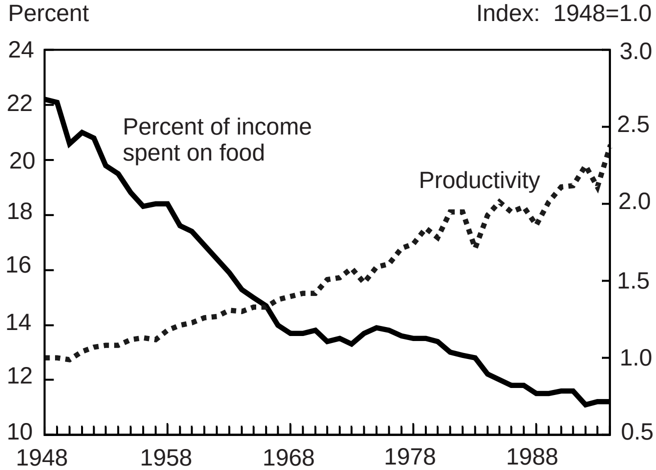
II. The Case for a More Sustainable Agriculture

To evaluate the sustainability of U.S. agriculture we review trends in the following indicators: agricultural productivity, soil erosion, ground-water quantity, surface-water quality, ground-water quality, and wetland conversion rates. While there is overlap between the services these indicators represent, one can think of agricultural productivity, soil erosion, and ground-water quantity as indicators of our ability to provide food to current and future generations. Surface-water quality, ground-water quality, and wetland conversion rates can be thought of as indicators of the environmental impacts associated with agricultural production.

Agricultural Productivity

Productivity measures the difference between output growth and input growth rates. If productivity growth is positive, then the same output can be produced with fewer inputs. Figure 1 illustrates the pattern of productivity growth in U.S. agriculture (Ahearn, Ball, Yee, and Nehring, 1998). From 1948 to 1994, output in U.S. agriculture grew at an annual average rate of 1.9 percent. A slight decline in input use accompanied this output growth, resulting in an annual productivity growth rate of 1.9 percent compared with 1.1 percent for the nonfarm sector. The prices of agricultural products reflect this productivity growth. Over the same period, the real prices farmers received for farm products dropped about 50 percent.

Figure 1
Income spent on food and agricultural productivity
Increases in agricultural productivity have resulted in lower food prices



Sources: Economic Research Service, USDA; Ahearn, Ball, Yee, and Nehring, 1998; Manchester and Allshouse, 1997.

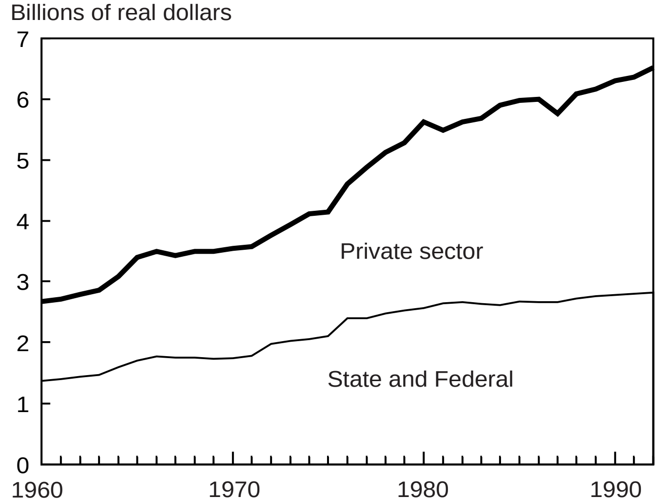
For major field crops in U.S. agriculture, yield growth parallels the observed pattern of productivity growth. Yields in major field crops grew rapidly, ranging from 1 to 3 percent per year. Among field crops, yields of corn, sorghum, and potatoes have grown the most rapidly. Since 1939, corn yields grew at an impressive 3 percent per year while wheat yields grew at around 1.8 percent. Over the same period, the real prices (market prices adjusted for inflation) for corn, sorghum, and potatoes dropped about 50 percent while the real price for soybeans dropped about 30 percent (USDA, National Agricultural Statistics Service, 1997).

Greater agricultural productivity growth, higher yields, and lower farm prices have benefited consumers.[3] As also captured in figure 1, in 1948, consumers spent 22 percent of their disposable personal income on food. By 1996, the share of disposable personal income spent on food had fallen to 11 percent (Manchester and Allshouse, 1997). These data suggest that, relative to the performance of the economy in general, agriculture has met a part of the sustainability challenge by supplying food to consumers at a reasonable cost.

Investment in agricultural research and development (R&D) contributes significantly to productivity growth. Figure 2 illustrates the pattern of R&D growth in U.S. agriculture (Fuglie and others, 1996).

[3]Productivity is a better indicator of agriculture's performance than prices because farm programs distort agricultural prices.

Figure 2
Research spending
Real private sector spending on R&D has outpaced State and Federal spending



Source: Economic Research Service, USDA; Fuglie and others, 1996.

Beginning in 1960, public research expenditures rose by 3 to 4 percent per year in real terms up to around 1980, but since then, growth has slowed to 0.7 percent per year. Although Federal expenditures have remained flat since 1976, growth of private sector research has been rapid. Most of the post-1980 growth has come from increased contributions by the private sector. The private sector now accounts for more than 50 percent of all agricultural research funds. If past patterns of R&D persist in the future, then it may be possible to maintain productivity growth rates in U.S. agriculture. Maintaining a productivity growth rate greater than the growth rate of food demand will contribute to the availability of food at a reasonable cost to future generations.

Soil Erosion

The link between agricultural production practices, soil erosion, and farmland's ability to produce output has been studied extensively. Recent studies have established that soil erosion does not threaten agricultural output (Alt and others, 1989; Crosson, 1995; USDA, 1989). For example, as part of the Second Resources Conservation Act (RCA) Appraisal, the U.S. Department of Agriculture (1989) estimated a 3-percent loss in overall agricultural output over the next 100 years if farming/management practices remained as they were in 1982. Similarly, Alt and others (1989) found that the output effects of soil erosion are small.[4]

One reason for the lack of an overall effect on output is that soil management practices have improved considerably in the last 50-60 years. For example, while cropland use has remained remarkably stable at about 400 million acres since 1938, soil erosion has declined by an estimated 40 percent (fig. 3) (Magleby and others, 1995). Most of this decline has occurred since 1982. In 1982, total erosion from cropland was estimated at 3.1 billion tons per year or 7.4 tons per acre per year. By 1992, total erosion from cropland had declined to 2.1 billion tons per year or 5.6 tons per acre per year. The post-1982 decline results from government programs aimed at mitigating the environmental impacts of agricultural production practices such as the Conservation Reserve Program (CRP) and the Conservation Compliance provisions of the Food Security Act of 1985.

[4]Both studies employ a crop production model, Erosion Productivity Impact Calculator (EPIC), that links production practices, erosion rates, and productivity.

Comparing the productivity growth rates with soil erosion rates over time indicates that productivity can continue to grow with natural resource degradation. This is because chemical inputs (e.g., fertilizer) can substitute for natural resources (e.g., soil fertility), and technological change can mitigate the negative agricultural productivity effects of resource degradation on most soils (Cleveland, 1995). However, a failure to consider off-site effects can affect the supply of environmental services. For example, soil erosion can affect surface-water quality with repercussions for recreational services that depend on this natural capital asset.

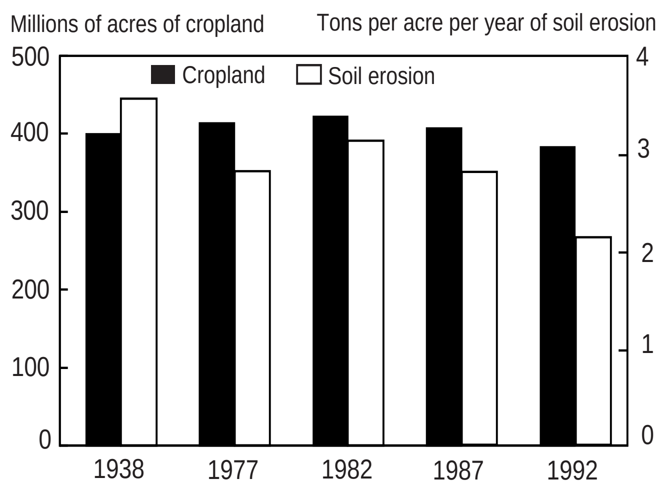
While the estimated costs of erosion in terms of lost output are not nationally significant, they may be significant at the regional or State level. For example, Faeth (1993) shows negative net economic value per acre after accounting for soil depreciation and off-site costs for Pennsylvania's best corn-soybean rotation over 5 years. This work demonstrates there may be significant regional variation in resource depreciation and off-site costs of agricultural production.

While the impact of erosion on loss of soil productivity is relatively straightforward, it is more difficult to assess a more comprehensive view of soil quality over time. For example, overall soil quality can be degraded physically (erosion, compaction), chemically (salinization, acidification), and biologically (declines

Figure 3

Cropland and soil erosion

The amount of cropland has remained stable over time while soil erosion rates have fallen considerably



Source: Economic Research Service, USDA; Magleby and others, 1995.

in organic matter or soil carbon) (National Research Council, 1993). Chambers and Lichtenberg (1995) found the incremental value of organic matter in soil to be quite high when the initial stock of organic matter is low, but the value diminishes rapidly. For example, for a conventional farming system, a 1-percentage-point increase in organic matter increased the value of land by $285 per acre when initial organic matter was 0.8 percent, but by only $60 per acre when initial organic matter was 1.9 percent. When organic matter was greater than about 2 percent, an increase in organic matter no longer increased land values.

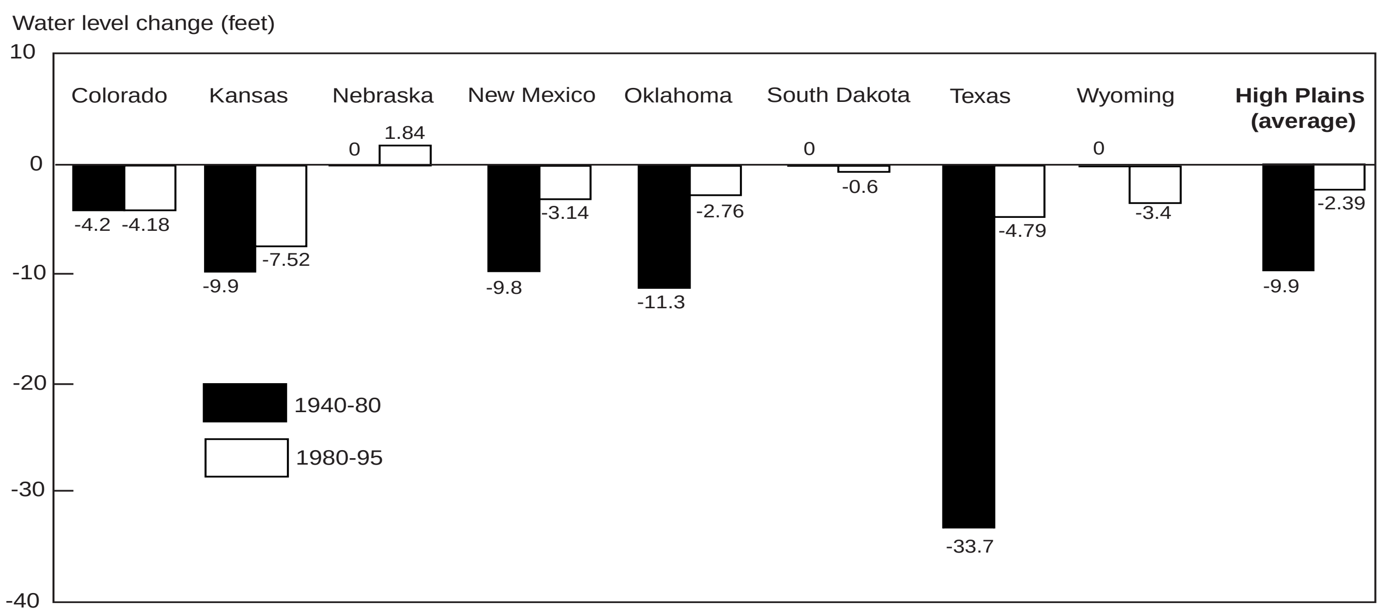
Ground-Water Quantity

In the longrun, an equilibrium is generally reached in terms of recharges (precipitation, imports from other regions) and discharges (natural evapotranspiration, exports to other regions, consumptive use, and natural outflow) from any ground-water system. However, in some water resource regions, discharge rates have consistently been greater than recharge rates, leading to a decline in the stock of ground water (U.S. Geological Survey-USGS, 1995). While long-term trend data for most of the Nation's ground-water stocks do not exist, measurements of change in the water level of the High Plains Aquifer (Ogallala) may indicate the effect of irrigation on ground-water levels. This aquifer provides approximately one-third of the ground water withdrawn for agricultural irrigation in the United States, and supports the agricultural activity in Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming (USGS, 1995).

Figure 4 illustrates the average drop in the water level of the aquifer in each of these States over two time periods. For 1940-80, the region's average ground-water level dropped 0.25 foot annually or a total of about 10 feet. Five of these States experienced declines in their ground-water stocks while three experienced no change in their stocks over this period. From 1980 to 1995, the average ground-water level for the High Plains dropped 0.16 foot annually or about 2.4 feet in total. An increase in ground-water stocks was reported in one State and smaller declines compared with 1940-80 were reported in four States (USGS, 1995).

While the total ground-water stock has declined from 1980 to 1995, the stock increased in 1993 and 1994. The average ground-water level rose 0.21 foot in 1993, and another 0.56 foot in 1994. The reductions in the rate of decline of the ground-water stock result from technological advances in irrigation development to increase the efficiency of water delivery and above normal precipitation in the region (USGS, 1995).

Figure 4
Change in ground-water level in the High Plains
While the ground-water level in the High Plains continued to fall, the current rate of decline is less than in prior years



Source: USGS, 1995.

The data on ground-water levels in the High Plains indicate that while ground-water mining contributed to significant drawdowns in the past, in recent years the Ogallala has experienced slower withdrawal rates. The ground-water withdrawals in this region primarily support irrigated agriculture. The private economic costs of extracting ground water and the social costs of ground-water drawdowns are significant. In the United States, the energy costs of extracting ground water can range between $11 and $74 per acre annually, and amount to more than $1 billion annually (USDA, ERS, 1997). These increases in energy costs are reflected in farm profitability. For example, Aillery (1995) estimated the returns to irrigation including the returns to water, fixed capital, and management above variable water costs and net of returns to dryland alternatives at $33 per acre-foot of water used in agricultural production.[5]

However, farmers' water costs do not reflect the total social cost of the extraction, and therefore, their expenditures on water do not accurately reflect society's demand for ground water. Water suppliers and farmers treat ground-water stocks as an open resource. By extracting water at a rate faster than recharge, water suppliers and farmers draw down the water level and decrease the aquifer's pressure. This requires water suppliers and farmers to use more energy per unit of water extracted than under a steady-state or increasing water level scenario. In addition, ground-water withdrawals can cause land subsidence, with significant economic consequences (National Research Council, 1991a).

Surface-Water Quality

Surface-water quality has generally improved since 1974, when monitoring began. In a 1974 survey, the Environmental Protection Agency (EPA) found that only about 40 percent of the largest rivers in the United States were safe enough for fishing and swimming (USEPA). In 1994, 60 percent of the Nation's surveyed rivers, lakes, and estuaries were safe enough for fishing and swimming. While surface-water quality has improved over the long term, the EPA has identified agriculture as an important contributor to the surface-water quality problems that do exist.

[5]An acre-foot of water is the volume of water required to cover 1 acre of land to a depth of 1 foot of water; also equal to 325,851 gallons (USGS, 1985).

According to the EPA's 1996 *National Water Quality Inventory*, agriculture is the leading source of impairment in rivers (contributing to impairment of 25 percent of the surveyed river miles), lakes (contributing to impairment of 19 percent of the surveyed lake acres, not including the Great Lakes), and the fifth leading source of impairment to estuaries (contributing to impairment of 10 percent of the surveyed estuary acres) (table 1).[6] Primary agricultural pollutants

[6]EPA defines impaired waters as waterbodies either partially supporting uses or not supporting uses (USEPA, 1998).

Table 1—Major sources of impairment to rivers, lakes, and estuaries
Agriculture is the leading source of impairment in rivers and lakes and is the fifth leading source in estuaries

Item[1]	Percent
River miles:	
Agriculture	25
Municipal	5
Hydrologic modification	5
Habitat modification	5
Resource extraction	5
Urban runoff	5
Lake acres:	
Agriculture	19
Unspecified nonpoint	9
Atmospheric deposition	8
Urban runoff	8
Municipal point sources	7
Hydrologic modification	5
Estuaries (acres):	
Industrial	21
Urban runoff	18
Municipal	17
Upstream sources	11
Agriculture	10
CSO's	8

[1]Examples of sources:
Agriculture—Crop production, pastures, rangeland, feedlots, animal operations.
Construction—Land development, road construction.
CSO's—Combined sewer overflows—Facilities that treat storm water and sanitary sewage.
Habitat modification—Removal of riparian vegetation, streambank modification.
Hydrologic modification—Channelization, dredging, dam construction, flow regulation.
Industrial—Pulp and paper mills, chemical manufacturers, steel plants.
Land disposal—Leachate or discharge from septic tanks, landfills.
Municipal—Publicly owned sewage treatment plants.
Resource extraction—Mining, petroleum drilling, runoff from mine tailing sites.
Urban runoff—Runoff from streets, parking lots, buildings.
Source: USEPA, 1998.

contributing to surface-water quality problems are sediment and siltation, nutrients, pesticides, salinity, and potential pathogens. For example, sediment and siltation affect 18 percent of surveyed river miles and 10 percent of lake acres (table 2). Similarly, nutrients affect 14, 20, and 22 percent of surveyed river miles, lake acres, and estuaries, respectively.

Maintaining surface-water quality is key to supplying recreational services that both current and future generations demand. For example, sediment and siltation affect water quality by harming fish, reducing water clarity, and filling in waterbodies. Ribaudo (1989) identified the following damages from sediment and siltation: reduced opportunities for freshwater and marine recreation and commercial fishing; increased cost for maintaining roadside and irrigation ditches, municipal water treatment, and steam power cooling; and greater chances of flooding. Similarly, nutrients in waterbodies (from lawn and crop fertilizer use, sewage, manure) can overstimulate the growth of aquatic weeds and algae, which then clog waterways, interfere with boating and swimming, and lead to oxygen depletion (USEPA, 1998).

Table 2—Major sources of pollution to rivers, lakes, and estuaries

Sediment and siltation affect 18 percent of surveyed river miles and 10 percent of lake acres

Item[1]	Percent
River miles:	
Sedimentation and siltation	18
Nutrients	14
Bacteria	12
Oxygen-depleting	10
Pesticides	7
Habitat alterations	7
Suspended solids	7
Lake acres:	
Nutrients	20
Metals	20
Sedimentation and siltation	10
Oxygen-depleting	8
Noxious plants	6
Suspended solids	5
Total toxics	5
Estuaries: (acres)	
Nutrients	22
Bacteria	16
Toxics	15
Oxygen-depleting	12
Oil and grease	8
Salinity	7
Habitat alterations	6

Source: USEPA, 1998.

When prices fail to convey information about the value placed on these services, feedback effects will likely be observed on the availability of this asset. The off-farm economic costs of agricultural pollution to surface waters appear substantial. Several studies have found improvements in water quality can yield significant benefits for individuals (Crutchfield, Feather, and Hellerstein, 1995). At the national level, Ribaudo (1989) found that retiring 40 to 45 million acres of highly erodible farmland through the CRP would result in national benefits (net present value) from reduced sediment pollution of $46 million per year. Comprehensive estimates of the damages from agricultural pollution are lacking, but soil erosion alone is estimated to cost water users $2-$8 billion annually (Ribaudo, 1989). Similarly, Hrubovcak, LeBlanc, and Eakin (1995) estimated the damages to surface-water quality from erosion on cropland at about $4 billion per year. Carson and Mitchell (1993) conducted a contingent valuation study to assess the public's value for national water quality. They provided survey respondents with water-quality improvement programs to meet the boatable, fishable, and swimmable goals of the Clean Water Act. The authors found that the mean annual willingness to pay to improve the Nation's water quality from nonboatable to swimmable status is $280 per household or about $29 billion per year.

Ground-Water Quality

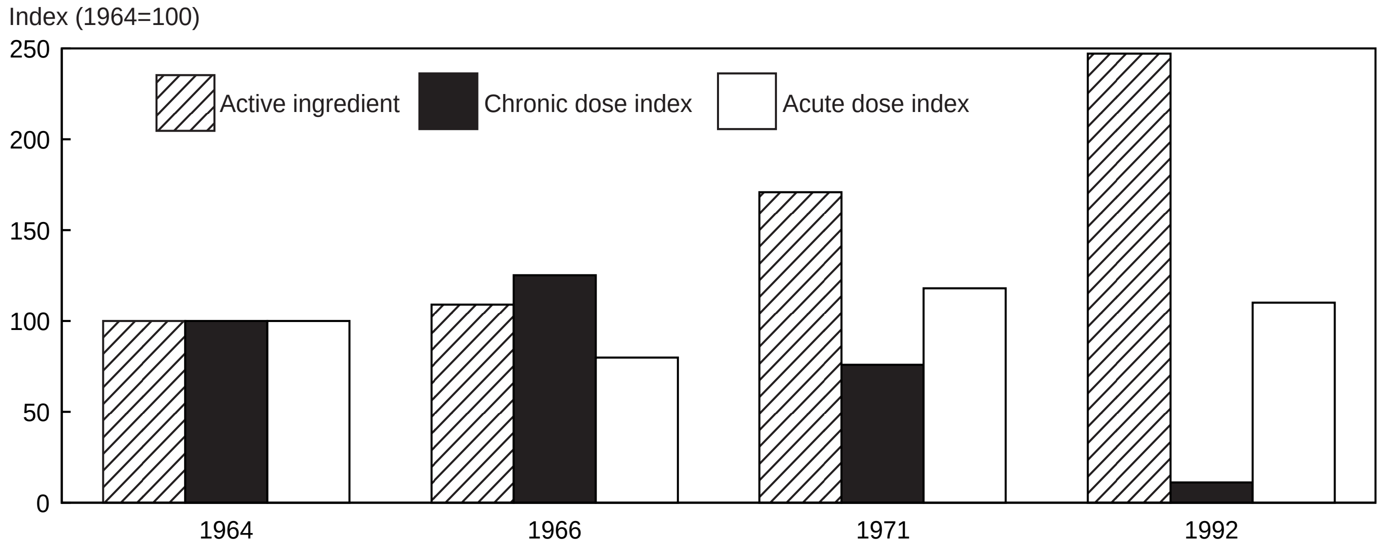
The infrastructure that monitors the Nation's environment cannot accurately depict trends in U.S. ground-water quality. Of 38 States reporting overall ground-water quality, 29 judged their ground water to be good or excellent. When degradation of ground-water quality does occur, it typically remains a localized problem and agriculture is often the source. Of 49 States reporting sources of ground-water contamination, 44 cited agriculture as a source (USDA, ERS, 1997).

Recent chemical use trends suggest that long-term improvements in ground-water quality may occur. After pesticide use more than doubled between 1964 and 1982, it declined slightly beginning in 1982 due to a decline in cropland acreage and the introduction of new pesticides that reduced application rates (fig. 5). The picture with regard to potential chemical toxicity is more complex. An index based on toxicity due

Figure 5

Pesticide use, chronic and acute risks

Although the total amount of pesticides based on the amount of active ingredients has increased since 1964, an index based on chronic risk has fallen while an index based on acute risk has remained relatively flat



Note: The chronic risk index combines Reference Dose (indicator of chronic toxicity) and soil half life (indicator of potential exposure). The acute risk index combines an oral LD50 (dose of a toxicant or microbe that will kill 50 percent of the test organisms within a designated period) with the soil half life measure. Source: Economic Research Service, USDA, 1997.

to long-term exposure to small doses shows an 89-percent decline since 1964. An index based on acute exposure increased by about 10 percent, and pounds of active ingredients more than doubled (USDA, ERS, 1997). Maintaining ground-water quality is important because it affects the supply of safe drinking water for many communities. Here again, a failure of markets to convey information about the value that communities place on the quality of a resource can affect the availability of a resource (safe drinking water) for future generations.

The evidence of ground-water quality impairment from agriculture paints an uncertain picture. While continued monitoring of ground water will clarify the Nation's understanding of pesticide and nutrient leaching, the risk of ground-water pollution carries significant economic costs.[7] Results from contingent valuation studies indicate a very large willingness by consumers to pay to avoid contamination of drinking water supplies. For example, Sun and others (1992) and Jordan and Elnagheeb (1993) evaluated the demand for ground-water protection from agricultural nitrate and pesticide leaching. Sun and others asked respondents for their willingness to pay for a protection program that would keep the ground-water quality below EPA health advisory levels in southwestern Georgia. The annual willingness to pay for this program averaged $641 per household. Jordan and Elnagheeb assessed the demand for protection from nitrate contamination of ground-water serving wells and drinking water utilities in Georgia. The authors estimated the annual willingness to pay for protection to average $120 to $150 per household for the different kinds of ground-water users.

Wetland Conversion Rates

Wetlands are an important asset for supplying environmental services. Wetlands provide opportunities for popular activities such as hiking, fishing, and boating. Similarly, wetlands provide fish and wildlife habitat, flood retention, and water filtration. Conversion of wetlands into cropland may increase the availability of food for the current generation but can affect the supply of environmental services, for both current and future generations. Because market prices may not convey information about the environmental services supplied by wetlands, there is a propensity to deplete this resource faster than would be justified by opportunity cost considerations.

The lower 48 States have lost about half of their wetlands since 1780. In 1780, wetlands in the lower 48

[7]Monitoring costs for agricultural chemicals have been estimated at $890 million to $2.2 billion for private wells (Nielsen and Lee, 1987).

States totaled slightly over 220 million acres compared with about 124 million acres in 1992 (USDA, ERS, 1997). Most of the original and remaining wetlands are in the Southeast, Delta, and Lake States. The Corn Belt has lost nearly 90 percent of its original wetlands, the Pacific States have lost nearly 75 percent, and the Plains States have lost approximately 50 percent. Between 1954-92, 64 percent of all converted wetland acreage supported agriculture.

Available data suggest that the rates of wetland loss in the 1980's are dramatically lower than in earlier decades (table 3). For example, from 1954 to 1974 and 1974 to 1983, the net rate of wetland losses in the lower 48 States was 458,000 and 290,000 acres per year. However, from 1982 to 1992, the net rate of wetland losses in the lower 48 States slowed to about 80,000 acres per year. From 1982 to 1992, almost 11,000 acres per year moved out of agricultural production and into wetlands.

Several studies have addressed the effects of agricultural production on the economic values of wetlands. In perhaps the most comprehensive evaluation of the economic values associated with wetlands, Heimlich and others (1998) assessed and classified 33 studies as to the function of wetlands, the goods they provide, and the economic value of those goods. Examples of the goods provided by wetlands include: marketed fish and fur (goods sold in markets by commercial fishermen and trappers such as blue crabs, fish, oysters, fur trapping); nonmarketed fish and wildlife habitat; nonmarketed recreation, fishing, and hunting opportunities; and nonmarketed ecological functions (nutrient filtering, storm damage). Heimlich and others then estimated the economic losses associated with the loss in wetlands from 1952 to 1992. Their estimates of the total direct economic damages range from $421 million for commercial fisheries to $135 billion for recreation and noncommercial fishing and waterfowl hunting. Based on total wetland losses of 12.9 million acres over that period, they estimate an imputed average value of $10,558 per acre of lost wetlands.

An Aggregate Assessment for U.S. Agriculture

Conclusions regarding the overall sustainability of U.S. agriculture depend on the vision of sustainability a researcher adopts. Aside from agricultural productivity, the remaining indicators are not consistent with a strong vision of sustainability (table 4). Soil continues to erode even though its impact on future agricultural output is small. Ground-water stocks continue to be depleted, although at slower rates than in the past. While data are not available to assess changes in the quality of surface and ground water over time, agriculture is likely the major contributor to impairments.

Agriculture made significant progress toward meeting the goals of sustainability in the 1980's. The growth rate of agricultural productivity was 3.3 percent per year from 1980 to 1994 compared with only 1.4 percent per year from 1948 to 1980. Interestingly, while productivity was increasing, soil erosion was declining from 3 to 2 billion tons per year, ground-water depletion rates were falling, and agriculture became a net supplier of wetlands, helping reduce net wetland conversion rates over time.

Recent research has integrated environmental and natural resource indicators in a consistent economic framework. For example, Smith (1992) compared the

Table 3—Wetlands conversions per year, 1954-74, 1974-83, and 1982-92
Wetland loss in 1980's are dramatically lower than in earlier decades

Item	1954-74			1974-83			1982-92		
	From wetlands	To wetlands	Net	From wetlands	To wetlands	Net	From wetlands	To wetlands	Net
				1,000 acres per year					
Agriculture	-592.8			-234.8	81.5	-153.3	-30.9	41.8	10.9
Development	-54.5			-14.0	0.4	-13.6	-88.6	1.5	-87.1
Other	-35.3			-168.1	53.4	-114.7	-16.4	28.8	12.4
Subtotal	-682.6	247.8	-434.8	-416.9	135.3	-281.6	-135.9	72.1	-63.8
Deepwater	-47.6	24.7	-22.9	-29.0	20.4	-8.6	-20.2	4.8	-15.4
Total	-730.2	272.5	-457.7	-445.9	155.7	-290.2	-156.1	76.9	-79.2

Source: USDA, ERS, 1997.

Table 4—Physical indicators of agricultural sustainability

Indicators give mixed signals with respect to agricultural sustainability

Indicator	Year	Physical change
		Growth rate per year (percent)
Agricultural productivity	1948-80	+1.4
	1980-94	+3.3
	1948-95	+1.9
		Billion tons per year
Soil erosion	1938	3.56
	1982	3.13
	1987	2.80
	1992	2.13
		Feet per year
Ground-water depletion	1940-80	0.25
	1980-95	0.16
Surface-water quality		Agriculture is leading source of impairment but less erosion has likely reduced damages from sediment
Ground-water quality		Of 49 States reporting sources of ground-water contamination, 44 cited agriculture as a source
		Acres per year
Net loss of wetlands*	1974-83	153,300
	1982-92	-10,900

* Attributed to agriculture. Sources: USDA/ERS, NRCS; USGS; and EPA.

effects of damages associated with soil erosion, wetland conversions, and ground-water contamination to the value of crops in 1984. His estimates of damages range from less than 1 to 7.5 percent of the value of crops grown in the Mountain region to 3.5 to 40 percent of the value of crops grown in the Northeast. Damages in the Corn Belt range from 6 to 7 percent of the value of crop output. According to his results, agriculture's contribution to social welfare far exceeds the environmental damages and deterioration of the stock of natural capital resulting from food production.

Similarly, Faeth (1996) paints a picture of an agricultural sector that is improving over time with respect to environmental damages. Faeth adjusts the agricultural productivity estimates presented in figure 1 for the off-site damages associated with soil erosion. From 1977 to 1992, agricultural productivity increased from 2.3 to 2.4 percent per year, reflecting the dramatic decline in soil erosion over that time.

Lastly, Hrubovcak, LeBlanc, and Eakin (1995) estimate that total farm income should be reduced by about $4 billion per year when adjustments are made for agriculture's contribution to the impairments in surface-water quality and draw-downs in the stock of ground water. Their adjustments to net farm income range from 6 to 8 percent and have decreased from 1987 to 1992.[8] They note one possible explanation for the decrease is that policies and programs for controlling soil erosion were effective during this period. In particular, removing nearly 22 million acres of highly erodible land from production through the CRP contributed to a nearly 21-percent decrease in estimated soil erosion on cropland even though planted acreage for grains increased by 6 percent. Conservation compliance requirements promulgated under the Food Security Act of 1985 provided additional incentives for reducing erosion.

These estimates are consistent with a view of U.S. agriculture where environmental problems exist and the resource base is depreciating, but the extent of the effects is in the range that can adequately be addressed by thoughtful policy.

[8]These estimated adjustments represent average costs of environmental damages. Marginal costs are likely to be higher.