida.

Urban development, measured by the change in urban land area between 1982 and 1992, can stress wetlands because of increased runoff from paved areas, toxic runoff from industrial pollutants and chemicals and oils deposited on roadways, and from trash and garbage dumped in wetland areas. Nearly all wetland watersheds (96 percent) had urban land increases, adding 7 million acres of developed land over the decade. Urbanization in wetland watersheds represented 48 percent of total U.S. urbanization. More extensive suburban development patterns may have less impact on wetlands than intensive development, particularly where zoning and floodplain management avoid loss of wetlands and riparian areas.

The four indicators together provide insight on the overall change in wetland quality from 1982 to 1992 (table 6.5.3). Mostly negative indicators suggest that many more watersheds declined in quality than improved. Watersheds with wetlands likely degrading in quality (all four indicators negative or unchanged) totaled 206, just over 30 percent of the 677 wetland watersheds. The majority of the remaining watersheds (300) had more negative than positive indicators, suggesting a possible decline in quality (though the net effects of the positive and negative factors are uncertain). In contrast, only 2 watersheds likely had improving wetland quality (all indicators positive or unchanged) and 142 possibly had improving quality (more positive than negative indicators).

Wetland Incentives and Programs

Landowners respond to a variety of economic and public policy factors that influence wetland conversion. The recent reduction in wetland losses is likely the cumulative effect of several important trends: (1) decline in the profitability of converting wetlands for agricultural production; (2) passage of the Swampbuster provisions in the 1985 and 1990 farm bills; (3) continued implementation of the Clean Water Act Section 404 program, as well as growth in State regulatory programs; (4) greater public interest and support for wetland protection and restoration; and (5) implementation of wetland restoration programs at the Federal, State, and local level.

Economic Factors

Economic factors have, over time, both encouraged and discouraged wetland conversion. Between 1954 and 1974, relatively stable net farm incomes and new drainage technology contributed to wetland conversion for agricultural uses, averaging 592,800 acres per year. Cropland acreage increased in Florida (21.9 percent), Arkansas (16.1 percent), North Dakota (8.7 percent), and Iowa (7.7 percent). The next period (1974-83) saw an overall decline in farm income, accompanied by price volatility caused by international market pressures. These economic conditions, along with wetland regulations, slowed conversion to 234,800 acres per year. In 1982-92, falling prices, lower farm incomes, high debt loads, and the Swampbuster provisions reduced agricultural wetland conversion to only 30,900 acres per year.

Government payments to farmers have influenced wetland conversion over time. In 1954-74, government payments increased the revenue received for the commodities produced on converted land, reduced risk by stabilizing prices and revenue, offered an incentive to increase crop acreage base, and required additional land for set-asides. In 1974-83, real direct government payments dropped to only 9 percent of net farm income and were almost zero when commodity prices spiked between 1974 and 1977. In 1982-93, government payments averaged 26 percent of net farm income, but program rules no longer allowed participants to expand their base acreage and payments were denied to producers who converted wetlands after 1985.

The economic cycle in the construction sector has also affected wetland conversions. In 1954-74, postwar stability and a sharp increase in construction activity in the early 1970's resulted in wetland conversion for urban purposes averaging 54,400 acres per year. In 1974-83, wetland conversion for developed uses fell to only 14,000 acres per year. Wetland regulation under Section 404, which began in 1972, probably affected the construction industry more than it did agriculture because of construction's greater visibility, its greater familiarity to EPA and U.S. Army Corps of Engineers (ACE) regulators, and its proximity to EPA and ACE offices in urban areas. In addition, recovery in housing construction occurred more in the West and Midwest, resulting in less wetland conversion for the necessary land because of the less frequent occurrence of wetlands in those regions.

In 1982-92, new housing starts sustained a renewed rate of wetland conversion for developed uses averaging 88,600 acres per year, primarily in the South. The increased wetland conversion occurred despite a perceived tightening of wetland regulation under Section 404 and in State programs since 1987.

Similar levels of economic activity in agriculture and construction do not produce similar wetland conversion from one time period to another (table 6.5.4). Wetland losses to agriculture dropped from 12.6 acres for each million dollars of net farm income in 1954-74 to 0.9 acres in 1982-92 (Heimlich and Melanson, 1995). Wetland losses dropped from 30.2 acres per 1,000 housing starts in 1954-74 to only 8 acres in 1974-83, then rebounded to 49.4 acres per 1,000 starts in 1982-92. In part, these observed differences in conversion rates can be explained by differences in the regional distribution of activity, in the type and size of housing constructed, and in expectations of future profits when a sector is contracting versus expanding. However, wetland

Table 6.5.4—Wetland loss rates per unit of economic activity, contiguous States, 1954-92

	Average annual economic activity		Gross wetland loss per unit of economic activity	
Period	Net farm income	New private housing starts	Loss per $ million of net farm income	Loss per 1,000 housing starts
	$ billion (1987)	*Million*	*Acres*	
1954-74	47.5	1.8	12.6	30.2
1974-83	37.2	1.8	6.4	7.8
1982-92	34.0	1.7	0.9	49.4

Source: USDA, ERS, based on Heimlich and Melanson, 1995.

Table 6.5.5—Swampbuster provision violations, 1987-93[1]

Year	Producers in violation	Land in violation	Benefits denied
	Number	*Acres*	*$ million*
1987	12	100	0.1
1988	127	1,490	1.2
1989	121	693	1.1
1990	105	560	1.3
1991	165	1,428	2.0
1992	156	3,221	1.6
1993	152	1,926	1.5
1994[2]	97	1,027	1.4
1995[3]	1	2	*
Total	936	10,447	10.2

[1] Includes producers and violating land for which price support or disaster benefits were denied. Benefits denied include price support payments, farm storage facility loans, crop insurance, and insured or guaranteed loans, but do not include a value for price support loans or disaster payments.

[2] Preliminary.

[3] Incomplete.

* Less than $100,000.

Source: USDA, ERS, based on FSA 1995 program data files.

regulatory programs increasingly mitigate conversion pressure arising from economic conditions.

Protection Programs

Until 1978, some government programs encouraged conversion of wetlands to other uses by providing financial and technical assistance (see box, "Evolution of Agricultural Wetland Policy," p. 319). A policy change toward preservation began in the late 1970's, using disincentives and regulation to reduce conversion.

Swampbuster. Indirect Federal assistance for wetland conversion was eliminated by the Swampbuster provision (Title XII C. P.L. 99-198) of the Food Security Act of 1985. The Swampbuster provision made a farm operator ineligible for price support payments, farm storage facility loans, crop insurance, disaster payments, and insured or guaranteed loans for any year in which an annual crop was planted on converted wetlands. Persons sanctioned for Swampbuster violations increased from only 12 in 1987 to 165 in 1991, but have dropped since then (table 6.5.5). Despite intensive debate, few changes were made to Swampbuster provisions in the 1996 Federal Agriculture Improvement and Reform Act.

Section 404 Permits. Wetland conversion is directly regulated by the U.S. Army Corps of Engineers and the Environmental Protection Agency, under Section 404 of the Clean Water Act. Few permit applications under section 404 are actually denied. In fiscal year 1994, the Corps received 48,292 permit applications (table 6.5.6). Of these, 43,753 (91 percent) were authorized through general permits, standard permits, or letters of permission (affecting 17,200 acres); 4,184 (9 percent) were withdrawn (about half of which qualified for general permits, administrative adjustments, or were not required); and only 358 (less than 1 percent) were denied. The Corps estimates that an additional 50,000 activities are authorized each year by general permits that do not require the public to notify the Corps. Of 2,454 enforcement cases in FY 1994, only 70 (3 percent) involving the most egregious circumstances resulted in litigation or administrative penalties (U.S. Army Corps of Engineers, 1995).

Table 6.5.6—Permit actions under section 404 of the Clean Water Act, FY 1994

Action	Number	Percent
General permits issued	39,619	82.0
Standard permits issued	3,760	7.8
Letters of permission issued	374	0.8
Applications withdrawn	4,184	8.7
Permits denied	358	0.7
Total applications	48,292	100.0

Source: USDA, ERS, based on U.S. Army Corps of Engineers, 1995.

Permits for agricultural activities were only 6.7 percent (3,430) of total permits considered in FY 1994. Of these, 87.5 percent were general permits, 11.7 percent were special permits, and 0.9 percent (30 permits) were denied. More than half of the agricultural activities that do require permits involve conversion of wetlands to developed uses. The vast majority of agricultural activities are covered by Section 404 (f) exemptions that preclude permits for "normal" farm activities such as plowing, seeding, cultivating, and harvesting. Most other activities associated with farming are also exempt as long as woody vegetation, if any, is not disturbed.

The Corps has been working to reduce permit evaluation time. While the number of permit actions increased 27 percent in 1990-94, average permit evaluation times dropped by 14 percent. General permit applications took an average of 16 days to process in FY 1994, while denied permits required an average of 164 days, for an overall average processing time of 27 days.

Table 6.5.7—Wetland Reserve Program results, by State, 1992-96

State[1]	Applications received		Applications enrolled	
	Number	*Acres*	*Number*	*Acres*
Louisiana	553	127,549	187	61,912
Mississippi	389	111,044	130	57,872
Arkansas	556	104,542	103	28,883
Missouri	1,005	92,324	198	23,306
Iowa	310	19,887	211	15,860
California	415	169,338	44	15,561
Oklahoma	141	41,676	23	12,777
North Carolina	54	10,725	28	10,725
Wisconsin	164	10,940	134	9,935
Texas	87	73,618	13	9,021
Oregon	33	12,134	17	8,277
South Dakota	149	10,670	84	5,913
Illinois	216	21,136	66	5,795
Tennessee	189	21,328	24	5,746
Nebraska	261	23,655	39	5,111
Minnesota	379	23,629	56	4,493
Washington	105	8,869	23	4,072
Kansas	80	5,834	44	3,894
Indiana	597	25,287	61	3,426
New York	154	7,446	58	3,192
Ohio	350	13,000	62	2,882
Montana	11	2,819	7	2,499
South Carolina	120	7,500	18	2,333
Georgia	115	15,682	4	2,005
Michigan	82	3,191	34	1,995
Maryland	16	1,693	12	1,483
Kentucky	187	16,830	9	1,420
Alabama	89	3,500	6	919
Colorado	28	1,040	10	725
Alaska	1	626	1	626
Virginia	140	21,000	16	623
Pennsylvania	35	1,000	19	516
Maine	11	1,000	3	500
Vermont	43	781	6	200
New Jersey	7	320	2	195
Connecticut	5	341	3	112
New Hampshire	24	103	3	103
Idaho	13	700	2	102
Wyoming	13	2,450	4	84
Delaware	6	52	3	52
Massachusetts	14	310	2	30
Utah	5	3,370	0	0
U.S. total	7,152	1,018,938	1,769	315,175

[1] Ranked in order of acres enrolled. No applications received from Arizona, Florida, Hawaii, Nevada, New Mexico, North Dakota, Rhode Island, and West Virginia.

Source: USDA, ERS, based on NRCS, 1996 (program data summary)

Table 6.5.8—Emergency Wetlands Reserve Program results, by State, 1993-1996

State	Applications received		Applications enrolled	
	Number	*Acres*	*Number*	*Acres*
Iowa	645	57,551	330	36,744
Missouri	496	65,275	128	21,927
South Dakota	152	15,850	81	9,904
Illinois	33	12,736	20	5,651
Minnesota	85	3,000	27	2,241
North Dakota	18	1,500	2	235
Kansas	5	146	4	142
Nebraska	13	233	4	55
Total	1,447	156,291	596	76,929

Source: USDA, ERS based on NRCS, 1996 program data files.

Restoration Programs

Restoration programs include activities to restore prior converted wetlands, enhance wetland function on existing degraded wetlands, and buffer wetlands from surrounding cropland uses.

Wetlands Reserve Program. Restoration of wetlands gained momentum in 1990 with establishment of the Wetlands Reserve Program (WRP). WRP has a goal of restoring 975,000 acres to wetlands by 2002. In the 1996 Farm Act, Congress reaffirmed the enrollment goal and required one-third of enrollments each in 30-year easements, cost-share agreements, and permanent easements. Farmers often express reluctance to cede rights to cropland permanently, and are generally more favorable toward shorter obligations (SWCS, 1994). The WRP program funds USDA to restore wetlands and purchase permanent or long-term easements to restrict agricultural use of the restored wetland. The landowner is allowed certain economic uses of the restored wetland that may reduce the cost of the easement. These uses include hunting, fishing, or other recreational activity, grazing during prescribed times, and selective timber harvesting that is compatible with wetland restoration. The landowner is paid up to 75 percent of the cost of restoring the former wetland.

Following successful WRP enrollments in 1992, 1994, and 1995, Congress appropriated $77 million in FY 1996 to retire more than 100,000 acres of cropland and restore them to wetlands. As of September 1996, USDA enrolled 315,175 acres from 1,769 landowners in nearly every State, out of more than a million acres offered (table 6.5.7). Expanding from 9 pilot States in 1992 to 20 States in 1994, WRP

Evolution of Agricultural Wetland Policy

Encouraging Wetland Drainage, 1780-1977

Early Encouragement 1780-1940—For the first 200 years of U.S. history, the Federal Government approved of and assisted with wetland drainage to further public health and economic development goals. Between 1849 and 1860, the **Swampland Acts** granted 64.9 million acres of wetlands to 15 States on the condition that proceeds of wetlands sold to individuals be used for reclamation projects. States also encouraged wetland drainage by passing legislation enabling creation of local drainage districts (Pavelis, 1987).

Agricultural Conservation Program (ACP), Great Plains Conservation Program (GPCP), and Conservation Technical Assistance (CTA), 1940-77—Cost-sharing and technical assistance for open ditch and tile drainage were used on some 57 million acres of wet farmland, including many wetlands. However, in response to Executive Order 11990 in 1977, USDA prohibited further use of ACP and GPCP cost-sharing for tile or surface drainage, except under limited circumstances.

Small Watershed Program, 1944-1977—Funds for flood control and drainage structures were provided under PL-566 and the PL-534 Flood Control Act. Construction of outlet channels under PL-566 provided drainage outlets for increased farm drainage in wetland areas. In 1977, USDA changed the programs in response to Executive Order 11990 to limit direct impacts on wetlands.

Encouraging Wetland Preservation, 1970 to present

Water Bank Program, 1970—In return for annual per-acre payments, landowners agreed not to burn, drain, fill, or otherwise destroy the character of enrolled wetland areas. Existing Water Bank contracts were terminated after 1990, but landowners could enroll in the Wetland Reserve Program.

Section 404, Federal Water Pollution Control Act Amendments, 1972—The only Federal program regulating wetland conversion is Section 404 dredge and fill permit requirements enacted in the 1972 Federal Pollution Control Act amendments, now called the Clean Water Act.

Food Security Act (FSA), 1985—Indirect Federal assistance for agricultural wetland conversion was eliminated by the wetland conservation provisions (**Swampbuster**) of the 1985 FSA. The Swampbuster provision was a quasi-regulatory policy that made a farm operator ineligible for price support payments, farm storage facility loans, crop insurance, disaster payments, and insured or guaranteed loans for any year in which an annual crop was planted on wetlands converted after 1985. In 1989, **Conservation Reserve Program (CRP)** eligibility was expanded to include wetland that had been cropped for at least two years between 1981 and 1985, but had not been drained.

Tax Reform Act, 1986—This Act restricted or eliminated many provisions that indirectly subsidized agricultural wetland conversion. Among these were deductions for land clearing expenses, deductions for soil and water conservation expenses, and preferential treatment of capital gains, including capital gains realized from draining wetlands.

Food, Agriculture, Conservation, and Trade Act (FACTA), 1990—In addition to some adjustments to the Swampbuster provision, this act authorized a **Wetland Reserve Program (WRP)**. The Act called for restoration of 1 million acres of cropland to wetlands, requiring permanent or long-term easements with the landowner to restrict agricultural use of restored wetland.

Bush Administration Wetlands Plan, 1991—Plan for accelerated regulatory reform, followed shortly by the 1991 interagency wetland delineation manual, substantially revised the 1989 manual. Little progress was made in implementing the Bush plan.

Clinton Administration Wetlands Plan, 1993—An interagency task force led by the new Council on Environmental Quality crafted their own wetland regulatory reform package that embraced the “no net loss” of wetlands goal, streamlined Section 404 permit processing, gave NRCS authority for wetland delineation on agricultural land, and supported wetland restoration through a variety of programs, including WRP.

Federal Agriculture Improvement and Reform Act (1996 Farm Act)—Continued the Wetland Reserve Program with a goal of 975,000 acres and required that, beginning October 1, 1996, one-third of total program acres be enrolled in permanent easements, one-third in 30-year easements, and one-third in restoration only cost-share agreements. Made changes to give farmers more flexibility, including expanding areas where mitigation can be used, providing more options for mitigation, and encouraging effective and timely use of "minimal effect" determinations. Wetland conversion activities, authorized by a permit issued under Section 404 of the Clean Water Act, which make agriculture production possible, will be accepted for farm bill purposes if they were adequately mitigated. The concept of "abandonment" was revised to ensure that Prior Converted designations remain as long as land is used for agriculture. A pilot program for wetland mitigation banking was established. Wetlands are once again eligible for enrollment in CRP.

Table 6.5.9—Wetland enhancement and restoration activity, 1987-95[1]

Program	1987	1988	1989	1990	1991	1992	1993	1994	1995	Total
					Thousand acres					
Partners for Wildlife	2	16	37	42	41	38	35	32	na	243
NAWMP[2]	--	--	38	65	98	88	51	50	na	390
Conservation Reserve	0	0	410	0	0	0	0	0	0	410
Wetland Reserve	--	--	--	--	--	42	0	144	116	302
Emergency WRP	--	--	--	--	--	--	25	0	31	57
Section 404	na	na	na	na	na	na	na	15	38	53
Total	2	16	485	107	139	168	111	241	185	1,455

na = not available

[1] Includes acres of wetlands restored from prior conversion, enhancements of existing degraded wetlands, and upland buffers.

[2] NAWMP = North American Waterfowl Management Plan.

-- = Plan or program not in effect.

Source: USDA, ERS, based on Tolman, 1995; USDA, FSA, 1995; U.S. Army Corps of Engineers, 1995.

operated nationwide in 1995 and 1996. Louisiana and Mississippi enrolled over 50,000 acres each, followed by Arkansas, Missouri, Iowa, California, Oklahoma, and North Carolina with more than 10,000 acres each. No land was enrolled in Florida nor in urbanized States like Rhode Island and Hawaii or in arid States like Arizona, New Mexico, and Utah.

WRP enrollment rose from 43,356 acres in 1992 to 196,747 acres in 1995/96. The average cost of enrollments is $680 per acre; costs range from more than $1,500 per acre in Massachusetts, Missouri, and New Hampshire to less than $500 per acre in Georgia, Minnesota, Oklahoma, South Dakota, Colorado, and Maine.

The Emergency Wetlands Reserve Program (EWRP) was established in 1993, using funds from the Emergency Watershed Protection Program authorized under emergency supplemental appropriations after the Midwest flood. The voluntary program helped landowners convert flood-damaged cropland to wetlands if the cost of the levee restoration and cropland renovation exceeded the value of the land. To date, more than 75,000 acres have been enrolled for restoration to wetlands in eight Midwestern States (table 6.5.8), mostly in Iowa and Missouri. Easement and restoration costs totaled $63 million, or about $800 per acre enrolled.

The U.S. Fish and Wildlife Service's Partners for Wildlife negotiated voluntary, nonbinding agreements with landowners to share the cost of restoring more than 240,000 acres to wetlands since 1987 (table 6.5.9). A related program of joint ventures with State and local governments and private organizations such as Ducks Unlimited and the Isaak Walton League under the North American Waterfowl Management Plan has restored and enhanced almost 400,000 acres since 1989. As discussed above, WRP and EWRP account for more than 390,000 acres of wetland restoration since 1992. CRP put more than 400,000 acres under 10-year contracts in 1989, many of which have been fully restored as functional wetlands. Finally, mitigation requirements under Section 404 restored more than 50,000 acres in 1993 and 1994. Additional mitigation has occurred since 1987, when the Corps adopted guidelines specifically requiring mitigation, but no data are available on restorations earlier than 1993.

Impacts of Proposed Changes to Wetland Programs

Congress proposed a number of changes to current wetlands programs. Proposed restrictions on programs affecting property rights would heavily impact wetland protection programs. In addition, direct changes in wetland protection and restoration programs have been proposed, including extensive changes to how wetlands are delineated. The focus on floodplain management deriving from the extensive flooding in 1993 is also stimulating proposals for change.

Section 404 Permit Program Changes

Some of the most vigorous debate over private property rights reform focuses on the section 404 permit program of the Clean Water Act (see box, "The Private Property Rights Issue," in chapter 1.2, *Land Tenure)*. As a regulatory program, section 404 is potentially vulnerable to "takings" compensation claims. Few permit denials under section 404 lead to takings claims filed against the Federal Government, and even fewer result in compensation. As of May 31, 1993, only 28 cases involving takings claims had been filed with the U.S. Court of Federal Claims (Claims Court) as a result of a regulatory action under the section 404 program (U.S. General Accounting Office, 1993a). Ten of these cases were decided in favor of the Federal Government, 3 were decided in favor of the claimant, 1 was settled before a decision was rendered, and 14 were still pending as of May 31, 1993. Since 1993, over 30 new takings cases have been filed under the section 404 program (Rugiel, 1996). As of December 31, 1994, three more cases had been decided, two of which were found to involve takings (Meltz, 1995). As of May 1993, the Government had paid compensation in only two cases—a case settled out of court and one of three cases decided in favor of the claimant. The Government has appealed the Claims Court's decisions in the other two cases.

Despite the low number of claims filed thus far, legislating compensation requirements would likely increase claims compensation liability. The Congressional Research Service estimated that compensation on almost 9 million acres would be required under changes to Section 404 in H.R. 1330, at a cost of $10.7 billion (CRS, 1992). Compensation exposure was estimated by the Council of Economic Advisors for a more recent proposal (H.R. 3875) at between $48 and $499 billion, depending on the assumed rate of conversion. ERS estimates of compensation payable under H.R. 925 for diminution in value of wetlands because of Swampbuster provisions range from $705 million to $1.4 billion.

In addition to compensation proposals, the 104th Congress considered other changes to Section 404 wetland regulation as part of Clean Water Act reauthorization amendments. Passed by the House, H.R. 961 requires that land be inundated for at least 21 consecutive days during the growing season to be considered wetlands, exempts small wetlands, and offers full protection only to those wetlands deemed most ecologically significant, requiring compensation for any loss in value of 20 percent or more. Senate Bill 851, introduced in May 1995, contains many of the House provisions, including similar delineation criteria, but has broader exemptions, especially for wetlands on cropland. Action on Clean Water Act reauthorization was not completed in the Senate. Remaining Section 404 protections against wetland conversion could become more important as reductions in commodity program payments reduce the incentive to comply with Swampbuster provisions. Environmental critics of these proposals focus on the large acreage of currently regulated wetlands that could potentially be lost if the delineation criteria that exempt drier wetlands are accepted. While some environmentalists press a more comprehensive, ecosystem-based regulatory approach, others view the proposed legislation as an excessive reaction to problems that can be dealt with administratively (Franco, 1995; Goldman-Carter, 1995).

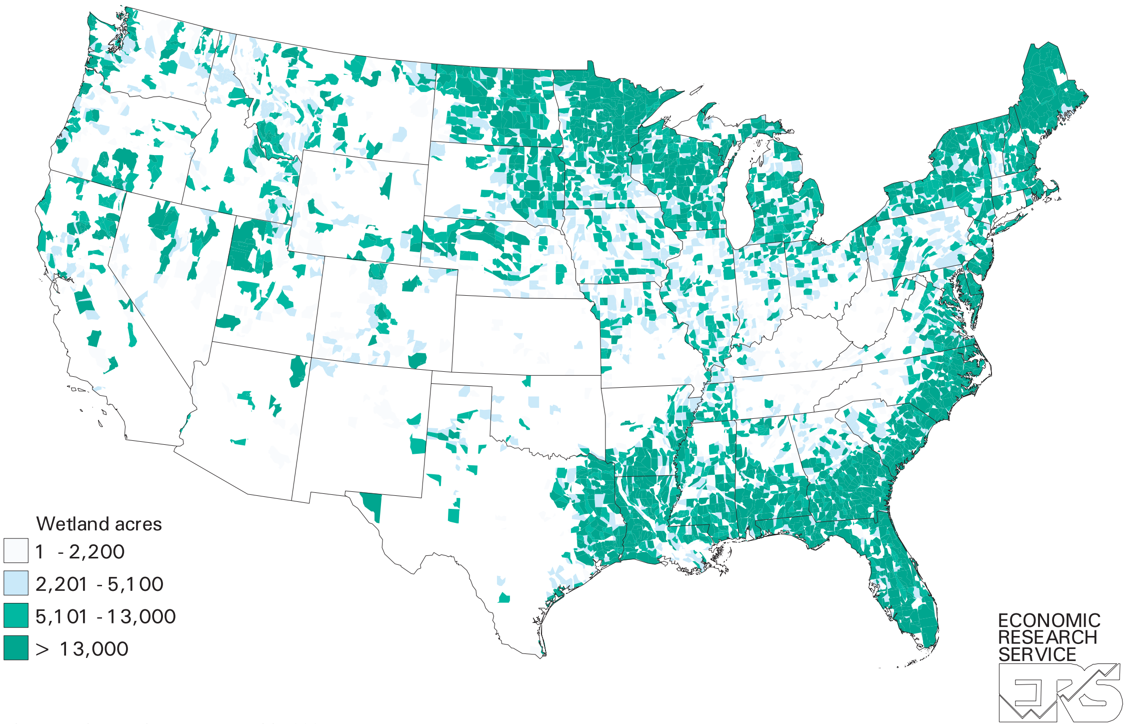
Swampbuster Changes

In contrast to Section 404, the Swampbuster provision is a condition on voluntary participation in Federal programs, and as such is not vulnerable to takings claims under current law. Nevertheless, legislation currently being considered in the 104th Congress would require compensation for diminution in property values due to both section 404 and the Swampbuster provision (see box, "The Private Property Rights Issue," in chapter 1.2, *Land Tenure*).

Two proposals for relaxing Swampbuster provisions were considered during the first session of the 104th Congress. Both proposals would redefine wetlands to reduce the acreage on which drainage would trigger Swampbuster sanctions. Consistent with proposed changes to Section 404, areas subject to Swampbuster would be limited to those typically covered with water (ponded or flooded) for 21 consecutive days during the growing season. Current law requires only that the soil be saturated within 18 inches of the soil surface for 7 consecutive days during the growing season. An estimated 71 million acres would be exempted from Swampbuster provisions under the 21-day criterion, about 82 percent of wetlands currently covered by Swampbuster (fig. 6.5.4). Two-thirds of exempted wetland is currently forested, 13 percent is marshland, while another 18 percent is split evenly between pasture and rangeland. The second proposal, the *cropped wetlands exemption*, would remove Swampbuster sanctions from 6 million acres of wetlands already used for crop production (fig. 6.5.5).

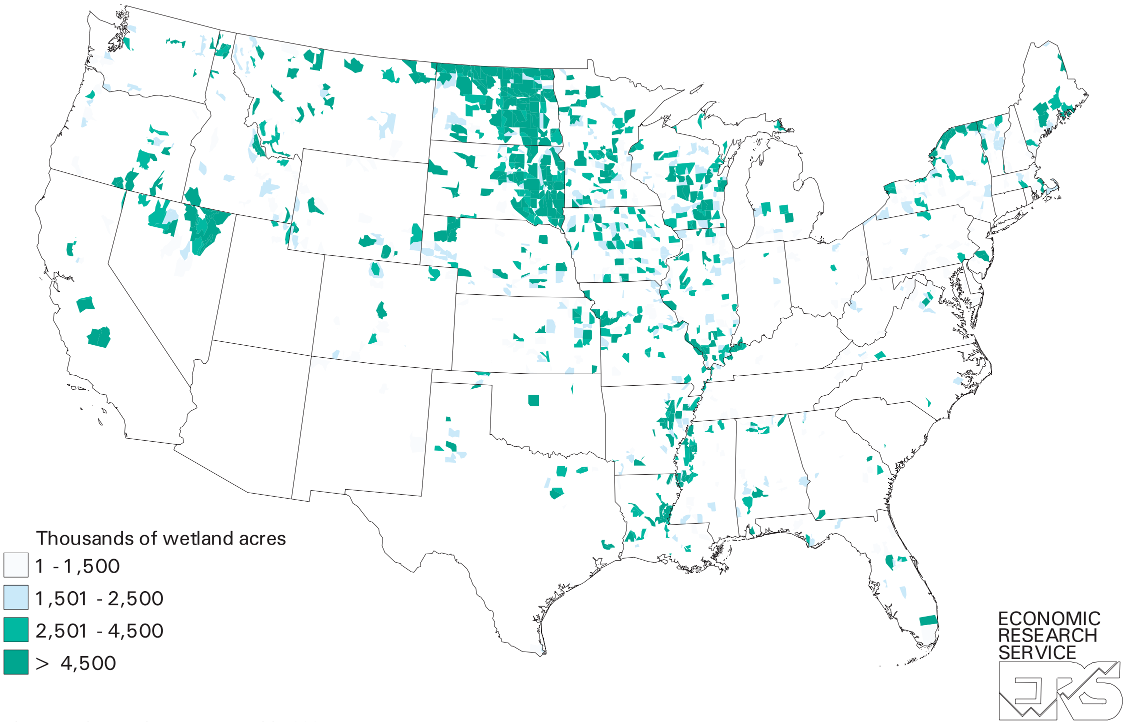
Based on expected crop prices and conversion and production costs, ERS estimated how much of the acreage that would be exempted under these proposals would be profitable to convert to crop production. Under the 21-day criterion and cropped wetland exemptions, drainage is estimated to be profitable on more than 9 million of the 71 million acres of exempted wetlands, more than half of which is located in 5 Southern States: North Carolina (16 percent), Arkansas (13 percent), Georgia (9 percent), Mississippi (7 percent), and Texas (6 percent).

Figure 6.5.4--Wetlands that would be exempted under 21-day proposal



Source: USDA, ERS, analysis of NRCS 1992 National Resources Inventory data.

Figure 6.5.5--Wetlands used in crop production, 1992



Source: USDA, ERS, analysis of NRCS 1992 National Resources Inventory data.

Table 6.5.10—Effects of proposed wetland exemptions on planted acreage, by region

Region	Baseline crop acreage[1]	Short run: 21-day criterion	Short run: Cropped wetlands exemption[2]	Long run: 21-day criterion	Long run: Cropped wetlands exemption[2]
	Million acres				
Northeast	12.3	0.3	**	0.2	**
Lake State	34.8	0.6	0.1	0.1	**
Corn Belt	84.5	1.5	0.1	0.3	**
Northern Plains	71.5	0.6	0.2	-0.3	**
Appalachia	18.5	1.6	**	1.1	**
Southeast	9.6	1.9	**	1.3	**
Delta States	18.3	2.5	0.1	1.9	0.1
Southern Plains	35.6	0.3	**	**	**
Mountain States	26.3	0.1	**	**	**
Pacific Coast	11.9	**	**	**	**
Total	323.4	9.5	0.7	4.8	0.2

** Fewer than 50,000 acres.

[1] Baseline acreage for commodities in USMP projected for 2001 from *Long-term Agricultural Baseline Projections, 1996-2006*. August 1995.

[2] Cropland acreage equivalents from improving drainage on land already in crop production.

Source: USDA, ERS, based on analysis of 1992 National Resources Inventory data.

Almost all of the cropped wetlands could be further drained for profitable crop production or to remove wetlands hindering farm operation. Because they are already cropped, further drainage of cropped wetlands adds fewer acreage equivalents to production than for newly converted wetlands.

The economic effects of bringing profitable exempted wetlands into production were estimated by ERS using the U.S. Regional Agriculture Sector Model (USMP). In the short run, producers are assumed to act on observed market prices and drain all wetlands where crop production is estimated to be profitable. After longrun adjustments, not all of the wetland acreage drained initially would be kept in production. For both shortrun and longrun scenarios, the estimated net effect of both wetland exemptions is increased planted acreage and production and lower prices. While farmers with acreage to drain may profit from increased production and sales, net cash returns to the farm sector would decline because of lower prices.

In the short run, under the 21-day criterion, soybean acreage would increase in the Delta States, Southeast, and Appalachia (table 6.5.10). The cropped wetlands exemption would increase wheat production in the prairie pothole region of the Northern Plains and soybean production on partially converted, formerly forested wetlands in the Delta States. After longrun adjustments, adoption of these proposed exemptions would increase planted acreage by only half the shortrun increase. Expected declines in net cash incomes would be greatest in the Corn Belt, the Northern Plains, and the Lake States, while increases in net cash income would occur in the Southeast and Delta regions (table 6.5.11). Overall, net cash returns would fall in both the short and long run, but producers in the Southeast, Delta, and Appalachian regions would benefit from increased production more than they lose from reduced prices.

Even though the 1996 Farm Act made few explicit changes to Swampbuster provisions, changes in commodity provisions will reduce Swampbuster's effectiveness in discouraging wetland conservation. The Act decouples farm program payments from current market conditions and phases payments down over 7 years. While the market transition payment still requires compliance with Swampbuster provisions, the disincentive to conversion is reduced proportionally as the payment declines. A producer with many acres of wetlands that could be profitably converted to or further drained for crop production at expected prices may forego commodity program participation when the loss of remaining farm program payments becomes smaller than the potential gain from conversion.

Floodplain Management Changes

Levees built to constrain rivers from their natural floodplains also have resulted in loss of wetlands, loss

Table 6.5.11—Effects of proposed wetland exemptions on net cash income, by region

Region	Baseline net cash income[1]	Short run: 21-day criterion	Short run: Cropped wetlands exemption[2]	Long run: 21-day criterion	Long run: Cropped wetlands exemption[2]
			$ million		
Northeast	4,108.6	-90.0	-7.6	-47.9	-2.0
Lake States	9,019.6	-588.1	-61.9	-255.2	-10.9
Corn Belt	20,232.4	-2,440.4	-255.6	-908.6	-68.8
Northern Plains	9,897.6	-920.3	-86.0	-405.1	-11.3
Appalachia	2,978.6	-69.4	-14.0	12.0	-4.9
Southeast	2,097.8	43.2	3.8	36.0	0.1
Delta States	4,285.0	-18.4	2.2	13.1	2.0
Southern Plains	6,148.7	-194.9	-19.7	-114.3	-8.0
Mountain States	3,876.8	-142.4	-9.0	-78.0	-3.3
Pacific Coast	5,796.3	-88.6	5.0	-72.1	6.7
Total	68,441.4	-4,309.3	-442.8	-1,816.5	-100.4

[1] Base income for commodities in USMP projected for 2001 from *Long-term Agricultural Baseline Projections, 1996-2006*. August 1995. Does not include deficiency payments.

Source: USDA, ERS, based on analysis of 1992 National Resources Inventory data.

of natural flood storage, and acceleration and amplification of flood flows and flood peaks. In 1993, rainfall that was unusual in both extent and duration resulted in ground saturation and flooding in the Midwest, causing widespread damage and raising questions about whether reliance should be reduced on levees and other flood control structures and whether floodplains should be returned to natural wetlands. As an alternative to restoring flood-damaged levees, the Emergency Wetlands Reserve Program was established in 1993 to help landowners convert flood-damaged cropland to wetlands if the cost of the levee restoration and cropland renovation exceeded the value of the land. Flooding in Georgia (in 1994), California (in 1995), and the mid-Atlantic States and Pacific Northwest (1996) raised further questions about appropriate floodplain management.

The White House Interagency Floodplain Management Review Committee (IFMRC), set up in 1994, found that loss of wetlands and upland cover (primarily to agricultural uses) had significantly increased runoff over the past century and a half, but that wetland restoration would have had little impact on conditions in 1993 (IFMRC, 1994a and 1994b). Economic damage estimates ranged from $12-16 billion, of which over half was accounted for by agriculture. As of June 1994, USDA emergency assistance paid to the nine Midwestern States most severely affected totaled $2.9 billion, most of it for disaster assistance and crop insurance (USDA Flood Information Center, 1994).

Despite the magnitude of losses in 1993, the IFMRC found that reservoirs and levees built by the U.S. Army Corps of Engineers worked essentially as designed, preventing more than $19 billion in potential damages. Watershed projects built by the Natural Resources Conservation Service (previously the Soil Conservation Service) were estimated to have prevented potential damages totaling an additional $400 million. However, they also found that nonstructural solutions—such as permanent evacuation of floodprone areas, flood warning, floodproofing of structures, and creation of additional natural and artificial flood storage—need greater emphasis.

Based on its findings, the IFMRC recommended a variety of administrative and legislative steps, improved coordination of Federal acquisition of environmentally related interests in land from willing sellers (see box, “Floodplain Restoration in Louisa County, Iowa”), and reforms to enhance the efficiency and effectiveness of the National Flood Insurance Program. The National Flood Insurance Reform Act of 1994 restricts lending secured by uninsured or underinsured property located in floodplains, extends the waiting period before new flood insurance policies become effective from 5 to 30 days, and denies Federal disaster assistance to individuals who failed to obtain and maintain flood insurance when required to do so as a condition for receiving disaster assistance.

Floodplain Restoration in Louisa County, Iowa

Levee District 8 covers 3,000 acres of Iowa River floodplain in southeastern Iowa's Louisa County. Prior to 1993, the district had received Federal funds to repair flood-damaged levees 14 times, at a cost of nearly $4 million (in 1993 dollars). The 1993 floods caused a further $757,000 in levee damage (Dettman, 1994). Rather than repair the levees again, the district's board voted in March 1994 to discontinue agricultural operations and disband the district.

As a result of an agreement among landowners, State and Federal agencies, and private conservation organizations, most of the land formerly protected by the district's levees is being reclaimed as part of the Iowa River's natural floodplain and restored to bottomland hardwood forest. The agreement is being implemented through a variety of integrated land acquisition efforts. Most of the district's landowners granted permanent easements to the Federal Government under the Emergency Wetlands Reserve Program (EWRP). Other interests in land, including residual interests in EWRP land, are being purchased by the U.S. Fish and Wildlife Service and by private conservation organizations. In addition to providing wildlife habitat, recreation, and educational opportunities, restoration will ease flooding downstream. The area will be maintained by the Fish and Wildlife Service as part of the Mark Twain National Wildlife Refuge (Wiebe, Kuhn, and Tegene, 1996).

The Midwest floods also prompted a review by the U.S. General Accounting Office (GAO) of how well Federal levees performed in 1993. Citing data from the Corps of Engineers, GAO reported that 157 (81 percent) of the 193 Corps levees located in the flood-affected area prevented severe flooding on about 1 million acres and over $7 billion in damages (GAO, 1995). Of 181 levees for which data were available, 177 performed up to their design capacity: 145 kept floodwaters out of the protected floodplain and 32 were overtopped when the flood exceeded their design capacity. Only 4 Corps levees failed prior to being overtopped. The Corps estimates damage from flooding on about 400,000 acres behind the 36 levees that were breached or overtopped at $450 million. By contrast, the Corps estimates that about 1,100 (81 percent) of the 1,358 nonfederal levees in the flood area failed in 1993.

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Recent Reports on ERS Research on Wetland Issues

"Proposed Delineation Changes for Wetlands." *Journal of Soil and Water Conservation* (1996) 51 (5): 402-407. Sept/Oct. (Keith Weibe, Ralph Heimlich, and Roger Claassen). This article estimates potential wetland conversion from exempting wetlands from Swampbuster provisions, as discussed during the 1996 Farm Bill debate. Short- and long-term economic impacts of exempting 71 million acres of wetlands are estimated based on the profitability of conversion and economic adjustments to increased acreage in production.

"Wetlands Lost, Wetlands Gained." *National Wetlands Newsletter,* (1995) 17(3):1,23-25 (Ralph Heimlich and Jeanne Melanson). This article presents estimates of wetland losses and gains from the 1992 National Resources Inventory and argues that wetland regulatory policies, restoration programs, and economic conditions resulted in nearly achieving the “no net loss” of wetlands goal during the 1980’s.

"Property Rights, Partial Interests, and the Evolving Federal Role in Wetlands Conversion and Conservation," *Journal of Soil and Water Conservation,* (1995) 50(6):627-629. Nov.-Dec. (Keith Wiebe, Abebayehu Tegene, and Betsey Kuhn). This article examines the nature of land ownership, the evolving Federal role in wetland use and conservation, and property rights reforms proposed in the 104th Congress. Particular attention is given to the evolution of Federal wetlands policies.

Partial Interests in Land: Policy Tools for Resource Use and Conservation. AER-744, Nov. 1996. (Keith Wiebe, Abebayehu Tegene, and Betsey Kuhn). This report examines the nature of land ownership and the evolving Federal role in land use and conservation. Particular attention is given to the ways in which conservation easements and other partial interests in land are acquired in farmland protection programs, the Conservation Reserve Program, and the Wetlands Reserve Program.

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Appendix:
Agricultural Resource Surveys and Data

Agricultural Land Values Survey (ALVS)

The ALVS was conducted annually in February-April from 1984 through 1994 by the National Agricultural Statistics Service (NASS) with funding participation from the Economic Research Service (ERS). In 1994, questions on land values and cash rents were added to the June Agricultural Survey (JAS) and the ALVS was subsequently discontinued. The ALVS polled a sample of farmers in each State by mail and telephone for their opinions of farmland values and cash rents in their localities**.** The switch to the JAS, a personal enumeration survey, permits information to be collected for specific tracts and linked to other farm and natural resource data through geo-referencing. For more on the JAS, see the description below.

Agricultural Resource Management Study (ARMS)

The ARMS, developed from combining the former Cropping Practices Survey (CPS) and the Farm Costs and Returns Survey (FCRS), was conducted for the first time in 1996 by NASS with funding from NASS and ERS. The ARMS provides data to answer questions about agricultural resource use and costs, farm sector financial conditions, and farm production practices, including Integrated Pest Management (IPM). The ARMS is conducted in three phases. Phase I or the screening phase takes place in June-August and collects general farm data on crops grown, livestock produced, and farm sales. These data are used to identify farms to be contacted in phases II and III. Phase II, conducted in October-December, collects data associated with agricultural production practices, resource and input use, and production. Phase III, conducted in February-April, gathers data on cost of production for specific commodities and on the financial condition of farms. The ARMS is conducted by personal enumeration of farmers. A multi-frame, stratified sampling procedure is used. The results are weighted and aggregated to develop State, regional, and national estimates. The data from the initial ARMS in 1996 are not available for inclusion in this report.

Area Studies Project

The Area Studies project was a data collection and modeling effort which linked farm production activities to environmental characteristics for 10 major U.S. watersheds. The effort involved the Economic Research Service (ERS), the Natural Resources Conservation Service (NRCS), U.S. Geological Survey (USGS), and the National Agricultural Statistics Service (NASS). The 10 areas for which usable data were obtained were selected from those included in USGS's National Water Quality Assessment Program, and included Albermarle-Pamlico Drainage, Central Nebraska Basins, Georgia-Florida Coastal Plains, Iowa/Illinois Basin, Lower Susquehanna River Basin, Mid-Columbia River Basin, Mississippi Embayment, Southern High Plains, Upper Snake River Basin, and White River Basin. Each area had significant cropland and agricultural chemical use. Surveys conducted in each area between 1991and 1993 collected detailed information on production technologies, cropping systems, and agricultural practices at both the field and whole farm level. The survey sample points corresponded with National Resource Inventory (NRI) sample points, for which NRCS had collected soil, water, and other natural resource data.

Census of Agriculture

The Census of Agriculture has been conducted every 5 years. A Census of Agriculture was conducted in 1992 by the Bureau of the Census, U.S. Department of Commerce. In 1996, responsibility for the Census of Agriculture was transferred to the USDA's National Agricultural Statistics Service (NASS) and the 1997 Census will be conducted by that agency.

The Census attempts to be a complete enumeration of the general characteristics of all agricultural operations. However, it uses a random sampling procedure to estimate a wide variety of financial and operator characteristics.

Chemical Use Surveys

Chemical Use Surveys were initially funded under the 1989 President's Food Safety Initiative. Fruit and vegetable crops are the primary target of the survey program, with even-year surveys to cover vegetables and odd-year surveys to cover fruits. In each year, certain commodities are targeted in order to obtain more comprehensive information on management practices and cost for those commodities. A significant emphasis has been placed on collecting data on IPM and on organic production. The surveys are conducted by NASS using personal enumeration of a stratified systematic sample of growers who produce at least one acre of the targeted crops. The 1990 survey was limited to 4 States. Since then, the surveys have gathered data on pesticide use for most commercial production of fruits and vegetables in the United States. The major producing States included in each of the surveys were as follows:

- 1990 vegetable survey: 4 States: AZ, FL, MI, and TX
- 1991 fruit and nut survey: 13 States: AZ, CA, FL, GA, MI, NY, NC, OR, PA, SC, TX, VA, and WA
- 1992 vegetable survey: 14 States: AZ, CA, FL, GA, IL, MI, MN, NJ, NY, NC, OR, TX, WA, and WI
- 1993 fruit survey: 9 States: CA, FL, MI, NC, NY, OR, PA, SC, and WA
- 1994 vegetable survey: 14 States: Same States as the 1992 survey
- 1995 fruit survey: 10 States: Same States as the 1993 survey with addition of GA
- 1996 vegetable survey: 13 States: Same States as the 1992 survey except IL dropped

Conservation Compliance Status Review

In 1995, the Natural Resources Conservation Service conducted a status review of tracts previously determined to be predominately highly erodible land (HEL) using a 4 percent random sample. The sample is statistically reliable at the State level for States with large acreage of HEL and high participation in USDA programs. It is reliable at the regional level for other areas. Each tract in the sample was visited to determine the extent of compliance with the HEL provisions of the 1985 and subsequent Farm Acts. The review results were weighted and aggregated to develop State, regional, and national estimates.

Conservation Reserve Program (CRP) contract data

The Farm Service Agency (FSA) develops and maintains a set of data on all tracts enrolled in the CRP, based on information provided by the program participants and observations by FSA during onsite inspections. This data set includes type of contract, location, acreage enrolled, land capability class and subclass, type and amount of crop base, average crop yield, conservation cover and practices, estimated before and after erosion, and rental rate.

Cropping Practices Surveys (CPS)

The Cropping Practices Surveys and predecessor surveys were conducted annually from 1964 through 1995 by the NASS with funding participation from ERS. In 1996, the CPS was merged into the Agricultural Resource Management Study (ARMS, described above). The CPS collected annual data on fertilizer and pesticide use, tillage systems, crop sequence, and data on other inputs and cultural practices. Fertilizer information has been reported from these surveys since 1964. In the mid-1980's, pesticide use, tillage operations, and prior crop questions were added to the survey. Integrated pest management and nutrient management questions were included in the 1990's.

The 1995 CPS gathered data on corn, cotton, soybeans, wheat, and potatoes and represented about 182 million acres. This area included the acreage in major producing States, which accounted for 70-90 percent of the total U.S. acreage for these crops. Changing information requirements and funding has caused the number of surveyed crops and the States surveyed to vary from year to year. For some time-series presentations, not all States surveyed in any one year are included in order to have greater consistency across years:

- **Corn**
  10 States: IL, IN, IA, MI, MN, MO, NE, OH, SD, and WI
  16 States: Above 10 plus DE, GA, KY, NC, PA, and TX
  17 States: Above 16 plus CO

- **Soybeans**
  8 States: AR, IL, IN, IA, MN, MO, NE, and OH
  7 Northern States: IL, IN, IA, MN, MO, NE, and OH
  7 Southern States: AR, GA, KY, LA, MS, NC, and TN
  14 States: Includes the 7 Northern and 7 Southern States
  16 States: Includes the above 14 plus KS and SC
- **Cotton**
  6 States: AR, AZ, CA, LA, MS, and TX
- **Winter wheat**
  11 States: CO, IL, KS, MO, MT, NE, OH, OK, SD, TX, and WA
  13 States: Includes above plus ID and OR
  15 States: Includes above plus AR and IN
- **Spring wheat**: 4 States—MN, MT, ND, and SD
- **Durum wheat**: 1 State—ND
- **Fall potatoes**: 11 States—CO, ID, ME, MI, MN, NY, ND, OR, PA, WA, and WI
- **7 crops and 28 States in 1994**—10 growing corn, 8 soybeans, 6 cotton, 13 winter wheat, 4 spring wheat, 1 durum wheat, and 11 potatoes.

The CPS used a stratified sampling procedure to gather data about a randomly selected acre of the crop. Since the random acre within a field was not identified, respondents (farm operators) were asked to provide field-level information on all fertilizer and nutrient treatments, all tillage operations prior to planting, crops planted in the previous 2 years, and data on other inputs and cultural practices. The operator also identified whether the field had been designated as highly erodible land (HEL) by the Natural Resource Conservation Service and whether the farm unit participated in farm price and income support programs.

Crop Residue Management (CRM) Survey

The CRM Survey is conducted by the Conservation Technology Information Center (CTIC) to provide State and national statistics on adoption of alternative crop residue management systems for all U.S. planted cropland. The CRM Survey provides estimates on five different tillage systems: no-till, mulch till, ridge till, conventional till (15-30 percent residue), and conventional till (less than 15 percent residue). A panel of local directors of USDA program agencies and others knowledgeable about local residue management practices complete the survey each summer as a group effort. These local judgments about the use of practices are summarized to provide State, regional, and national estimates. In addition, several States also conduct statistically derived physical surveys of crop residue levels for validation of the panel-derived estimates. CTIC is a division of the National Association of Conservation Districts and is administered by industry, government agencies, foundations, organizations, and growers.

Current Research Information System (CRIS)

CRIS maintains a data set on all agricultural and forestry research funded by USDA, including research problem area, subject, field of science, funding, objectives, approach, performing organizations, and responsible individuals. The system is maintained by the Agricultural Research Service.

Farm Costs and Returns Survey (FCRS)

The FCRS was conducted annually, through 1995, by NASS with funding from NASS and ERS. In 1996, the data requirements were merged into the new Agricultural Resources Management Study (ARMS) and FCRS was terminated. The FCRS was conducted to gather information on the financial situation of farm and ranch businesses, the costs of producing various crop and livestock commodities, and the characteristics and financial situations of farm operators and their households. The data were collected by personal enumeration of the operators of a statistical sample of farms of various sizes and types**.** Results were weighted and aggregated to develop estimates reliable at regional and national levels.

Farm and Ranch Irrigation Survey (FRIS)

The Farm and Ranch Irrigation Survey (FRIS) is a follow-on survey to the Census of Agriculture. All producers that report irrigation in the Census are eligible to receive a FRIS questionnaire. A FRIS has followed the last four Censuses of Agriculture, with data collected in 1979, 1984, 1988, and 1994. The survey is based on a stratified, random sample of irrigators and then adjusted to represent all eligible irrigators. The survey does not include irrigators in Alaska and Hawaii, nor irrigation on horticultural specialty, institutional, experimental, research, and Indian reservation farms. Past FRIS data were collected by the Agricultural Division, Bureau of the Census, Department of Commerce. However, the 1997 transfer of the Bureau of Census's Agricultural Division to the National Agricultural Statistics Service means future FRIS data will be collected by NASS.

The FRIS data are collected to be statistically reliable for the conterminous United States and each of the 18 major water resource areas. State data are available for 17 Western States plus Arkansas, Louisiana, and Florida for 1979 and 1984. In 1988 and 1994, data are reported for 27 States, which account for over 95 percent of the irrigated acreage in the Nation: Arizona, Arkansas, California, Colorado, Florida, Georgia, Idaho, Illinois, Kansas, Louisiana, Michigan, Minnesota, Mississippi, Missouri, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oklahoma, Oregon, South Dakota, Texas, Utah, Washington, Wisconsin, and Wyoming. Data are collected on irrigation—water sources, costs, application technologies and frequency, and crop yields—water conservation activities, and water management practices. From 17 to (most recently) 24 crops are covered.

Farm Real Estate Tax Survey

Data on real property taxes on farm and ranch lands and buildings levied by State and local governments are collected annually through a nationwide mail survey of over 4,000 taxing officials. The survey, conducted by the Economic Research Service, provides tax and acreage information on about 42,000 parcels of farm and ranch lands in the 48 contiguous States. Data on taxes levied (tax bill) rather than taxes paid are collected because taxpayer challenges or delinquencies may take several years to resolve. Over time taxes levied and taxes paid are about equal.

Foreign Ownership of U.S. Agricultural Land

The Agricultural Foreign Investment Act of 1978 (AFIDA) requires all foreign owners of U.S. agricultural land (all land used for agricultural, forestry, or timber production) to report their holdings to the Secretary of Agriculture as of February 1, 1979. Subsequent acquisitions and dispositions of such land by foreign owners are to be reported as they occur. This provides USDA with a continuing inventory of such ownership that is netted out at the end of each calendar year and reported to the President and the Congress. The information on holdings and transactions are received by the Farm Service Agency and provided to ERS for summarization and annual reporting. Foreign owners under the Act include foreign governments; entities (e.g., partnerships and corporations) created under the laws of, or that have their principal place of business in a foreign country; and U.S. entities in which there is significant foreign investment or substantial control.

June Agricultural Survey (JAS)

The JAS is a personal enumeration survey conducted by NASS to gather data on crop plantings and cropland use. It is based on an area frame sampling technique that gathers data from about 1 percent of the total land area of the entire United States. The unit of observation is the tract, which may contain one or more fields or land uses and represents a particular operator’s acreage within a sample segment (approximately 1 square mile). Expansion factors are used to weight the tracts so as to develop State and national estimates. In 1994, questions on land values and cash rents were added to gather information previously secured in the Agricultural Land Values Survey (see above). Also, the JAS provides geo-referencing and the opportunity for greater analysis of land and resource use issues.

National Resources Inventory (NRI)

The NRI, conducted every 5 years by NRCS field staff, was last done in 1992. It provides information on the status, condition, and trends of land, soil, water, and related resources on the Nation’s non-federal land (including all States and territories except Alaska). Data for the 1992 NRI were collected from more than 800,000 sample locations and are statistically reliable for national, regional, State, and sub-State analysis. The 1992 NRI provided a nationally consistent data base that was constructed specifically to estimate 5- and 10-year trends for natural resources from 1982 to 1992.

INDEX

[Note: The index is alphabetized word-by-word (e.g., Land use precedes Landlords).]