Agriculture's Broadening Environmental Priorities 4

Covering nearly half of all the land in the United States, farms and ranches have a profound effect on the nation's environment. The quality of water and wildlife habitat—and indeed, the continuing productive capability of soil itself—depend on how farmers and ranchers manage their land, and how the environment responds to their management techniques.

Research and monitoring of agroenvironmental conditions—those produced by the interaction of agricultural and environmental systems—provide some broad evidence of agriculture's role in the quality of soil, water, and wildlife resources. The first section of this chapter reviews the evidence, which indicates that some agricultural practices have had a significant impact on the nation's environment. While, on the one hand, erosion of cropland has decreased significantly for several decades, agriculture remains the nation's primary contributor to surface water pollution, principally because of sediment deposition and agrichemical runoff from dryland and irrigated systems. Nitrate from fertilizers used in agricultural production have leached into and contaminated groundwater, exceeding federal drinking water standards in many agricultural areas. Comprehensive monitoring of agricultural pesticides in groundwater is not yet available, but some state studies focused on agricultural areas indicate concentrations in excess of drinking water standards do occur. Further, observations of wildlife show that impaired water quality as well as agricultural land uses can degrade the quality of habitat of aquatic, wetland, and terrestrial species. Indeed, agricultural practices have been linked with at least one-third of endangered species and with the extinction of species. But conservation programs introduced in the mid 1980s have also significantly increased some species populations.

It is important to note that at this time, a comprehensive assessment of agriculture's effects on environmental quality is not possible, because agroenvironmental monitoring is incomplete and the interactions between agricultural activities and the environment are not well understood. There is a pressing need not just for more research, but for more sophisticated agroenvironmental science to clarify the functioning of agroenvironmental systems, describe their conditions, and interpret the environmental implications of those conditions.

The second half of this chapter focuses on the basic approaches the federal government is using for both known and emerging agroenvironmental problems. Currently, Washington gives incentives to farmers and ranchers to adopt conservation and environmental technologies through several different kinds of programs. Voluntary educational and technical assistance programs, which came into being during the Great Depression, have remained one of the government's chief vehicles for doing so—even though there is a lack of scientific evidence to indicate that without subsidies, such programs lead to significant environmental improvements. Subsidy programs have produced conservation and environmental gains, but generally have not been targeted to areas of greatest environmental significance and have not always encouraged cost-effective practices. Further, they are increasingly vulnerable to budget-cutting pressures. Compliance schemes, a landmark development of the 1985 Food Security Act, link environmental performance on high erodible lands and wetlands to receipt of agricultural program payments. Regardless of their efficacy to date, the schemes suffer two basic shortcomings—the size of the compliance penalty and thus the size of the incentives to implement the conservation plan may not align with environmental priorities, and their longevity depends upon continued renewal of agricultural program benefits.

Environmental regulations also affect several types of agricultural activity, although less so than for other industries. However, the perceived impacts of regulation are broad, perhaps because several new efforts have begun over the past two decades. Pesticide registration involves a protracted and costly review process that is behind schedule and has created impediments to innovation. Problems in reregistering compounds for minor use crops with small pesticide markets exemplify the costliness, prompting recent administrative improvements. Farmers applying for permits to alter wetlands for agricultural purposes have also met with time delays, although the delays are improving. Water pollution controls for confined animal operations have not been uniformly enforced. Treatment of agricultural pollutants in coastal zones is still in the planning stages; endangered species protection within the agricultural sector is largely undocumented; and imports of harmful nonindigenous species accompanying expanded trade are covered by an incomplete set of regulations. The prospects of future potential regulatory efforts are likely contributing to the broadly perceived impacts of regulation.

Taken as a whole, the incremental institutionalization of at least 40 separate federal agroenvironmental programs, with no comprehensive oversight, has meant that there is no clear set of environmental objectives and priorities for the agricultural sector. Clarifying agriculture's environmental responsibilities, and the public and private roles in accomplishing those objectives, would reduce uncertainty for all sides and allow scarce public resources to be focused on high priorities.

Given the potential scope and long-run seriousness of many poorly understood agroenvironmental interactions, and given the various problems that persist in many government programs, the future environmental agenda for agriculture must accommodate incomplete science, while also promoting research and program incentives for achieving agricultural production and environmental quality simultaneously. Interest in such "complementarity" between agricultural production and the environment has grown within the research community, among farm producers, among agribusinesses, and among consumers. Technological research and development aimed at enhancing such complementarity holds considerable promise to achieve improved environmental quality while maintaining competitiveness. Nonetheless, the low level of federal funding for agroenvironmental research and lack of major program goals to enhance such technology will slow the reorientation of public research priorities from traditional production emphases to complementary technologies.

AGRICULTURE AND ENVIRONMENTAL QUALITY

Since the 1960s, public awareness of the links between agricultural practices and the environment, and evidence that those links can have serious implications for both human and environmental health, has been growing. Consequently, federal and state legislation has increasingly been aimed at ensuring that farming practices balance output goals with soil, water, and other environmental quality objectives. Wetlands, which were once considered undesirable swamps, are now recognized for their contributions to water quality, flood control, and habitat. Erosion control, once pursued mainly to preserve crop yields, now plays a strong role in reducing water pollution from sediment and agrichemical runoff. Some agricultural lands are cultivated for crop production while also protecting wildlife habitat.

The environmental effects of agriculture may be re-evaluated when residential and agricultural activities come in close proximity. For example, localized leaching of farm chemicals into groundwater may be perceived as more harmful if that aquifer becomes the primary source of public drinking water in new residential areas. The environmental effects of long-standing farm practices such as aerial pesticide applications or hog production may also be redefined by the proximity of residential and agricultural lands.

Despite growing evidence of agriculture's effects on the nation's environment, the nature of the effects are not sufficiently documented. At this writing, many federal programs independently monitor natural resources, but their data are not designed to be integrated into an overall assessment. No federal databases comprehensively evaluate national water quality conditions, trends in soil quality (except erosion), or agriculture's effects on wildlife. Moreover, federal programs do not address many of the biological, chemical, and physical links between agricultural practices and environmental conditions. Indeed, many agrichemicals have not been evaluated fully for their potential effects on the health of humans or environmental systems. The National Research Council (NRC) has noted that the nation's agroenvironmental research agenda is too poorly funded (about 12 percent of the total agricultural research budget) and lacks focus (65).

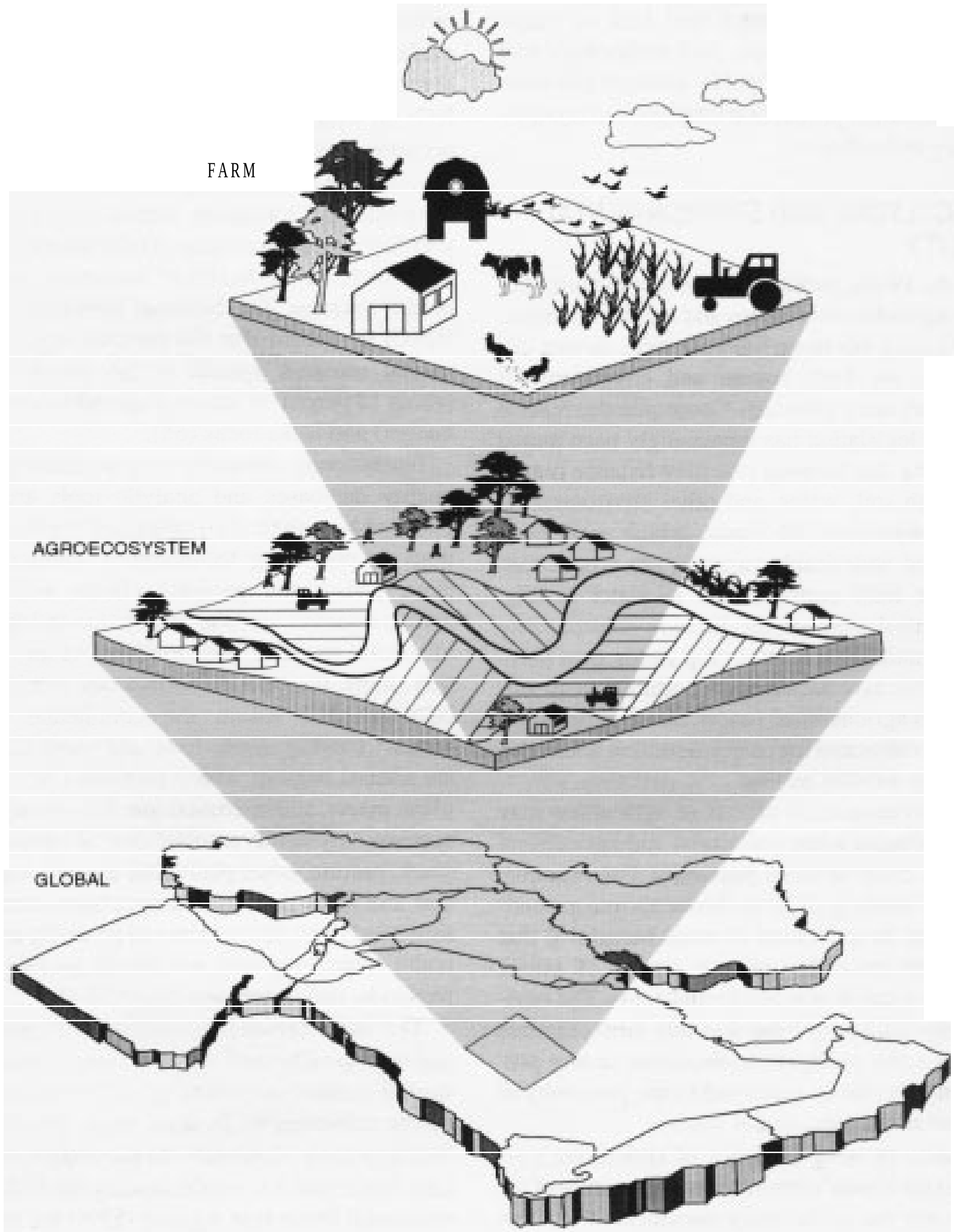
Institutional obstacles to constructing high-quality databases and analytic tools are compounded by technical complexities, such as variations in prevailing technologies, cultural practices, policy and program effects within and among regions—and the sheer range and diversity of natural resource endowments. As an illustration, more than 2,111 distinct watersheds have been mapped within the continental United States.[1] Cutting across land and water divisions are natural habitats with a profusion of wildlife, plant, insect, and microbial life. Diverse agroecosystems—dynamic associations of crops, livestock, pasture, other plants and animals using air, soil, and water span this resource base, encompassing nearly one billion acres of privately and federally owned cropland, woodlands, grazing lands, wetlands, and waterways (figure 4-1).

The links between environmental conditions and biological health[2] implications are a matter of special concern in evaluating agriculture's effects on the environment. In some cases, this link has been expressly addressed: the maximum contaminant levels (MCLs) established by the U.S. Environmental Protection Agency (EPA) are used for monitoring drinking water quality to protect hu-

[1] A watershed is an area of land from which water drains to a stream or to a lake, wetland, or reservoir.

[2] Biological health, as used in this report, refers to the viability and safety of plants, wildlife and humans.

FIGURE 4-1: Agroecosyste



The term "agroecosystem" Indicates that farms do more than produce cultivated vegetation and domesticated animals. Farina also affect nutrient cycling, hydrologic flows, soil and water quality, and wildlife habitat. The term also refers to the area that most directly supports the environmental and productive functions of farms and, conversely, in which most environmental effects of production-such as sediment deposition, modification of wildlife habitat, or changes in water quality-are likely to be detected.

SOURCE: Adapted from EPA Environmental Monitoring and Assessment Program (EMAP), 7992 *Agroecosystem Pilot Project Plan (EPA/620/R-93/010),* **January 1993.**

TABLE 4-1: National Surface Water Quality, 1992

Water	Total resource base[a]	Percent assessed	Percent impaired of assessed	Percent of assessed that fully support designated uses	Rank of agriculture as source of pollutants
Rivers and streams	3.5 million miles	18	38	56	1 - primary source
Lakes, ponds, reservoirs	40 million acres	46	44	43	1- primary source
Great Lakes shoreline	5,382 miles	99	97	2	NA[b]
Ocean shoreline	56,121 miles	6	14	80	NA
Estuaries	36,890 sq. miles[c]	74	32	56	3- notable source[d]
Wetlands	277 million acres	4	50	50	1 - primary source

NA - Not Available.

[a] Contiguous United States and Alaska.
[b] Atmospheric deposition is ranked first.

[c] Not including Alaska.
[d] Municipal point sources and urban runoff are ranked first and second.

Percent impaired plus percent fully supporting may not sum to 100. The difference is comprised of "threatened" waters—those that are now fully supporting but at risk of impairment.

SOURCE: EPA, National Water Quality Inventory, 1992 Report to Congress

man health. In general, however, standards that link environmental quality and biological health are tentative or nonexistent, a result of inadequate science, incomplete policy guidance, and the complexity of the issues.

Primary Elements of Natural Resource Quality[3]

Surface Water Quality

As a result of normal farming practices, soil sediment, pesticides, nutrients (nitrate and phosphorous), toxic metals, and pathogens can and do make their way into the nation's surface waters (rivers, streams, lakes, ponds, wetlands, and estuaries). Water quality data collected by the Environmental Protection Agency (EPA) suggests that the majority of the nation's surface waters that were assessed in 1992 were of sufficient quality to support one or more "beneficial use" designated by states[4] (table 4-1). However, EPA and state officials consider nonpoint source pollution[5] from agriculture to be the major contributor to remaining national surface water quality problems (120).

Although the federal government does not systematically monitor surface water quality conditions[6] and their environmental implications, agriculture's predominant role in polluting surface water-especially in regions where crops are intensively cultivated or where livestock operations are concentrated—is corroborated by numerous reports and studies conducted by government and independent researchers. The U.S. Geological Survey (USGS) recently found that 71 percent of U.S. cropland is in watersheds where at least one

[3] This review of agriculture's effects on the environment focuses on the three primary natural resource groups—water quality, wildlife, and soil quality. Discussion in chapter 6 covers the effects of air pollution on agricultural productivity. The potential effects of climate change on agricultural and environmental systems are covered in "Preparing for an Uncertain Climate," U.S. Congress, Office of Technology Assessment, 1993.

[4] Designated beneficial uses include aquatic life support, fish consumption, shellfish harvesting, drinking water supply, recreation (swimming and boating), and agricultural production (120).

[5] The term "nonpoint source" or "nonpoint" refers to the inability to trace pollution to a specific source or "point" of origin.

[6] USGS studies of water conditions, while consistently collected and extensive, are not designed to satisfy the need for comprehensive monitoring. State-reported data compiled by EPA do not represent a statistical sample, and moreover, are not consistently collected across states. They are, at most, suggestive of national surface water quality (120).

Rain and irrigation waters carry sediment and chemicals from cropland into surface waters. Drainage off fields, as shown above, or from underground tile empties into streams, rivers, lakes, or wetlands. The cumulative effect of drainage like this from many fields influences the quality of entire watersheds. Almost three-quarters of all U.S. cropland **lie** *in watersheds where levels of sediment, fertilizer residues, or bacteria from livestock manure exceed EPA guidelines.*

agricultural contaminant exceeds guidelines established by EPA for recreational safety or the ecological health of the water (83).

Several large-scale studies show that agriculture has played a significant role in supplying the nitrogen, phosphorus, and sediment found in the nation's surface waters (35,82,120). Crutchfield et al. (19) found that 50 percent of nutrients reaching freshwater systems nationwide come from agricultural runoff, and the U.S. Geological Survey's National Water Quality Assessment (NAWQA) sampling program confirmed that, in 90 percent of the watersheds studied, agriculture supplied most of the nutrients found in rivers and streams in rural areas (116). Evidence also indicates that the level of common agricultural pollutants in regional watersheds declined during the last decade (83).

The environmental implications of agricultural pollutants in surface water depend on how prevalent the pollutants are; how toxic they are to humans, aquatic life, and other wildlife; how chemically stable they are in water; and how mobile they are in water systems. Existing research as noted above suggests that agricultural pollutants are prevalent in surface water, especially in areas where land is cultivated intensively with mechanical tillage, and irrigation and/or chemicals are applied. Research on the toxicity of agricultural pollutants remains incomplete—nitrate and some pesticides are established toxins, but the vast majority have not been fully tested. It is not known how quickly nutrients and pesticides degrade in water, but field studies suggest that chemicals are more stable in water than in soil (37), and sediment does not degrade. Some agrichemicals and sediment can migrate long distances through rivers and streams. Volatile agrichemicals can be transported through the atmosphere and deposited with rain into surface waters far beyond their region of origin (39).

According to state reports, agricultural runoff of nutrients and sediment is a primary cause of "impairment" of lakes, ponds, wetlands, and estuaries (120).[8] High nutrient levels promote eutrophication, a condition of excessive algal growth that depletes dissolved oxygen in aquatic habitat and increases the incidence of fish kills. Buildup of sediment, known as siltation, reduces water quality for drinking or recreation, fills in bodies of water, reduces navigability, increases the likelihood of flooding, and interferes with the spawning (reproduction) of many kinds of fish. Annual damages from agricultural siltation have been estimated to be between $3 and $13 billion in 1980 (14) and between $5 and $17.6 billion in 1989 (101). The large range for damages reflects that both studies had to use preliminary and incomplete water quality and economic information.

Atrazine and other herbicides as well as insecticides are almost always detected in surface waters in regions where they are used (36,64,83,103).

[7]The contaminants monitored were suspended sediment, dissolved nitrate, total phorphorus, and fecal coliform bacteria (83).

[8]Estuaries are water passages where the sea tide meets a river current and contain brackish(mixed salt and fresh) water.

Within regions where fertilizer use and livestock are common, evidence of nitrate in surface water may vary considerably across the region (36). Herbicide and nitrate concentrations in surface water vary seasonally but, in many streams, agrichemicals may be detected year-round as they are slowly released from storage in surface water reservoirs, groundwater, and soil (36,54,76). The seasonality of insecticide concentrations is similar to that for herbicides, but, compared to herbicides, insecticides in surface water are less persistent, concentrations are lower, and peak concentrations occur later in the season (36).

While nitrate levels peak in fall, winter, and early spring, herbicide concentrations tend to peak in the late spring and early summer when heavy rains wash agrichemicals from newly treated fields. During this "spring flush," herbicide levels in streams and rivers often exceed EPA drinking water standards expressed as MCLs (appendix 4-1). Atrazine has been measured at more than 30 times the MCL in some Midwestern streams and more than 3 times the MCL in large rivers (37).[9] In most cases, nitrate and herbicide levels fall to within federal standards by late summer, as agrichemicals are utilized, degraded in riverbed sediment, stored in soil or groundwater, volatilized into the atmosphere, or carried downstream.

The stability of agricultural pollutants in water enhances the likelihood that when agricultural pollutants disappear from flowing waters in the regions where they originate, they may be transported to coastal zones, lakes, wetlands, or reservoirs. Indeed, researchers found that agriculture supplied an average of 24 percent of total nutrients and 40 percent of total sediment in 78 estuarine systems (18). At least one herbicide was detected in 92 percent of the reservoirs sampled in 10 midwestern states between April and November of 1992.[10] Perhaps the best known example of the mobility of agricultural pollutants involves California's Kesterson Wildlife Refuge where accumulations of selenium carried in irrigation flows draining into the refuge poisoned waterfowl and made the wetland uninhabitable.

Recent monitoring showed generally less than 3 percent of each herbicide applied on farms in the Mississippi Basin and the equivalent of 15 percent of all nitrogen fertilizer used on regional crops enter the Gulf of Mexico from the Mississippi River. These percentages equate to 123 and 321 metric tons, respectively, of common herbicides like metolachlor and atrazine and 967,000 metric tons of nitrate (6). Tributaries from Iowa, Illinois, and Minnesota were determined to be significant sources of agrichemicals transported to the Gulf, illustrating that agricultural pollutants can remain stable and mobile over long distances. Similarly, diazinon, a spray pesticide used on orchards in the Central Valley of California, has been detected throughout the Sacramento-San Joaquin Delta and San Francisco Bay, in concentrations that exceed aquatic health recommendations established by the National Academy of Sciences (114).

Reservoirs and large lakes that are slow to recharge (i.e., where water replacement takes 6 months or more) can become "sinks" for agricultural pollutants transported seasonally by streams, rivers, and the atmosphere. Reservoirs sampled in 1990, 1991, and 1992 held atrazine levels that exceeded EPA drinking water standards even in winter months, when chemical concentrations would be expected to be at their lowest (38). Agrichemicals, such as DDT, atrazine, and alachlor, which can volatilize into the atmosphere and be deposited with rainfall, may accumulate in reservoirs and have been detected in all of the Great Lakes (box 4-1) (39,80). Herbicide residues can pose a

[9]Maximum contaminant levels (MCL), or drinking water standards, have been established by the U.S. Environmental Protection Agency for several herbicides and nitrate (see appendix 4-1). MCL's for herbicides are based on an annual average of four or more samples and are legally enforceable under the Safe Drinking Water Act. The MCL for nitrate is based on a single sample and not an annual average. MCL's have been established only for individual compounds and do not address the possible effects of complex mixtures of pesticides and their degradation products.

[10]Illinois, Indiana, Kansas, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin.

BOX 4-1: Surface Water Quality

Persistent Contaminants in Freshwater Sources: Great Lakes

Toxic agrichemicals remain in the Great Lakes surface waters despite strenuous efforts at remediation and despite significant reductions in industrial sources of pollution In the Great Lakes basin, which holds 21 percent of all the fresh water on earth (1 0,80), concentrations of toxic contaminants generally went down between the 1970s and 1980s, Decreased concentrations of agricultural pesticides, especially organochlorines such as dieldrin and DDT-related compounds, in fish tissue are considered a key indicator of that trend However, the decline in contaminants leveled off in the early 1980s, leading scientists to reconsider the Iikely behavior of waterborne pollutants within the Great Lakes environment

Several causes for the chemical persistence have been observed, Some chemicals, notably DDT, are extremely persistent (i e , resist degradation). Toxins that are bonded to bottom sediment are remobilized by dredging or by the natural shifting of the lake bottoms, Slow leaching of contaminants from a variety of sources continues Chemicals from agricultural runoff and industrial or municipal effluent are transferred from tributaries. Volatile pollutants are transported across regions and even continents through the atmosphere and deposited through rainfall into the Great Lakes, Finally, water in the Great Lakes has an extremely long residence time. It will take a full century for the water currently contained in Lake Michigan to be naturally filtered and replenished; in the case of Lake Superior, volume replacement will take 172 years (79), As a result, these lakes are vulnerable to the cumulative effects of runoff, atmospheric deposition and the persistence of the contaminants which they contain

Atrazine has been detected in Lake Superior in pristine locations that are inaccessible to all migration pathways except for the atmosphere (39) In fact, atmospheric deposition ranks as the primary source of pollutants in the Great Lakes (1 20) Some of the persistent agrichemicals were banned in the United States as much as 15 years ago but are believed to enter the Great Lakes Basin through the atmosphere Others are manufacturing residues of pesticides that were never actually in use in the Great Lakes basin at all but manufactured in the region for export.

Independent and synergistic effects of pesticide contaminants, primarily on wildlife and human health, are still being investigated. Reproductive failures, developmental abnormalities, morphological abnormalities, and tumors in wildlife have been Iinked to agrichemicals, byproducts of agrichemical production, and their breakdown products (10) Some of the species known to be affected by persistent contaminants in the Great Lakes include mink, otter, double-crested cormorant, herring gull, snapping turtle, lake trout, and bald eagle (10)

Persistent Agrichemicals in the Great Lakes

Compound	Agricultural uses	Use status	Pathway to Great Lakes basin
Mirex	insecticide	canceled 1976	release during manufacture
Hexachlorobenzene	fungicide	canceled 1990	atmospheric deposition
Dieldrin	soil Insecticide	canceled 1971	leaching
DDT/DDE	insecticide	canceled 1971	atmospheric deposition
Toxaphene	cotton crop insecticide	canceled 1982	atmospheric deposition

Source” Office of Technology Assessment, 1995 special problem for public water supplies that draw from surface waters because conventional water treatments cannot remove them.

Wetlands are recognized best for their role as wildlife habitat, but they also function as surface waters, acting as a sink and filter for agricultural pollutants, and serving as flood storage and control areas. The economic significance of these surface waters extends beyond water quality and has been estimated in the billions of dollars for the recreation, timber, and trapping benefits that they provide (42,92). Today, about 5 percent of the lower 48 states are comprised of wetlands falling from about 10 percent in 1780 (21). Very little data has been collected to describe the quality of wetlands or their roles in attaining improved surface water quality, however. According to EPA, states (which are responsible for monitoring water quality and for monitoring wetlands conservation under the Clean Water Act) have not yet adopted criteria to evaluate wetlands quality and function, including water quality roles (123).

MCLs developed by EPA for use as drinking water quality criteria, are often used as the benchmark for evaluating surface water quality. Overall, however, the effects of chronic, low-level exposure to agrichemicals on human health[11] and on wildlife have not been fully determined. The National Cancer Institute and other organizations have reported correlations between significant exposure to certain pesticides and cancer in humans (7,58). The relationship between elevated nitrate levels in drinking water and methemoglobinemia ("blue baby syndrome") has been clearly established (47). The risk of cancer from exposure to nitrate has been less well-defined (11), although it has been shown that N-nitroso compounds—many of which cause cancer in laboratory animals—are produced in the human digestive tracts of people who ingest water-borne nitrate (56). The evidence, although incomplete, also suggests that low-level, continuous exposure to nutrients and pesticides can harm aquatic plants and wildlife (10,64).

The adoption of so-called best management practices (BMPs) can reduce nitrate and pesticides in surface water that degrade the quality of drinking water and negatively affect wildlife that use water resources. Technologies to reduce manure, sediment, and chemical runoff have led to sometimes dramatic improvements in surface water quality, as case studies in several states show (87). However, widespread adoption of BMP's may not produce rapid improvements in environmental quality because interactions among soils, surface water, and groundwater may be difficult to manage with BMP's alone. For example, the quality of the South Platte River in Colorado is strongly influenced by groundwater quality. It is estimated that, even with complete elimination of all nitrogen leaching, nitrate currently held in groundwater might enter the river for the next 25 years (54).

Groundwater Quality

There has been no comprehensive assessment of national groundwater quality, but accumulating evidence from national and state studies is helping to understand agriculture's role. Monitoring has confirmed that nitrate and agricultural pesticides are in groundwater in almost every state. Analyses of hydrologic systems show that soil, surface water quality, and groundwater quality are interlinked (124). Furthermore, the susceptibility of groundwater to agrichemical leaching is marked by significant variability across the nation, but land use plays an important role.

For example, nitrate levels are much more likely to exceed drinking water standards in groundwaters under cropland than under any other land use. Monitoring and analyses of pesticides have not yet revealed their roles in groundwater quality on a comprehensive basis. However, a range of

[11]The range of acute (short-term) and chronic (long-term) health effects that might be investigated could include gastrointestinal or circulatory disorders, cancer, neurotoxicity, immune system dysfunction, genotoxicity, and endocrine disruption. See appendix 4-1 for potential health effects of agricultural chemicals that guide EPA drinking water standards.


USDA, AGRICULTURAL RESEARCH

Numerous state studies show that fertilizer residues and pesticides do leach into aquifers. Hera, USDA researchers test the effects of different tillage practices on pesticide movement to groundwater. Because comprehensive monitoring of national groundwater quality is not performed, overall trends in groundwater quality are unknown, and the extent of groundwater degradation due to agriculture is uncertain.

pesticide concentrations have been found under cropland by individual studies, some in excess of drinking water standards.

Evidence that agricultural pesticides and nutrients were reaching aquifers began to accumulate in the . 1970s (box 4-2). By 1990, at least 46 pesticides had been detected in groundwater in 26 states, and nitrate contamination had become more prevalent (86,93). EPA's review of groundwater studies conducted from 1971 to 1991 in 45 states revealed that 132 pesticides or their breakdown products had been found. Of the 23 compounds detected most often, virtually all were associated with agriculture (118). More recently, of 44 states that submitted reports to EPA in 1992 declaring that agriculture was a source of groundwater contamination, approximately one-third ranked agricultural activity as the source of "highest priority" contaminants (120).

EPA's National Survey of Pesticides in Drinking Water Wells (NPS) (117), which randomly sampled drinking water wells across the country, found detectable nitrate levels in 52 percent of community wells and in 57 percent of rural domestic wells. Less than 3 percent of detections exceeded the MCL for nitrate. Detectable pesticide residues were found in 10 percent of community wells and 4 percent of rural domestic wells. Fewer than 1 percent of wells exceeded MCLs for pesticides. From these results, EPA concluded that groundwater quality was a local or regional rather than national issue.

By contrast, groundwater studies conducted in 45 states, compiled as part of EPA's Pesticides in Groundwater Database (PGWDB), focused on areas of intensive pesticide use (1 18). Historically, the majority of such sampling has been targeted to agricultural, rather than nonagricultural areas. As a consequence of this sampling strategy, the PGWDB reported a greater number of wells in violation of pesticide MCLS than did the NPS. Indeed, in its interpretation of the data, EPA cautioned that these high pesticide concentrations probably do not mirror statewide conditions because most studies sampled heavily in agricultural areas where pesticides are used extensively. For example, 11 percent of California wells and 27 percent of New York wells sampled between 1971 and 1991 contained pesticides in excess of federal drinking water standards or MCLs (118). Even though agriculture is not the only source of pesticides in groundwater, many of the pesticides found most often in state studies are used in agricultural production. These partial studies suggest that agricultural areas may be at greater risk to groundwater contamination from pesticides.

Studies conducted by USGS confirm that high nitrate concentrations are often found in aquifers under agricultural areas (59). Nitrate levels in excess of federal drinking water standards have been detected in many aquifers. For example, along the South Platter River in Colorado, groundwater nitrate levels have exceeded MCLs for 20 years, leading to impairment and, in some cases, abandonment, of public drinking water wells (54). In the Lower Susquehanna area of Pennsylvania, all 38 wells with nitrate concentrations higher than the MCL were located in agricultural areas (54). In

BOX 4-2: Agrichemicals in Groundwater Detection: Selected Cases

- Nitrate levels increased between 1974 and 1984 in the Central Platte River Valley, Nebraska (30)
- In California, the nematocide DBCP was found in more than 2,000 wells in the San Joaquin valley and was known to have contaminated groundwater for 7,000 square miles. Between the late 1970s and mid-1980s, more than 50 pesticides were found in the groundwater of 23 California counties (45).[1]
- Several pesticides associated with potato crops, Including aldicarb, were confirmed in the groundwater underlying Suffolk County, Long Island, in 1979-80 (45) [2]
- Between 1982 and 1983, state officials in Wisconsin detected 12 pesticides in the state's groundwater,[3] and developed a monitoring priority list of 45 pesticides determined to be most susceptible to leaching (45)
- In Florida, extensive and highly concentrated presence of aldicarb and EDB, and Isolated, low-concentration cases of silvex and lindane in state groundwater were confirmed in 1982-83 (45).
- Pesticide residues have been detected in 33 percent of over 700 wells tested in Iowa and 39 percent of over 500 wells in Minnesota (1 30).
- In 1985, 84 of more than 430 National Wildlife Refuges were threatened by groundwater and surface water contaminants, 35 from agricultural causes (1 30).
- Between 1986 and 1988, elevated concentrations of nitrate, atrazine, and Indicator minerals related to agricultural activities were detected on the Delmarva Peninsula of Delaware, Maryland, and Virginia (41)

[1] The presence of a host of agricultural pesticides were confirmed through monitoring, a partial list includes 1,2-dibromethane (EDB), 1,2-/1,3-dichloropropane (D-D), simazine, atrazine, carbofuran, DDT and its associates, 2-4-D,Endosulfan, Dinoseb (DNBP) and lindane---all in more limited cases and/or at much lower concentrations than DBCP (45).

[2] aldicarb, carbofuran, chlorothalomil, dacthal, dinoseb, oxamyl, D-D, EDB

[3] alachlor, metolachlor, aldicarb, dinoseb, atrazine, butylate, eptam, cyanizine, carbofuran, chloramben, DCPA, and metribuzin. Most detects were for aldicarb, followed by atrazine, alachlor, and metoachlor.

a regional study of 12 Midwestern states,[12] Kolpin et al. (51) found that 29 percent of samples contained elevated nitrate levels and 6 percent were equal to or greater than the MCL. Sampling at 12,000 sites revealed that groundwater under agricultural croplands exceeds EPA drinking water standards (MCLs) for nitrate 16 percent of the time versus 6 percent or less for groundwater under land in other uses (59).

Efforts have been made to determine what conditions lower or raise the potential for contaminants to leach into underground aquifers in different regions of the country. Mueller et al. (59) noted that groundwater in certain agricultural regions—parts of the Northeast, Midwest, and West Coast—are more vulnerable to nitrate leaching because the soil in these areas does not hold water and nutrients easily, and because fertilizers and irrigation are used more extensively in these regions than elsewhere. In general, shallow aquifers (within 100 to 150 feet of the land surface) are most susceptible to nutrient leaching. Kellogg et al. (49) estimated that the areas where groundwater was most vulnerable to pesticide leaching were the Corn Belt, Southeast, and Lake states. Groundwater in the Northern and Southern Plains, they posited, might be most vulnerable to nitrate leaching.

The actual pattern of groundwater contamination may be somewhat more variable than vulnerability models predict because of the diversity within and among watersheds of a given region. For example, even though fertilizers are used extensively in the Corn Belt, little nitrate appears in the region's groundwater—which suggests that a subsurface geological barrier that prevents

[12] Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin.

agrichemicals from leaching into groundwater exists in the region (49,59). However, other areas of the Midwest, including Iowa and Wisconsin, have different soils and geology, and the groundwater in them is highly vulnerable to leaching of atrazine, other pesticides, and nitrate. Mueller et al. (59) note that in areas where they cannot infiltrate groundwater, agrichemicals may be diverted to surface waters in runoff rather than fully used by crops, held in the soil, or degraded. A notable exception to this pattern occurs in the Southeast, where both surface water and groundwater show very little leaching of agrichemicals. A combination of poorly drained soils, interspersal of agricultural land with forests and wetlands, and high levels of soil organic matter that sequester chemicals and accelerate their degradation may be the reason (54).

Increasingly, states have used fertilizer reduction programs or restricted the use of leaching pesticides in efforts to help clean up groundwater that clearly exceeds state or EPA drinking water standards. However, these state efforts demonstrate the difficulty of getting agricultural contaminants out of groundwater. On Long Island, researchers expected aldicarb residues in aquifers to decompose according to a half-life of three years. However, aldicarb proved to be stable in aquifers, and it is now predicted that aldicarb levels will exceed the state safety guideline of 7 ppb for decades (45). Similarly, although a rigorous program of nitrate management in the Central Platte of Nebraska has resulted in measurable improvement in local groundwater nitrate levels, land use changes alone are unlikely to reduce nitrate levels to drinking water standards within the lifetimes of those currently farming because of the long residence time of groundwater in aquifers.

Changes in how land is used may not be enough to improve groundwater quality, because chemicals that degrade quickly in soil are often much more stable in chemical conditions that are typical of aquifers. Technological reinforcement of land use changes may not be sufficient to reverse contamination, either. A 1994 report by the National Research Council (NRC) noted that it may be impossible to remove agricultural contaminants from groundwater with current clean-up technologies. Even when it is feasible, remediation remains very complex and potentially ineffective while well replacement is often prohibitively costly (66). Because approximately 50 percent of all U.S. residents and at least 95 percent of rural residents (a total of 130 million people) get their drinking water from groundwater aquifers (59), the potential risk associated with groundwater quality problems could be widespread.

Wildlife Habitat

Because U.S. agriculture covers such a vast land area—as much as one-half of the nation's coterminous land base—its effects on the quantity and quality of habitat and on the rate of species disappearance are the subject of some concern.[13] Available research suggests that patterns of agricultural land use, the degree of diversity in crops and animals produced, and the amount and kinds of chemicals used largely determine how agriculture affects wildlife habitat both on and off the farm. Field studies show that trends over the last decades—especially in areas where crops are cultivated intensively—have reduced both the quantity and quality of regional natural habitat. At the national level, agricultural development is the most frequent cause of habitat alteration or loss and the most prominent reason for endangerment among all species, especially mammals and amphibians (32). Grazing is also a significant cause of endangerment, particularly affecting plants in certain regions (32). In total, the status of more

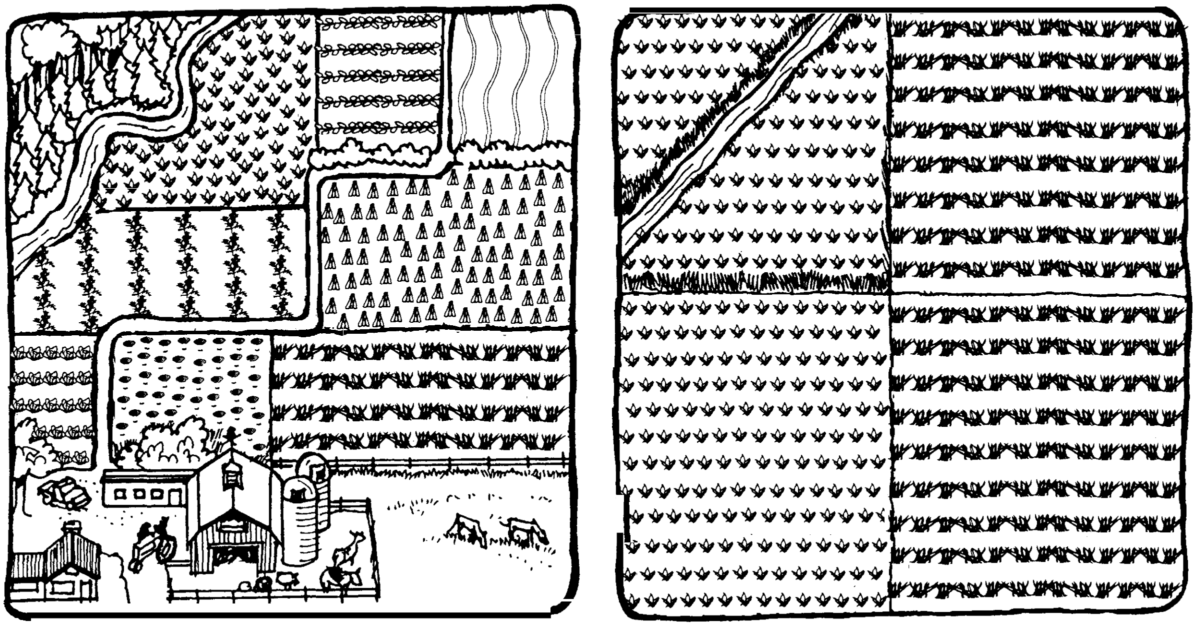
[13] Some scientists estimate that at the present, extremely rapid rate of species loss, two-thirds of all living species, worldwide, could be extinct by the end of the next century (73). This has promoted interest in evaluating the status of species in the United States.

than one-third of all species listed as threatened or endangered has been linked to agriculture. 14

Land (terrestrial) habitats are eliminated, degraded, or fragmented when forests are cleared, wetlands are drained, and grasslands are cultivated. New kinds of vegetation may be established in place of native species. While some wildlife species are attracted to and thrive in the highly modified, frequently fragmented habitats that result, others are not. The range of the red fox, for example, expanded westward as a result of agricultural development. For ground nesting birds, on the other hand, which require large tracts of grasslands, islands of nesting cover interspersed with cropland have increased their exposure to predators (3,125).

Once land has been allocated to farming, the types of practices put in place can either enhance or further reduce the compatibility between production and habitat protection. Agricultural land use trends dominated by large, contiguous fields; cultivation of only one or two crops; and elimination of native tree stands, grassland corridors, and long-term nesting cover play a key role in reducing the amount of terrestrial habitat for many birds, mammals, insects, and plants (figure 4-2). Miles of water (aquatic) habitat are reduced, and the remaining habitat degraded, by straightening

FIGURE 4-2: Dynamics between Trends in Land Use and Wildife Habitat in Agricultural Areas



Over the last four decades, farm fields have gotten bigger, crop diversity has declined, mixed crop/livestock farms are less common, natural stream flows have been altered, native plants have been removed from field edges and stream banks, and mechanical and chemical inputs have intensified While some wildlife have thrived in the new farm landscapes, many have declined.

SOURCE: Office of Technology Assessment, 1995 Assistance provided by Dale Crawford, National Biological Service, Fort Collins, Colorado.

[14]In 1989,45 percent of federally listed Endangered and Threatened species were associated with some form of agriculture (113). In 1994, 38 percent of species listings were related to agriculture (32). The decline in percent does not necessarily infer improvement. as the number of listed species has increased. Also, these statistics were developed separately, not as part of continuous study.

streams (channelization) to support field drainage and irrigation. Nearly 22,000 miles of streams in Minnesota have been lost due to channelization (70). Eliminating vegetation from stream banks or altering in-stream water flows (through flood control, for example) can further reduce the quality of aquatic habitats. The result of these trends has been a reduction in species abundance and diversity, particularly in certain regions (3 1,70,1 25).

Studies of avian populations east of the Mississippi River found that the total number of bird species has declined as forests have been converted into intensive cropland. Moreover, among the species that remain in the cropland setting, the populations of some birds—such as red-winged blackbirds and house sparrows-have increased while the populations of other birds that were once dominant have declined (9).

In the eastern Great Plains region and upper Midwest, the conversion of 30 to 99.9 percent of native prairie, much of it to intensive crop production, represents the largest reduction of any North American ecosystem (78). This conversion has caused sharp declines in the populations of many wildlife species that have historically depended on that habitat, and grassland birds are declining faster than any other group of species in North America (78). At least 55 grassland species in the United States are listed as threatened or endangered, 728 more may soon be listed, and several species indigenous to the Great Plains such as the Audubon bighorn sheep and plains wolf are now extinct (78).

Trends in certain ("keystone") species may indicate the viability of other species that are dependent on them for habitat or food. As an example, the loss of 98 percent of the prairie dog population in the Great Plains has been correlated to declines in the populations of dependent species, including the black-footed ferret, swift fox, ferruginous hawk, and mountain plover (55,78). Similarly, the populations of "indicator species," used to assess farmland habitat quality for all nongame species in 14 Midwestern states, declined significantly (24 to 96 percent) between the 1950s and late 1970s (31). However, because crop cultivation promotes the increase of certain "edge" species like rabbits. white-tailed deer, robins, and cowbirds, underlying changes in species abundance and diversity brought about by agricultural development may not be obvious to the casual observer.

Because they are inherently more complex than cropland and generally involve less intensive cultivation, rangeland regimes in the West and Southwest can be relatively more compatible with native habitat uses. However, technologies for maintaining native grasses on semiarid and arid rangelands are lacking, and the introduction of non-indigenous plant species to improve grazing conditions or to control pests has caused critical declines in animals, insects, and plants that are unique to these areas (77,95). Grazing in riparian areas, especially in the Southwest, California and the Northwest, has increased sedimentation in some streams, covering spawning sites, clogging fish gills, and elevating water temperature.

Since the 1970s, appreciation for the unique function of wetlands as wildlife habitat has grown. As a specialized form of surface water, wetlands provide seasonal or permanent habitats for one-third of the nation's endangered and threatened species and sustain 75 percent of commercially landed fish and shellfish (42,92). The

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The prairie pothole region of the Great Plains remains a unique example of natural wetland/grassland habitat in an intensive agricultural region. An important hub of the Central Flyway used by migratory birds, the pothole region is also the breeding ground for more than half of all ducks native to North America.

Prairie Pothole Region, about one-fourth of which lies in the Dakotas, produces 50 percent of North America's duck population (112). Prairie pothole ecosystems also provide habitat for mammals, such as deer, mink, and fox, and are thought to play a critical role in maintaining plant diversity (112). Wetland losses due to agricultural conversion have declined considerably since the 1950s, and an increasing number of farmers are exploring the potential for compatibility between cultivating crops and restoring wetlands on suitable parts of their fields.

The extent to which normal use of agricultural chemicals affects wildlife species is not fully understood, but a range of direct and indirect effects on terrestrial species have been documented (33). EPA estimated that in the 1980s, one to two million birds died every year from exposure to the pesticide carbofuran (113). The U.S. Fish and Wildlife Service (FWS) determined that nearly 20 percent of species that became endangered or threatened in 1988 had been adversely affected by pesticides (113). Pesticides can reduce insects that provide food for birds and other animals, an effect that is associated with declining populations of the bobwhite quail (3).

As noted previously, aquatic life can be harmed by nutrients carried in runoff to surface waters. Eutrophication reduces dissolved oxygen and may release toxins into the aquatic habitat. In addition, herbicides in the aquatic environment can diminish the food supply for fish and other herbivores. Chronic, low-level concentrations of both herbicides and insecticides in surface water have been linked to reproductive failure and developmental abnormalities in fish and other aquatic organisms (10,64). Some pesticides that become concentrated in animal tissue ("bioaccumulate") as they move through the food chain to predatory birds and mammals may have long-ranging and pervasive negative effects on both aquatic and terrestrial habitat quality, and particularly on sensitive species (10).

Changes in some farming practices and field patterns can reverse the decline of many species and enhance wildlife habitat both on and off the farm. Multi-cropping systems increase diversity of habitat structure and species richness (31,78). Field patterns that minimize fragmentation of habitat areas or that intentionally link habitat areas through landscape corridors can greatly benefit wildlife. Wetlands are being restored on farms in several states. Land set-asides, such as those created by the Conservation Reserve Program (CRP), can improve long-term grassland cover. Declining populations of pheasants, migratory waterfowl, and grassland birds have made dramatic reversals on lands (48,61). Changes in irrigation water use are also being used to enhance aquatic habitat (box 4-3).

Innovative applications of agricultural technologies may also make farming more compatible with wildlife habitats. In California, post-harvest flooding and cage-rolling of rice straw is providing seasonal wetlands for migratory waterbirds. This innovation is an alternative to rice straw burning, which will be banned by the year 2000 (27). Some farmers are exploring the relationship between various commodity crop mixes and bird habitats (111). Various techniques to reduce agrichemical use, create riparian buffers to keep runoff out of surface waters, and plant grassland edges alongside fields (to provide habitat) are being investigated. Such technologies, used in tandem with new land use patterns, point to cases in which it may be possible to enhance both agricultural productivity and wildlife habitat.

Soil Quality and Soil Erosion

The rate of soil erosion is often used as a benchmark of soil quality, but it is only one indicator. The term "soil quality" covers physical, chemical, and biological elements, including microbial density, organic content, electrical conductivity, acidity, structure, chemical contamination, and infiltration rate, in addition to smell, color, and texture (26). Soil quality can also be assessed in terms of the soil's capacity to perform productive and environmental roles. In this regard, there are three key indicators of soil quality:

- productive capacity (the capacity to promote the growth of plants);

BOX 4-3: California's Central Valley Improvement Project to Restore Habitat

In response to Increased pressure to safeguard the environment, the federal government and the California State Water Resources Board have taken actions in a prime agricultural area to protect water for fish and wildlife (126) Under the new federal law (P.L. 102-575), about 15 percent of the Bureau of Reclamation's Central Valley Project water normally available to agriculture is reserved for flow requirements for fish and wildlife propagation and restoration, During years of normal precipitation, this reservation level would not significantly affect agriculture However, in years of low precipitation, water available to farms would be reduced accordingly, In effect, the project's drought buffer goes to fish and wildlife rather than to farmers

The California State Water Resources Board actions were taken to improve water quality in the Sacramento-San Joaquin Delta Estuary They include measures to make more water available during fish migrations and fees on irrigation districts to finance wildlife habitat and urban conservation measures What are the possible implications for California's lucrative agricultural trade sector if the scheme is fully Implemented? According to a study by the U.S. International Trade Commission, agricultural production and exports wiIl not decrease significantly in the long term, but the composition of those exports wiIl change to include more crops such as fruits and vegetables, and/or crops that use less water (1 26) On December 15, 1995, the state of California and the federal government signed an agreement resolving the particular elements of how to Implement the new law—a complicated process because multiple environmental statutes and several political jurisdictions were involved.

The final details will be worked out by state and local officials, but it appears that farmers will face the greatest annual costs, and cities wiIl have less water in dry years, while commercial and recreational Interests stand to gain (20) The process of reaching a consensus water quality plan involving multiple, fractious parties with large stakes at risk was considered a future model for such negotiations.

SOURCE: Office of Technology Assessment, 1995

- ecosystemic function (the ability to regulate infiltration and surface movement of water within a watershed); and
- environmental function (the ability to act as a buffer for water and air quality by sequestering and degrading carbon, agricultural chemicals, and organic wastes).

Despite the intuitive appeal of the soil quality concept, it remains immature and therefore comprehensive data or assessments are not at hand (64).

Soil erosion is only one element of the broader soil quality concept, but it is the only element with extensive data. Despite some questions about the reliability of historical data,[15] national estimates reveal that aggregate cropland erosion has declined significantly over the past four decades. The average water erosion rate has fallen approximately 50 percent, from six to about three tons per acre, and the wind erosion rate has declined about one-third, from about nine to six tons per acre between 1945 and 1992 (50). Between 1982 and 1992, National Resources Inventory (NRI) data show decreases in water and wind erosion of 22 percent on cultivated land (71). Reduced erosion on all U.S. cropland saved nearly one billion tons of soil in the past decade (25).

Marked differences in soil erosion are apparent when data are examined regionally. Between 1982 and 1992, erosion declined the most in the Northern Plains (31.7 percent), followed by the Mid-

[15]The accuracy of erosion control statistics is complicated by different sampling and measurement methods. Data are marginally more consistent than they were when the National Resources Inventory was instituted in 1977, but comparisons overtime should be made cautiously.

Soil quality depends on more than the rate of erosion. Color texture, organic content, electrical conductivity microbial populations, acidity porosity and concentration of toxic substances are some of the many other characteristics that determine the quality of soil.

west (21 percent), Southern Plains (14.8 percent), and the Mountain region (7.4 percent) (25). Water and wind erosion patterns varied within those regions, depending on which crops were planted. For instance, soil erosion due to water increased on all cultivated land in the Southern Plains, on soybean acreage in the Northern Plains, and on cotton acreage in the Mountain region. Soil erosion due to wind increased on wheat and soybean acreage in the Midwest, and on wheat acreage in the Mountain region (25). Furthermore, the 1992 NRI data reveal substantial variation in soil erosion trends within regions (50).

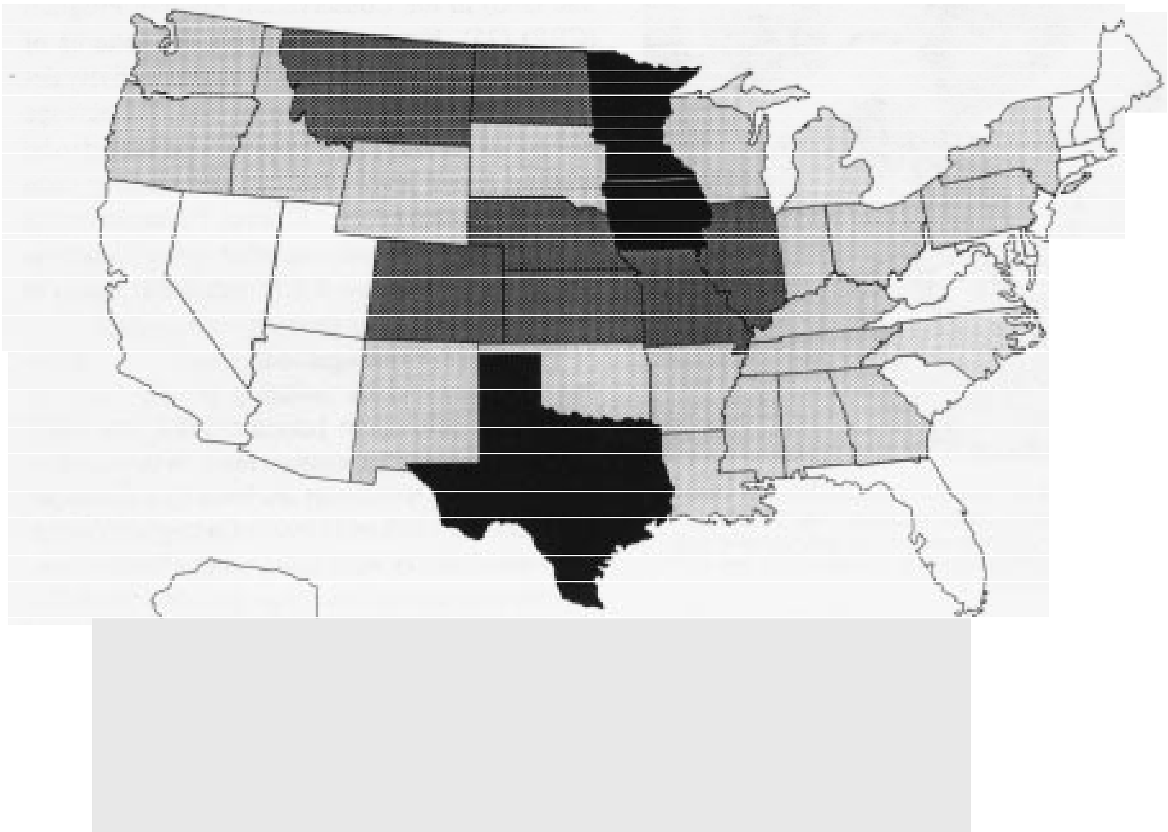
Even though these statistics suggest overall improvement, they do not describe remaining erosion problems, and do not distinguish the influence of management from lands of varying erodibility moving into and out of production (71). Indeed, the most recent aggregate declines in erosion may heavily reflect the idling of acres (more than one-third of the country's most erodible land) in the Conservation Reserve Program (CRP) (25). Figure 4-3 portrays the patterns of cropland vulnerable to long-term productivity declines due to water and wind erosion. The acreage categories include those croplands estimated to be eroding above levels that can sustain long-term productivity, termed the "T" level, [16] plus the highly erodible lands currently enrolled in the Conservation Reserve Program (CRP) that could return to crop production after their contracts expire.

The effect of management changes on erosion can be estimated by isolating acreage that remained in cultivation between 1982 and 1992. NRI data suggest that erosion rates on land continuously planted with crops declined by 1.6 tons per acre between 1982 and 1992, a finding which suggests that farmers were using more effective conservation practices over that decade (25,64,71).

A shift in technology away from "clean-tilling" and toward crop residue management has been a key factor in reducing both soil and water runoff from fields. While reduced tillage may not yield environmental benefits under all conditions, studies indicate that it generally improves soil and surface water quality Its effects on groundwater and wildlife are not fully understood.

[16] The tolerance, or "T," level is set by the SCS and approximates the maximum target erosion level above which unacceptable on-site degradation is believed to occur. The accuracy and usefulness of T levels is somewhat controversial.

FIGURE 4-3: U.S. Cropland Vulnerable to Long-term Productivity Declines Due to Erosion



The severity of soil erosion depends on a combination of inherent soil characteristics, climatic factors, and land management. The number of acres now eroding over the level that leads to long-term productivity losses, the "T" level, plus the number of CRP acres with the potential to erode at a rate over T if returned to crop production, comprisas the total vulnerability of U.S. cropland to erosion-mduced declines in productivity

SOURCE: OTA, 1995. Compiled from data provided by Tim Osborn, Agricultural Economist, USDA/ERS, personal communication, 1995; J. Jeffrey Goebal, "Estimated Average Annual Sheet and Rill and Wind Erosion In Relation to T-Value of 1992 Cropland," US. Department of Agriculture, Natural Resources Conservation Service, 1995.

Although farmers used conservation tillage more during the past decade,[17] they may also have engaged in more contouring and strip cropping, constructed terraces and grass waterways to control erosion, and shifted their crop rotations.

Rangelands pose special soil quality problems. Box (8) suggests that rangeland productivity on private and public lands has generally improved since the Taylor Grazing Act of 1934. In 1982, more than 33 percent of rangelands were judged to

[17] Box 2-1 of Chapter 2 defines conservation tillage. Dicks (25) notes that between 1983 and 1991, the acreage under no-till management increased from 8.6 million (2 percent of the total crop base) to 24 million; however, no correlation has been made between the option of no-till and highly erodible land. He suggests that although conservation tillage by definition should produce conservation gains, conservation is likely not the most important inducement for adoption. Pierce and Nowak (71) conclude from analysis of 1992 NRI data that conaervation tillage acreage declined between 1982 and 1992, and that adoption is not highly correlated with the most highly erodible acres. These findings conflict with official USDA estimates reported in chapter 2, but an explanation for the conflict is lacking.

be in "excellent or good condition" (22). However, the 1982 and 1987 NRI showed that 19 percent of acreage (76 million acres) eroded over the "T" level (22,109). The 1992 NRI shows that rangelands suffer from higher wind erosion rates than land used for other purposes, and that few improvements have been observed since 1982 (25). Ruyle (77) notes that rangelands are inherently vulnerable to erosion, and explains that poor management can exacerbate the problem.

Erosion indicators are mostly measures of soil quantity and cannot convey comprehensive soil quality conditions. But historical trends in erosion may suggest the changes in overall soil management which, in turn, influence soil quality (64). The level of correlation between erosion trends and soil quality remains unclear. Moreover, conservation practices designed to reduce erosion may or may not improve overall environmental quality. Conservation tillage is a prominent example. Conservation tillage changes the biological, physical, and chemical properties of soil, but the balance between benefits and risks is not totally predictable. In field studies, conservation tillage has been linked to beneficial sequestering of carbon in the upper layer of soil, which helps prevent loss of ozone-depleting gases; to improving wildlife habitat by reducing mechanical disturbance of ground nesting sites; to retention of bulk organic matter, which aids water retention and infiltration as well as promotes microbial life; and to reduced erosion and water runoff. The long-term environmental effects of conservation tillage are still under investigation. Some conclude it will ". . . contribute to a net decrease in total potential water quality degradation (104)." However, there is conflicting evidence on the effects of conservation tillage on groundwater quality (28,40). Perhaps the most important result of studies to date is that the benefits associated with conservation tillage have not occurred universally. As with all technologies, its applicability varies depending on site-specific hydrogeological and soil characteristics, cultivation practices, and the management skills of the farm producer. Several initiatives are under way to develop techniques for evaluation that may allow farmers to directly gauge the impacts of their farming practices on soil quality.

Strengthening Agroenvironmental Science

There is a vast difference between the percentages of USDA research monies devoted to increasing agricultural production (historically more than 60 percent) and addressing environmental issues related to agriculture (historically about 10 percent). This relative lack of federal support for agroenvironmental research will limit the quality of information available to university scientists, extension agents, federal and state program managers, agribusiness, farm consultants, farmers, and environmentalists. Knowledge of unique regional agricultural, socioeconomic, and environmental characteristics is also critical to devising effective policies—both in terms of production and environmental enhancement—in agricultural regions. Incomplete information may lead to agroenvironmental policies that are poorly targeted and unnecessarily costly to the private and public sectors.

Expanded monitoring alone is unlikely to fill the gaps in knowledge, because the nature of many agricultural interactions with environmental resources remains poorly understood. (See box 4-4.) Indeed, more monitoring without better science to guide the monitoring will likely be inefficient. As noted above, the significance of many agrichemicals for water or soil quality and, consequently, for biological health, is still under investigation, and the significance of habitat modification and destruction brought about by intensive cultivation remains a topic of debate. The role of agriculture in the functioning of specialized or rare ecosystems, such as wetlands, has not been extensively examined. The need, then, is not just for more research, but for more sophisticated agroenvironmental science. Three areas in particular (derived from the analyses of this chapter and corroborated by recommendations of the National Academy of Sciences (64,65) must be explored: the functioning of environmental and farming systems and their interrelationships, the spatial environmental conditions that flow from these rela-

BOX 4-4: Who Answers Key Scientific Questions on Water Quality?

Water resources—surface water and groundwater—have been studied for decades, and yet national trends in the condition of this important resource have never been evaluated systematically. At the state level, water quality assessments are performed every two years (as stipulated by the Clean Water Act (CWA), but they do not represent a coherent strategy to monitor the conditions and implications of national water quality. As a result of current research and monitoring, questions remain about the extent of agricultural contamination and about its significance for aquatic habitat, for the availability of safe drinking water, for agricultural production, and for recreation. As noted in this chapter, water safety standards adopted by the EPA reflect that the implications of poor water quality remain only partially known. What don't we know about water quality? Why don't we know? Who should be asking researchers to fill in the missing answers?

Researchers have found that agricultural herbicides, insecticides, and nitrogen fertilizer residues are prevalent in rivers, streams, lakes and reservoirs in regions where they are used. Furthermore, some of these agricultural chemicals, notably herbicides, have been found to degrade more slowly in water than they do in soil. This stability in water, combined with the natural movement and linkages among surface waters and between surface water and groundwater, result in the capability of agricultural pollutants to migrate great distances, affecting water quality hundreds of miles from their point of origin. Such findings raise a number of questions for agricultural producers, consumers and policymakers:

- How long do agrichemicals remain in regional surface waters and at what *concentrations?*
- What conditions affect the speed at which these chemicals degrade? Can technology help?
- How far can agrichemicals go in water systems? Are they ultimately stored, degraded, or transported indefinitely?
- Do commonly found levels of agrichemicals affect the ability of water to support plants and wildlife?
- How many people, nationwide, are exposed to agrichemicals in excess of safe drinking water levels?
- What effects on human health can emerge from regularly swimming in or drinking low-dosage mixtures of many herbicides, Insecticides, and fertilizer residues?

While some of these questions have been asked in some studies, a focus on the links between water systems, conditions, and implications has not been emphasized in most large-scale studies of water quality. A research agenda that focuses on conditions without supplying a context of understanding for environmental or health implications makes it very difficult for such research to be meaningful in the policy process. By the same token, a policy agenda that remains disengaged from the research agenda Increases the risks that relevant questions will remain unanswered.

The best example of the inadequacies of current research and monitoring of the nation's water resources may be state water quality reports submitted to EPA under section 305(b) of the CWA. These data form the basis of EPA's biannual Water Quality Inventory report submitted to Congress, they are frequently cited in research reports about national water quality; and they remain the most comprehensive national monitoring effort to date. Because of the way studies are conducted, however, they may not accurately reflect national trends. For instance, 305(b) evaluations only include a fraction of riverways, lakes, estuaries and coastlines (see table 4-1), but the evaluations performed need not represent a scientific sample. From year to year, and state to state, evaluations are not required to follow consistent protocols or result in trend information. Thus, the CWA process has produced 20 years of data that add up to an incomplete and even incompatible set of answers.

SOURCE Off Ice of Technology Assessment, 1995 tionships, and the dynamic implications of these conditions for environmental health.

Analyses have underscored the importance of understanding how agricultural systems interact with environmental systems (64,93). An agroecosystem approach parallels a shift in emphasis from on-farm, on-site environmental concerns to linking on-site practices with off-site conditions and, indeed, with the total agroenvironmental system. The fundamental research questions are not whether interaction between agricultural and environmental systems occurs, but how it occurs.

The geographical diversity of environmental conditions and regional variations in agricultural production make a better understanding of geospatial relationships crucial. Inadequate spatial information precludes better targeting of program responses. For example, as Mueller et al. (59) and Smith et al. (83) illustrate in their research, effective targeting of water quality policies would entail: a good understanding of regional vulnerability to agrichemical leaching and sediment erosion, and monitoring data that describe actual water quality conditions.

A critical dimension of farm and environmental systems is the way they interact over time. These long-term dynamics provide a link to understanding long-term implications for agroenvironmental health. The stress, response, adaptation, and recovery or extinction processes that are integral to ecological resources take place often over long periods of time, as mentioned with groundwater pollution and rehabilitation.

Many traditional soil and water conservation programs have been implemented over past decades without precise understanding of these systems, conditions, and environmental implications. However, as population and production pressures places more stress on environmental resources, it is not at all clear that general guidance can suffice. The diffuse and diverse nature of agricultural runoff, which has impeded progress on nonpoint water pollution for 20 years, is unlikely to be resolved without much more sophisticated understanding of the problem than currently exists. In particular, such problems require more sophisticated science than past efforts to help develop programs that meet environmental goals while maintaining farm profits and U.S. competitiveness in international agricultural markets.

FEDERAL CONSERVATION AND ENVIRONMENTAL PROGRAMS

Since the early 1970s, public pressure has progressively expanded the mandate of both traditional farm legislation and general environmental laws to go beyond boosting agricultural productivity to promoting environmental health. As programs to manage the environmental side effects of agricultural practices have expanded, traditional soil and water conservation programs have declined, relatively speaking. These developments reflected a growing recognition of farmings' effects on environmental quality not captured by market prices, and rising concern about the long-term sustainability of production (17).

Depending on the definition of a program, there are at least 35 separate USDA programs for conservation and environmental purposes, including about 12 for research and data gathering (appendix 4-2). At least another 20 are administered by other agencies, including EPA, the Department of Interior, the U.S. Army Corps of Engineers, and the National Oceanic and Atmospheric Agency (appendix 4-2). Estimated public expenditures for all programs are $6.5 billion for 1995 (104).

The large number of programs raises questions of overlap, conflict, coordination, and mixed incentives to farmers and ranchers, but a comprehensive program analysis has not been conducted, even within USDA. Opportunities for reconfiguring and targeting the programs—to clarify the signals and incentives they give to farmers, agribusiness, legislators, and environmentalists and to save budget expense—may exist. Possible policy options for restructuring program approaches are explored in the last chapter. Diagnosing the nature of private incentives to adopt agroenvironmental practices is a key principle to be used in any restructuring (5).

Three general types of federal policy approaches to soil conservation, water quality, and wildlife habitat issues are discussed in this section. Voluntary efforts aided by education, technical assistance, and subsidy programs have been the predominant approach to environmental management in agriculture. As illustrations, the dominant soil conservation programs are examined in detail. Environmental compliance schemes, which are integrally linked to farm commodity programs and supply programs, are discussed next, followed by an assessment of regulatory approaches. The objective of the assessment is to review the performance of the three program approaches and identify strengths and weaknesses for application to agriculture's broadening environmental agenda. In the chapter's final section, we discuss the potential of technology research and development aimed specifically at enhancing agriculture's environmental performance while simultaneously maintaining profitability. These "complementary technologies" have not received program emphasis, but hold the potential to bring private incentives into closer correspondence with public environmental objectives.

Voluntary Education, Technical Assistance, and Subsidy Programs

A multitude of past and present USDA conservation and environmental programs are comprised of either voluntary education, technical assistance, and/or subsidy (VETAS) elements. These kinds of programs have historically received more funding, and have a broader scope, than other kinds of conservation and environmental programs.[18] Education and technical assistance and subsidies for conservation practice cost-sharing or for land rental and easement payments have often been operated together. Thus they are examined as one category here. In situations where conservation-oriented technologies do not offer cost savings or other private benefits, education and technical assistance are likely to be ineffective without subsidies.

Estimated annual expenditures for USDA conservation and environmental programs total just under $3.6 billion for 1994, although that figure is projected to fall to about $3.1 billion in 1995 (appendix 4-3). With the primary exception of technical assistance and administration for compliance schemes detailed in the 1985 farm bill, those monies fund VETAS programs. More than 50 percent, almost $1.8 billion of the total, will pay for land that is set aside in 1995 under the CRP, plus the Water Bank and Wetland Reserve programs. Most of these land "rentals" by the government are scheduled to end sometime between 1996 and 2005. The largest share of the remaining $1 billion will pay for technical assistance, extension services, and administration, followed by public works projects such as emergency watershed protection, which helps flood recovery efforts. Less than $100 million is slated to install cost-sharing practices under the Agricultural Con-

[18] The Natural Resources Conservation Service (NRCS), formerly the Soil Conservation Service (SCS), provides farmers with education and technical assistance. Typical education/assistance efforts include laying out erosion control practices such as terraces, and providing information about conservation crop rotations, tillage options, and wildlife habitat. The Extension Service also provides conservation education and technical assistance, sometimes in cooperation with the NRCS and sometimes separately, depending on the state and the project.

Several programs distribute subsidies. The Agricultural Conservation Program (ACP), begun in the 1930s and now operated under the Consolidated Farm Service Agency (CFSA), provides financial assistance in the form of cost-sharing to implement conservation practices. For example, farmers are given a share of the expense of installing terraces (usually 50 percent or more) subject to CFSA eligibility requirements, available funding, technical approval by NRCS, and approval by a local conservation board. Annual ACP payments are limited to $3,500 per farm, which can effectively rule out large-scale projects in any year. Other programs using conservation practice cost-sharing monies include the Great Plains Conservation Program, Emergency Conservation Program, CRP, Wetland Reserve Program (WRP), and the Colorado River Salinity Control Program.

In addition to cost-sharing subsidies, rental and easement payments remove land from production temporarily or attach use restrictions for conservation purposes. The CRP, approved in the 1985 farm bill, has set aside 36.4 million acres to control erosion and for other environmental purposes. The maximum annual rental bill so far has been $1.8 billion. The WRP, though much smaller, protects wetlands through rental and easement payments. Also, the Water Bank Program has rented land near water bodies for habitat and other purposes.

servation Program (ACP) in 1995—a drop of nearly 50 percent from levels during the past decade.

Appendix 4-3 presents the expenditures for each USDA conservation-related program from 1983 to 1995. Although there are at least 35 programs, a large number of them have relatively low funding—a few large programs account for the majority of expenditures. Many programs were authorized at higher levels, but actually received little or no funding. A comprehensive review of all the ETAS programs has not been conducted and is not possible here. Rather, the discussion focuses on the largest program component—soil conservation—and the largest single program within soil conservation—the CRP. These soil conservation programs, especially during the last decade, have also incorporated water quality objectives and affected wildlife habitat.

Soil Conservation Programs

Federal soil conservation programs began in the Great Depression, when farmers faced the combined woes of a collapsing economy, drought, and massive erosion on their land. One program authorized work on soil erosion control as a means to reduce unemployment (72). To overcome legal obstacles to paying income support to farmers for restricting production, soil conservation programs and farm income payments were joined. Both programs have endured. "Despite the 'New Deal' intent of providing emergency relief, the farm commodity programs and the soil conservation programs have continued with few modifications to the present" (4).

Several evaluations have found that soil conservation program expenditures could be redirected and result in greater erosion control (100).[19] In a 1974 study, USDA estimated that cost-sharing used for conservation practices in the Great Plains Conservation Program (GPCP) could help to further reduce wind and water erosion if those subsidies were used for more cost-effective erosion control practices (107). Another USDA study found that lands with erosion rates very near the so-called T level received nearly half of ACP financial assistance (98). By implication, that half of the available program subsidies was not applied to land with severe erosion problems.

Evaluations by the General Accounting Office (GAO) of the technical and financial assistance programs also concluded that improved targeting of program resources could lead to better control of erosion (88,89). In a later evaluation, the SCS found that 40 percent of its technical assistance was applied to lands eroding under the T level (108). In the same study, the SCS determined that the effectiveness of technical assistance was lower in areas targeted for erosion control, which implied that more intensive effort was needed to accomplish erosion goals in those areas.

The 1977 GAO study also found that farms participating in the conservation programs did not achieve erosion rates significantly lower than those on farms that did not participate. A county-level study similarly found that farmers with SCS conservation plans did not achieve significantly greater erosion control than farmers without such plans (29).

[19]In the midst of these evaluations (1977), Congress passed the Soil and Water Resources Conservation Act (RCA), which directed USDA to collect comprehensive resource data to assess the nature of conservation problems on private lands, evaluate conservation programs, and construct a National Conservation Plan (NCP). The RCA established the National Resources Inventory (NRI), conducted in 1982, 1987, and 1992, which provides critical data for program evaluations and monitoring resource trends (110).

Two principal findings emerge from these and other evaluations. First, soil conservation education, technical assistance, and practice cost-sharing have not been focused on the most severe erosion problems or on delivering the most cost-effective practices. Second, voluntary education and technical assistance alone have not led to significant conservation benefits (60). By their nature, these information programs are most effective if they make operators aware of practices and technologies that offer cost savings or increased returns while simultaneously reducing erosion—the complementary or "win-win" situations. These findings also likely apply to VETAS approaches to water quality and wildlife problems where insufficient targeting has occurred and farmers face major practice costs.

Evaluations also suggest that cost sharing or subsidies are likely the most important determinants in inducing farmers to adopt certain agroenvironmental practices (29,34). If conservation benefits are to be realized in cases where farmers do not have private economic incentives, either subsidies or some form of regulation must be employed. The other, longer term alternative is to develop profitable technologies that can be substituted for currently unprofitable technologies.

In a comprehensive assessment following the studies of the late 1970s and early 1980s, the USDA's Economic Research Service (ERS) performed the first nationwide benefit-cost assessment of the ACP, Conservation Technical Assistance (CTA), and the GPCP (100). Estimated erosion control benefits and reduced offsite damages were compared with costs. A key finding: on average, the estimated benefits exceeded costs only for land eroding at a rate of more than 15 tons per acre. Given that the programs were devoting most of their resources to lands eroding at a rate of less than 10 tons per acre, and nearly half of program resources went to lands eroding at a rate of less than five tons per acre, the study concluded that significant public benefits could be secured by redirecting program resources to the lands that were eroding the most. ERS made five major recommendations for program reform, which have anticipated policy developments to a substantial degree:

1. target erosion control programs,
2. include offsite damage reduction as an erosion control benefit,
3. base conservation incentives on public benefit,
4. estimate erosion control benefits and costs, and
5. improve research and data for program evaluation.

On the heels of these evaluations, and with the benefits of 1977 and 1982 national surveys of natural resource conditions and a National Conservation Plan, the 1985 farm bill authorized three major erosion control programs aimed directly at highly erodible lands. The CRP, a massive effort to retire highly erodible or other environmentally vulnerable land through voluntary 10- or 15-year contracts, was the principal program.

Conservation Reserve Program

Although the achievements of the 1985 farm bill's conservation measures cannot be documented until full implementation and evaluation of all effects, several studies have assessed their preliminary performances. The CRP has been the subject of intense scrutiny because it represents the largest expenditure of conservation funds, nearly $20 billion, and affects nearly 10 percent of U.S. cropland. Preliminary evaluations have arrived at two basic conclusions: the program appears to generate net economic benefits, mostly from environmental improvements, but net governmental costs are positive, implying a drain on the federal treasury.[20] At this writing, a final economic judgment cannot be made, because it is still not possible to measure with precision the full physical and biological effects and the dollar value of environmental benefits.

Regardless of such difficulties, one conclusion of CRP evaluations has been strong and virtually unanimous: the early benefit-cost ratio could have been much higher with better environmental targeting and more effective controls on the payments made to farmers for "renting" their land (67,74). As a result of the 1990 farm bill, USDA changed CRP enrollment procedures to address environmental priorities specified in the farm bill legislation. The changes included a rudimentary targeting scheme as well as a provision to hold rental payments at or below market levels (67).

A regional study of the land enrollment patterns in California, Idaho, Oregon, and Washington shows that the 1990 CRP was more successful in concentrating enrollment of land in highly erodible counties than the 1985 version (129). On average, this change should produce more environmental benefits, but detailed assessments of enrollment patterns within the counties are also necessary. Concern now centers on what will happen to CRP lands after the government stops renting them. Experience with the Soil Bank, an earlier major long-term set-aside program in operation from 1958 to 1972, shows that most (probably two-thirds or more) of the idled land will again be used for producing crops and could trigger another round of environmental problems—which in turn would increase the need for remedial programs.

Conservation and Environmental Compliance Programs

The compliance provisions of the 1985 farm bill represent a departure from traditional agricultural conservation and environmental programs. They were, in fact, considered landmark legislation, because they made farmers adhere to conservation standards in return for their agricultural program benefits, including commodity deficiency payments. The compliance mechanisms were meant to help control erosion on existing cropland (conservation compliance); they were also intended to regulate farmers' efforts to turn grasslands into cropland (Sodbuster), and convert wetlands to cropland (Swampbuster). The Sodbuster and Swampbuster provisions were a tacit recognition

[20]The first comprehensive assessment, conducted midway through CRP enrollment and before the 1988 drought lowered crop surpluses, estimated the potential supply control, food cost, environmental benefits, and other effects of a 45-million acre CRP, as authorized in the 1985 farm bill (128). The preliminary investigation concluded that the CRP would likely produce net economic benefits in the range of about $3.5 billion to $11 billion. However, the study methodology and data were admittedly incomplete concerning such subjects as the effects on consumer food price increases, interaction between government supply control instruments, some environmental benefits, and the likely pattern of enrollment after midway signup. Although its net economic benefits were estimated to be positive, the CRP was projected to cost the federal budget more than it saved in reduced supply control expenses—a range of $2 billion to $6.6 billion over the program's life.

To reflect new developments, an updated CRP assessment was conducted after the effects of the 1988 drought had been felt and more lands had been enrolled in the CRP (102). Although the studies are not strictly comparable, because the methodologies used to estimate production, supply control, and price effects differed, the basic conclusions remained the same. The CRP was estimated to produce net economic benefits in the range of $4.2 billion to $9 billion, but the likely net government cost rose to $6.6 billion to $9.3 billion. Notably, from a net economic perspective, increased farm profits and higher food costs nearly offset each other, and the environmental and timber supply benefits accounted for most of the positive margin. Again, the methodologies for estimating the value of environmental benefits are crude, relying on estimates based on large area projections rather than specific documented effects.

If the projected soil erosion reductions or presumed linkages to environmental resources are not accurate, then the estimated environmental benefits, such as water quality, will not be what they are expected to be. Also, recent survey results indicate that most enrolled acres will likely be used for agriculture again if CRP payments end, and so the expected benefits may be brief (85). Ex post studies of environmental changes resulting from the CRP should be conducted to check the accuracy of estimated effects. For example, a study of changes in stream water quality conditions in southern Illinois, where large amounts of CRP land were enrolled, did not reveal improvements had occurred as anticipated (23). The geographic pattern and timing of benefit streams do affect the program's economic bottom line. Similar assessments should be conducted on timber and wildlife benefits, which account for between about $5 billion and $6 billion of the net benefits. The final benefits and costs of the CRP remain unclear until those assessments are completed.

on the part of legislators that, as traditionally administered, federal commodity program payments likely gave farmers economic incentives for converting grasslands and wetlands to crop production (42,52).

Not surprisingly, the measures have been the subject of controversy since their inception. Farmers worried that meeting the originally proposed conservation standards would cost too much and force them out of the commodity programs, thus denying them price and income supports. The SCS ameliorated that concern by developing the concept of alternative conservation systems (ACSs), which were intended to allow farmers more flexibility in attaining the compliance standards (99). Widespread adoption of conservation tillage systems by many farmers (primarily to save fuel, labor, and machinery costs) often satisfies conservation compliance requirements and appears to have minimized potential economic distress for the overall sector. However, an internal investigation of the application of the ACSs suggests they were used without clear and consistent rationales and have not been documented to achieve compliance erosion control standards (106).

A mid-term external investigation of the conservation compliance measures suggested that the programs were not being implemented in a uniform manner to achieve the standards defined in program regulations (84). Generally, near one-half of the cases in sampled counties did not satisfy the requirements of implementing regulations. The same external field-level evaluation of the Swampbuster provisions indicated that the sanctions did slow the conversion of wetlands to cropland, but were not being uniformly enforced (84). Another evaluation conducted by the USDA's Office of Inspector General, based on a 1991 audit, found a similar rate of noncompliance (105). (The sample size was, however, extremely small.) In contrast, SCS internal status reviews of progress have indicated a small percentage of producers are not in compliance with their plan requirements (103). There is no official explanation available for the different findings of the external reviews and internal status reports. Questions about sampling, different performance criteria and standards, and measurement of plan implementation require answers. Congressional oversight hearings have been held on these issues.

These mixed evaluations are not entirely unexpected. Compliance measures placed SCS, now the Natural Resources Conservation Service (NRCS), in a quasi-regulatory role, which is in marked contrast to its traditional role of serving clients mostly on a voluntary and willing-cooperator basis. Thus, "cultural" issues have probably retarded effectiveness (91). Also, the novelty and sheer size of the compliance task stretched NRCS personnel and institutions far beyond their traditional resources and roles. Some unevenness in enforcement from region to region could therefore be expected. Whatever the relative roles of these constraints, conservation compliance measures are still inadequately enforced (91).

Regardless of administrative efficacy in implementing them, compliance mechanisms have basic shortcomings as agroenvironmental measures. First, agricultural program payments, i.e., the incentives for achieving compliance, may not be correlated with priority environmental problems (43). Moreover, compliance schemes linked to agricultural program payments lose their effectiveness when they are often needed most. When commodity prices rise and deficiency payments decline, the penalty for not complying with conservation measures also falls. Further, in such a situation, production pressure expands and increases farmers' incentives to farm more intensively or bring new land into production. Finally, as the federal budget shrinks and agricultural program payments fall, the relative scope and effectiveness of compliance programs declines. The last two limitations are expected to become more evident over the next decade, as agricultural trade is liberalized and pressure to cut the federal budget grows.

Agroenvironmental Regulation

Although precise figures do not exist, agriculture appears to be affected less by environmental regulation than other industries. The reasons include agriculture's long history of voluntary subsidy approaches, and its basic structure: diffuse, diverse, and numerous (nearly 2 million) operations that generate mostly nonpoint pollution are difficult to identify, monitor, and regulate. However, when environmental problems are concentrated in certain inputs, subsectors, or local areas (and so can be monitored and measured) and minimum environmental standards have been established, regulatory approaches have been applied. Almost by definition, the regulatory approach is best-suited to cases in which private incentives and public environmental goals are quite disparate.

Pesticides

Pesticide registration is the largest regulatory effort affecting U.S. agriculture. The government began regulating chemicals used in U.S. agriculture at the beginning of the 20th century (75). The goal at that time was to protect farmers from commercial frauds. The history and performance record of the effort delineates the challenges of regulating a diverse and diffuse industry in the face of scientific uncertainty.

The registration and reregistration of products is a complicated and lengthy process that does not appear to satisfy consumers, environmental groups, or industry groups. It can take four to eight years for a product to undergo an elaborate scientific review. At this writing, more than 3,000 chemicals are classified as pesticides under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)—a listing that includes active pesticide ingredients and more than 2,000 inert ingredients that are not subject to reviews (96). Perhaps because the review process can be interminable, the vast majority of 880 active pesticide ingredients have not been fully cleared by EPA review and remain effectively unregulated. Further, EPA's efforts apparently have had relatively little effect on the total use or sale of agricultural pesticides (69) Critics allege that severe resource constraints within EPA have hampered its ability to make effective registration decisions. However, evidence suggests that active participation by either environmental or pesticide industry interest groups in the registration process does significantly affect EPA's registration decisions (16).

Pesticide use in the United States grew steadily from 1950 to 1984, but leveled off and started to fall in the mid-1980s (12; table 2-7). On the whole, as fewer acres have been cultivated, smaller amounts of pesticides have been used. The modest decline in the mid-1980s may also reflect the cumulative effects of rising pesticide prices, regulation, and the introduction of more potent compounds. Restrictions on the use of products, posted on legally binding labels, define permissible methods of application, maximum dosages, preharvest intervals, and use restrictions near water.

The threat that a new compound will not be approved by EPA has increased the profit potential of more environmentally benign pesticides, and has encouraged the introduction of a variety of new products (69). Accordingly, although overall pesticide application rates have changed only slightly, the composition of products may have changed much more. Unfortunately, the lengthy and costly EPA review process has probably restricted the rate at which the new, more environmentally benign products appear (62). Efficient regulation can stimulate innovative technologies that reduce the cost of meeting environmental performance standards.

Inevitable uncertainty pervades any evaluation of pesticide policy and programs. Critical assessments seem unending, and there are few definitive conclusions that all sides can endorse. The costs of restricting or banning a pesticide can be reliably estimated in the short run, but long-term estimates are more difficult to make, primarily because it is unclear what problems new products might pose and what kinds of management practices will be used to respond to regulatory action.

Generally, the farm sector as a whole has not suffered economically from pesticide regulation. Consumer prices of products produced with banned or restricted chemicals have risen slightly instead (69). Individually, however, some farmers may lose—or gain—from pesticide regulation. Farmers who have traditionally depended on restricted compounds may grow and sell less, for example, while farmers who have not used such compounds can benefit from the price rises resulting from lower yields and less supply. Farmers who grow crops on which relatively limited amounts of pesticides are used, termed "minor use" crops, such as vegetables, fruits, nuts, and ornamental crops may be particularly disadvantaged. The lack of broad markets that, say, corn and soybeans have, means the cancellation of the registration of compounds for minor used crops can cause significant losses. In effect, because "minor use" compounds have what is considered to be a relatively small market, it is not always profitable to reregister or develop substitutes for canceled compounds.[21] In this context, it is interesting to note that crops requiring "minor use" pesticides may account for fully 45 percent of total U.S. agricultural output and $5 billion in exports (127).

Regulation of individual compounds, whether they are used for soybeans or tomatoes, is not likely to cause severe economic harm when good substitutes are available. However, eliminating a whole class of chemicals without apparent substitutes could cause serious economic hardship in the short run (68). Consequently, the sequence of regulatory decisions, substitutability among chemicals, and the availability of nonchemical alternatives to pesticides are extremely important. The potential risks of using a pesticide must be weighed against costs and the likelihood of developing a substitute to ascertain the magnitude of both short-run and long-run effects.

Even though it is possible to estimate regulatory costs, current science and data usually cannot measure regulatory benefits, or the costs of inappropriate pesticide use. Pesticide-laden runoff that contaminates streams, rivers, and lakes, as well as pesticide residues that leach into groundwater or remain on foods, can damage the environment and have been associated with cancer, developmental impairments, and reproductive problems in humans. Yet the precise nature of the links between pesticides and the damage they cause is poorly understood. Long-term epidemiological (human health) information on the effects of pesticides individually, and in combination with other chemicals or environmental stresses, is lacking. Also lacking is long-term information on how pesticides, individually and in combination with other chemicals and stresses, affect environmental systems. As a result, EPA reviews must often use incomplete and surrogate data to infer risks to humans and the environment from pesticides. Many existing pesticides are being used while tests on them are being completed.

Two important developments in pesticide policy occurred in 1993 (53). A National Academy of Sciences panel on pesticides in the diets of infants and children recommended moving to a health-based standard with careful consideration of children's exposure, and additional testing of pesticides for developmental toxicity (63). The panel noted that because of their weight and diet, children may be at risk of developmental effects from pesticide residues—and so pesticide risk assessments should differentiate between children and adults. In addition, the Clinton administration issued a new pesticide proposal for a unified health-based negligible risk standard for fresh and processed food; a quicker review process, during which registrants must prove that their products are safe or lose approval; special provisions for

[21] EPA has recently been trying to improve minor use registrations. Based on national surveys, the reregistration of about 1,000 minor use pesticides will not be pursued by manufacturers and another 2,600 new pesticides will be needed for minor uses by 1997—creating a need for up to 3,600 minor use products very shortly. To retain important minor use compounds, EPA is: 1) working closely with USDA and an interregional research group that facilitates minor use pesticide research, 2) granting waivers for low volume/minor use data where feasible, 3) moving to revise its crop groupings for residue testing to encourage minor use registrations, 4) encouraging third-party registrations, 5) providing fee breaks and expedited processing, 6) coordinating with agricultural users and the pesticide industry, and 7) considering legislative changes (123).

"minor use" registration and reregistration; and programs to encourage integrated pest management (53,122). These actions, some requiring congressional action, have yet to be approved. Whether they will mark a fundamental policy change for USDA—from primary emphasis on expanding food production by using pesticides to more emphasis on the possible health and environmental risks of pesticides—remains an open question.

Confined Animal Facility Water Pollution

Confined animal operations such as feedlots—some of which, depending on their size and nature, can generate large quantities of nutrients and bacteria—and be a "point" (readily identifiable) source of water pollution. Under the Clean Water Act, such operations fall under regulatory programs to control excessive effluents. States may require the use of specific technology or adherence to certain pollutant limits, as well as monitoring and reporting. EPA delegates the responsibility for implementing such water pollution control provisions, and for achieving designated water quality standards, to states. For its part, EPA is responsible for ensuring compliance with federal legislation.

A review of 10 state programs shows considerable variation in the scope and degree of point-source control programs for these animal facilities (46). Some technical assistance and cost-sharing programs were available in all states through the ACP to help producers comply with the federal standards. Half of the states also provided financial assistance. There are insufficient data to compare the net control costs of these facilities with those of industrial sectors subject to similar regulation. A study conducted for EPA suggested that the applicable regulations were unevenly and weakly enforced (15).

Coastal Zone Water Quality

Pollution of coastal zone waters became a subject of growing concern in the 1980s. As noted earlier in this chapter, coastal estuary water quality has been affected by nitrate and sediment from agricultural sources. Congress enacted a set of Coastal Zone Act Reauthorization Amendments (CZARA) in 1990, which laid out a comprehensive process for improving water quality. Programs aimed at coastal nonpoint source pollution were included. For agriculture, the act sets out specific ways to attain coastal zone water pollution reductions (121). First, farmers in coastal zones are required to adopt "economically achievable" management measures within three years from a list compiled by the federal or state/local agencies. (Presumably, farmers will be given education and technical assistance, but will not be eligible for substantial cost-sharing.) Plans for controlling agricultural and other sources must be submitted by June 1995. If states do not comply with the CZARA provisions, they may possibly forfeit coastal zone development grants and other related federal funds.

During the first stage, the CZARA process requires that certain technologies be implemented for all agricultural land in coastal zones by January 1999. Different technology lists apply to crop and livestock enterprises, for example. Following a two-year monitoring period (to January 2001), the states have three more years to implement additional measures where necessary to achieve specified water-quality standards. States must ensure the implementation of the measures through enforceable mechanisms, including regulation and innovative incentive schemes. Because the CZARA will be implemented over the next several years, its effects on agriculture remain uncertain—but potentially large. For example, almost all counties in Michigan may be affected by CZARA rules because of their proximity to the Great Lakes. One analysis estimates the annual costs of the proposed measures as typically less than $5,000 per farm for most farm sizes (44).

Wetlands Alterations

Section 404 of the 1972 Federal Water Pollution Control Act Amendments regulates actions taken to alter wetlands—including converting them to agricultural uses. Designed primarily to deal with wetlands adjacent to navigable waters, section

404 requires permits administered by the U.S. Army Corps of Engineers for the discharge of dredge and fill material. The role is one long associated with federal regulation of navigation. Most normal agricultural activities were explicitly excluded under section 404 provisions, until President Bush issued his "no net loss of wetlands" (NNL) policy dictum in 1987.

Attempts to implement that policy have necessitated more inclusive definitions of wetlands and have put more agricultural activities under the scrutiny of the section 404 review and permit process. Changes in levees, dikes, and drainage on farmland classified as wetland, and other agricultural wetland conversion, may require a section 404 permit. Under a 1994 agreement between the U.S. Army Corps of Engineers, the FWS, EPA, and the SCS, final rules exempt wetlands converted to cropland before December 1985 from section 404 requirements (131). Most recently, the NRCS was given responsibility for certain aspects of the section 404 program affecting agriculture.

The impact of section 404 wetland permit regulation has been in dispute. Some data imply that the overall restrictiveness has not been great: 67 percent of the applications made in 1990 were approved, 30 percent were withdrawn or processed as general permits, and only 3 percent were denied (42). The time and resources involved in seeking the permit, however, can be considerable. A study of a sample of permit records for 1992 concluded that it took the average applicant 373 days to get through the "individual permit" process, and that 93 percent of the individual permit applications exceeded the 60-day "evaluation-time" target (2). Such individual permit applications normally constitute about 10 to 15 percent of the section 404 permit applications and apply to controversial cases requiring lengthy evaluation. However, when the remaining 85 to 90 percent of general permits are added to individual permits, the average time for the process falls significantly (132). During 1994, the average time was 27 days for the total of more than 48,000 applications, and the time for individual permits fell to 127 days. In addition, the backlog of applications more than two years old fell from 202 to 81 between January 1994 and January 1995 (24). Despite these statistics and the trends they reveal, substantial uncertainty may still exist in farmers' minds about the section 404 process and consequences. In addition to regulatory reform to minimize unnecessary delays and costs, educational programs may be necessary to explain the permitting process and reduce uncertainty for those farmers likely to be little affected.

Endangered Species

The potential application of land use restrictions under the Endangered Species Act to restore threatened and endangered species causes significant worries among agricultural producers who rely on using the lands implicated in recovery plans. The restrictions may affect producers' pesticide use, for example; their plans to convert pasture to cropland; or other development options. Understandably, producers fear that public restrictions will impose costs without compensation.

To date, the impacts on agriculture appear to be isolated cases that may significantly decrease incomes in specific areas. Possible recovery plans invoked for threatened and endangered fish species in Western waters may be broader in scope. Moore and Weinberg (57) report that of the 93 fish species considered threatened or endangered, 67 are found only in Western rivers—a large number of which provide water for agricultural irrigation. Potential recovery plans for the Columbia River's sockeye salmon runs could restrict irrigation in a large section of the Pacific Northwest (Idaho-Washington-Oregon) and impose significant costs on specific agricultural subsectors, even though the costs to the overall regional economy would be small (1). A larger concern centers on potential restrictions based on the number of species expected to become threatened or endangered over the next 10 years. Little systematic analysis of the overall effects on agriculture has been undertaken due to the uncertain path of species preservation actions and required management measures.

Harmful Nonindigenous Species

The accidental importation of harmful nonindigenous species has caused significant commercial losses to agriculture and degraded the environment. However, regulatory mechanisms and rules to screen unwanted species introductions appear incomplete. This issue is discussed in detail in chapter 5.

■ Stimulating Agroenvironmental Technology Development and Adoption

Despite a broadening environmental agenda, public agricultural research and technology development continues to focus predominantly on increasing production, as it has for most of this century.[22] Public research funds simply have not been targeted to developing technologies aimed at simultaneously enhancing environmental quality as well as agricultural production. Since the 1970s, more than 60 percent of agricultural research by federal research agencies and by state land grant universities has been related to production, while about 10 percent has been dedicated to natural resource or environmental topics (chapter 2). The result has been policies and programs that put production and conservation goals in competition with each other.

Interest in promoting "complementarity" between agricultural production and the environment has grown within the research community, however, and among farm producers, in some agribusinesses, and among consumers. The broad adoption of conservation tillage and growing use of soil nutrient testing, as well as producer involvement in collaborative R&D networks across the country are supportive of the "complementarity" notion (93). Consumers favor a reduction in farm chemical use and show increasing demand for food with fewer chemical residues (81). The market potential for some complementary technologies is reflected in enthusiasm for emerging technologies such as precision farming (described below). Environmental groups also stand to gain from supporting complementary technologies, because they can help achieve lower cost and longer lasting environmental improvements.

Market forces have "induced" agricultural technology innovation that reduces the costs of relatively expensive market inputs, such as land and labor. The costs of these inputs are not difficult to determine. However, the costs of many environmental problems associated with agriculture—such as degraded drinking water or diminishing wildlife habitats—are difficult to capture in the marketplace. Consequently, the environmental costs (and benefits) stemming from agricultural production generally have not been incorporated into the costs farmers pay or the prices they receive for their goods, and there is little impetus for technological innovation that ameliorates, or even addresses, environmental problems.

Public policies, too, are responsible for the technological bias toward agricultural production. Public subsidies may encourage farmers to adopt some technologies to clean up pollution, but as a rule, those subsidies do not act as incentives for developing technologies that will enhance both environmental quality and agricultural output. Pesticide regulation is the major exception, insofar as the restriction of certain agrichemicals essentially creates market incentives for cost-effective, more environmentally sound alternatives. However, regulation may not always be the best approach for stimulating complementary technologies. The present agricultural program regime has fostered a piecemeal approach to agroenvironmental technology innovation: complementarity is the exception rather than the rule, and potential public and private benefits are lost as a result.

[22] Current allocations to agroenvironmental research reflect two special initiatives enacted in the 1985 and 1990 farm bills—the National Research Initiative and the Sustainable Agriculture Research and Education (SARE) program. Both were implemented as competitive grants programs through USDA. The National Research Institute allocates 20 percent of its grants to research topics of natural resource or environmentally related content (65). The SARE program promotes multidisciplinary research applied to farm problems with significant agroenvironmental content.

Technological innovations are not costless. Either private industries or the public sector, or both, must invest in research and development. The chief challenge to public and private technology development will be in identifying critical goals for the sector as it confronts present and future challenges, and stimulating complementary technology innovations that enable individual producers on diverse farms to meet those goals.

The Transition to Complementarity

In practical terms, "technology" means the management scheme by which various practices and inputs—labor, information, machinery, water, chemicals, biological inputs, and capital—are combined into a coherent system to achieve certain goals. As noted in chapter 2, a virtual technological revolution is under way in agriculture, and is having a profound impact on both technological tools and goals. Just as the emphasis on producing abundant food spawned technologies that promoted intensive production and economies of scale, the shift toward a emphasis on both abundant food and environmental quality signals the need for new technologies that prevent pollution and maintain profitability from the outset. For industries such as agriculture, in which nonpoint pollution processes dominate and monitoring enforcement costs are high, preventing pollution may be less expensive and more effective than treating pollution after the fact.

Some analysis suggests that pollution prevention technologies may not be efficient enough to offset the investment required to adopt them and thus not be complementary technologies (97). However, the success of pollution prevention technologies is determined by the efficiency with which it meets socially defined pollution control goals, not simply by its private rate of return in the absence of environmental quality goals. Complementary technologies move a step beyond this standard by requiring environmental quality improvement while maintaining or improving private profitability.

The feasibility of developing and tailoring complementary technologies has not been investigated because, as noted above, there are few market and/or public program incentives to do so. However, some agricultural and environmental technologies currently used suggest that there is great potential for development and adoption of complementary technologies within the agricultural sector. Possible examples of these technologies include: integrated pest management, conservation tillage, soil nutrient testing, rotational grazing, and organic farming systems.

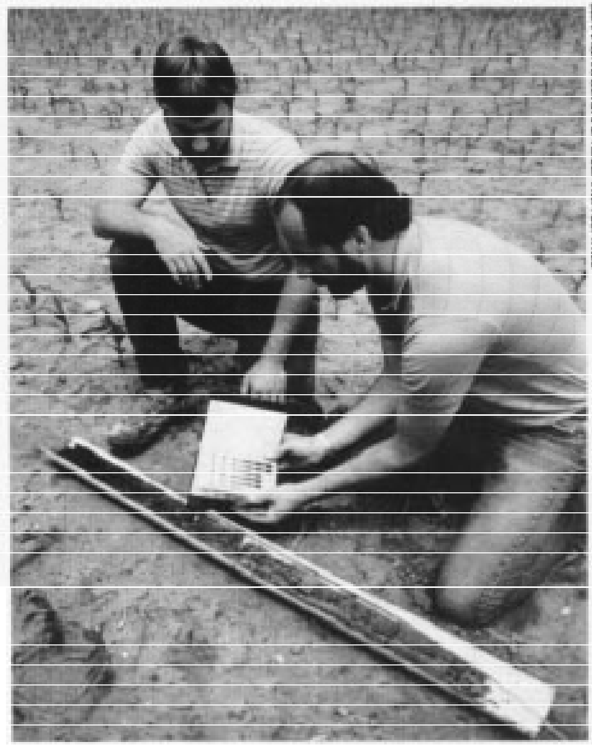
Initiating development of complementary technologies requires first defining the criteria by which their performance will be assessed. For example, critical thresholds for environmental quality and production could be set on a regional or national basis. Environmental quality components include water quality, soil quality, and wildlife habitat criteria and the minimum standards relevant to the region. Similarly, production criteria would capture the crop and livestock regional priorities. Within those critical thresholds (the "feasible set" of technologies), trade-offs between the two goals could provide stimulus for further innovation.

The existence of a feasible range suggests that no single complementary technology will be the "best" choice in all cases and in all regions of the country. There will likely be no "silver bullets." On different kinds of farms, or in the hands of different farmers, the complementarity of a given technology is likely to differ as well.

While complementary technologies may be distinctly different from each other, their successful application uniformly requires sophisticated management skills and a "holistic" or "systems" approach to farm management (94). Thus, the nature of farmer management capacity and goals defines the technology set most relevant to his or her farm. Chief among the tools that may make complementary technologies more feasible are biotechnology, biologically based pest controls, and information technologies.

Biotechnology

Biotechnology involves the insertion of genes carrying desirable traits into plants or animals. As outlined in chapter 2, there are many plausible applacations for biotechnology in agricultural production, ranging from pest resistance in plants to increased growth efficiency for livestock. Most current biotechnology applications are designed primarily to reduce risks associated with crop production or to increase production efficiency, with only incidental consideration of environmental concerns. But there is no reason that biotechnology could not be employed directly toward complementary aims. Biotechnology could be used, for instance, to develop drought-tolerant crops (which could permit a significant reduction in irrigation and its negative environmental consequences). Rather than turning their efforts toward creating Bt-engineered corn (which may enhance the resistance of pests to the toxin) or herbicide-tolerant crops (which do not encourage reduced chemical use or any other conservation practice), scientists might instead investigate the feasibility of conferring inherent resistance to pests without toxins. Markets, however, may not stimulate research and development in that direction because of incomplete environmental pricing.



SDA AGRICULTURAL RESEARCH SERVICE

Testing soil for stored nitrogen helps farmers decide how much fertilizer their crops realty need. In many states, such testing has enabled farmers to save money and curtail nitrate leaching by reducing fertilizer applications. Further development of inexpensive, readily available soil testing technologies could increase the benefits to both farmers and water quality

Biologically Based Pest Controls

The term "biologically based pest controls" refers to a wide variety of products designed to substitute for conventional synthetic insecticides, herbicides, and fungicides. Biologically based pest controls involve the introduction of predators, parasites, pathogens, pheromones or natural competitors specifically to control pests (13). Overall adoption to date of such approaches is low, and biological pesticides currently comprise only a fraction of the total pest control market. Nevertheless, use is growing and is now quite high to control certain pests such as gypsy moths and pest mites in strawberry fields (13).

Interest in exploring biological alternatives to conventional pest control may increase, corresponding to increasing concerns about human safety and environmental quality. The Sustainable Agriculture Research and Education (SARE) program has funded field research into the effectiveness of some biologically based pest management technologies. EPA has designed an accelerated registration process for biologically based pesticides, on the assumption that they are environmentally preferable to synthetic products. Marty may pose fewer threats to human health than some conventional pesticides, but their potential impacts on ecosystems need to be carefully examined.[23]

Information Technologies

Information technologies generally enable farmers to manage their farms in a more sophisticated and cost-effective manner. The range of infor-

[23]The National Academy of Sciences and OTA are both engaged in studies of the status and potential of biologically based pest controls.

USDA, AGRICULTURAL RESEARCH SERVICE

'Scouting" to determine the abundance of pests in farm fields is an increasing& common aspect of both conventional and alternative methods of pest control. Armed with data collected in the field, with knowledge of pest behavior and the availability of various technologies, farm managers can seek the most effective yet environmentally sound control strategies. Here, researchers observe the effectiveness of an insect trap baited with pheromones.

mation technologies available to farmers is quite broad and the full set of technologies based on intensive use of information continues to evolve. In many cases, these technologies may permit farmers to make market transactions more efficiently (through electronic mail, for instance, and electronic auctions) and minimize their use of certain costly inputs by permitting them to target their resources better (through precise application of agricultural chemicals, computer-simulated trials, "just-in-time" inventory maintenance, and other means). Of particular interest from the environmental perspective is the capacity of informational technologies to ameliorate the negative environmental impacts of agricultural production.

"Precision (or "site-specific") farming" involves using advanced satellite information-retrieval and information-management products to improve farm management. Among other things, private firms offer precision-farming technologies to make pesticide and fertilizer use more efficient. Global positioning systems (GPS), used in conjunction with ancillary data from census, surveys, or other sources, can help farmers predict crop yields and vary inputs as needed in different parts of even a single field. Used in tandem with computer-assisted or telecommunications-enhanced decision-making software ("expert systems"), these data can serve myriad functions: provide soil quality data to researchers, increase efficiency of input use, predict crop yields for producers, and anticipate and control potential environmental problems resulting from the adoption of certain production practices. Theoretically, precision farming can help farmers reap broad environmental benefits while enhancing the productivity of their farms. These technologies are still being developed, however, and their full potential to satisfy the criteria for complementarity remains unknown.

Other systems-oriented, information-intensive technologies may also help farmers tailor their management of inputs and pest control to their own needs. Perhaps the most prevalent approach, typically called integrated pest management (1PM), involves "scouting" or monitoring fields for the presence of target pests. Based on scientific principles of pest reproduction and behavior, pesticide applications can be very specific. Although integrated pest management is not always synonymous with reduced agrichemical use, it is less ecologically intrusive than repeated, blanket spraying of pesticides.

Another system-based alternative, integrated crop management, uses certain crop mixes to create an inhospitable habitat for pests and boost production. Many of the approaches to production developed through the SARE program and through state-supported and private sustainable agriculture networks use information intensively to manage production and environmental goals.

In the end, these and other technologies discussed above could make it easier for farmers to decide how to achieve optimal yields as well as maintain soil quality, safeguard water quality, and minimize degradation of wildlife habitats. To the extent that new technologies help operators and public agencies develop and use a better understanding of how agricultural systems and environmental interaction affect both on-farm productivity and on-site and off-site resource quality, they may enhance the environmental agenda for agriculture while enhancing on-farm profitability. In general, the future significance of these technologies for agriculture and the environment depends on: 1) their practical relevance to production, 2) their availability, and 3) their ultimate rate of adoption (table 4-2). Even though the potential for complementarily is high, technologies that simultaneously address production and environmental goals may not become broadly available until specific environmental and agricultural production goals are set to provide signals for private markets and guide public research allocations.

TABLE 4-2: Emerging Technologies and Potential Environmental Effects of Their Adoption

Technology category	Agricultural application[a]	Availability of technology	Factors affecting adoption	Potential environmental benefits or costs
Biotechnology	▪ weed control (c) ▪ insect control (c) ▪ disease control (c,l) ▪ reproductive control (1) • market readiness (c) ▪ herbicide resistance (c)	▪ significant public, private research • regulatory process Incomplete ▪ few current applications satisfy complementarily criteria	▪ risks of transition ▪ consumer acceptance ▪ management ability ▪ relevance to on-farm goals ▪ rates of technology development and transfer " cost	▪ may reduce or substitute for some pesticide use ▪ may Improve agricultural nonpoint pollution problems ▪ may reduce poisoning of nontarget plant and animal species ▪ may create problems with weediness and nonindigenous species ▪ may reduce stress on natural inputs through enhanced efficiency ▪ benefits may be vulnerable to pest resistance
Biologically based Pest Controls	▪ weed control (c) • insect control (c) ▪ pathogen control (c)	▪ uneven public, private research and development ▪ limited number of products ▪ some active public sector uses ▪ potential for complementarity not clearly established	• as above	▪ as above ▪ may enhance biodiversity in agroecosystems ▪ may reduce biodiversity when biocontrol diminishes nontarget species
Informatlon-Intensive Management[b]	▪ weed control (c) ▪ insect control (c) ▪ enterprise planning (c,l,m) ▪ resource monitoring (ae) ▪ whole farm planning (c,l,m,ae)	▪ emerging private, public research ▪ limited number of applications ▪ some active private sector uses of prototypes ▪ potential for complementarily not clearly established	▪ as above	▪ as above ▪ may facilitate complementarity between production and agroenvironmental planning ▪ may reduce public cost of monitoring of soil, water conditions ▪ may encourage cooperation between private and public resource management

[a] Activity category: c= crops, I = livestock, m= marketing, ae= agroenvironmental
[b] These include integrated crop management, certain nutrient management schemes, whole farm planning approaches, integrated pest management, and other pollution-prevention technologies.

SOURCE: Office of Technology Assessment, 1995

CHAPTER 4 REFERENCES

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Appendix 4-1: National Primary Drinking Water Standards

Contaminants	MCL (mg/L)	Potential health effect: ingestion of wate	Sources of contaminant in drinking water
Giardia Iambia	4 0	Skeletal and dental fluorosis	Natural deposits; fertilizer, aluminum industries, water additive
Total Coliform*	< 5%+	Indicates gastroenteric pathogens	Human and animal fecal waste__
Turbidliy*		Interferes with disinfection, filtration	Soil runoff
Viruses	TT	Gastroenteric disease	Human and animal fecal waste
Mercury* (inorganic)	0.002	Kidney, nervous system disorders	Crop runoff; natural deposits, batteries, electrical switches
Nitrate'	10	Methemoglobulinemia	Animal waste, fertilizer, natural deposits, septic tanks, sewage
Nitrite	1	Methemoglobulinemia	Same as nitrate; rapidly converted to nitrate
Alachlor	0.002	Cancer	Runoff from herbicide on corn, soybeans, other crops
Aldicarb sulfone*	0002	Nervous system effects	Biodegradation of aldicarb
Aldicarb sulfoxide*	0.004	Nervous system effects	Biodegradation of aldicarb
Atrazine	0.003	Mammary gland tumors	Runoff from use as herbicide on corn and noncropland
Carbofuran	0.04	Nervous, reproductive system effects	Soil fumigant on corn and cotton; restricted in some areas
2,4-D*	0.07	Liver and kidney damage	Runoff from herbicide on wheat, corn, rangelands, lawns
Dibromochloropropane	0.0002	Cancer	Soil fumigant on soybeans, cotton, pineapple, orchards
Lindane	0.0002	Liver, kidney, nerve, immune, circulatory	Insecticide on cattle, cotton, soybeans, canceled 1982
Methoxychlor	004	Growth, liver, kidney, nerve effects	Insecticide for fruits, vegetables, alfalfa, livestock, pets

(continued)

Contaminants	MCL (mg/L)	Potential health effects from ingestion of water	Sources of contaminant in drinking water
Pentachlorophenol	**0.001**	**Cancer, liver, and kidney effects**	Wood preservatives, herbicide, cooling tower wastes
Toxaphene	0.003	Cancer	Insecticide on cattle, cotton, soybeans; canceled 1982
2,4,5-TP	0.05	Liver and kidney damage	Herbicide on crops, right-of-way, golf courses; canceled 1983
Dalapon	02	Liver, kidney	Herbicide on orchards, beans, coffee, lawns, road/railways
Dinoseb	0.007	Thyroid, reproductive organ damage	Runoff of herbicide from crop and noncrop applications
Diquat	002	Liver, kidney, eye effects	Runoff of herbicide onland, aquatic weeds
Dioxin	0.00000003	Cancer	Chemical production byproduct, impurity in herbicides
Endothall	01	Liver, kidney damage	Herbicide on crops, land/aquatic weeds, rapidly degraded
Endrin	0002	Liver, kidney, heart damage	Pesticide on insects, rodents, birds; restricted since 1980
Glyphosate	0.7	Liver, kidney damage	Herbicide on grasses, weeds, brush
Hexachlorobenzene	0001	Cancer	Pesticide production waste byproduct
Hexachlorocyclopentadiene	005	Kidney, stomach damage	Pesticide production intermediate
Oxamyl (V ydate)	02	Kidney damage	Insecticide on apples, potatoes, tomatoes
Picloram	05	Kidney, liver damage	Herbicide on broadleaf and woody plants
Simazine	0004	Cancer	Herbicide on grass sod, some crops, aquatic algae
1,2,4-Trichlorobenzene	0.07	Liver, kidney damage	Herbicide production, dye carrier
Arsenic'	005	Skin, nervous system toxicity	Natural deposits; smelters, glass, electronics wastes, orchards

Appendix 4-2: Listing of Federal Conservation and Environmental Programs Related to Agriculture[1,2]

Education and Technical Assistance

1. Comprehensive State Ground-Water Protection (EPA)
2. Conservation Technical Assistance
3. Extension Education
4. Flood Prevention
5. Forest Stewardship
6. Resource Conservation and Development

Research or Data Activities

7. Agricultural Research Service
8. Army Corps of Engineers (U.S. Army)
9. Bureau of Land Management (DOI)
10. Bureau of Reclamation (DOI)
11. Cooperative State Research Service
12. Environmental Protection Agency (EPA)
13. Economic Research Service
14. Fish and Wildlife Service (DOI)
15. Forest Service
16. Geological Survey (DOI)
17. National Agricultural Library
18. National Agricultural Statistics Service

19-24. Natural Resources Conservation Service
- 19. National Resources Inventory
- 20. Resource Conservation Act Appraisal
- 21. River Basin Surveys
- 22. Soil Surveys
- 23. Snow Surveys
- 24. Plant Material Centers

Regulation or Compliance

25. Animal and Plant Health Inspection Service
26. Coastal Nonpoint Pollution Control (NOAA and EPA)
27. Conservation Compliance
28. Dredge and Fill (wetlands) Permits (U.S. Army Corps of Engineers)
29. Endangered Species Protection (DOI)
30. National Pollution Discharge Elimination System Permits (EPA)
31. Pesticide Registration (EPA)
32. Pesticide Record Keeping
33. Safe Drinking Water Act (EPA)
34. Sodbuster
35. Swampbuster

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[1] Programs are categorized based on their predominant program approach.

For a brief description of the programs, see U.S. Department of Agriculture, Economic Research Service, Natural Resources and Environmental Division "Agricultural Resources and Environmental Indicators," *Agricultural Handbook No. 705*, December 1994, pp. 162-174.

[2] Lead agencies are identified for programs outside the U.S. Department of Agriculture: EPA = Environmental Protection Agency; DOI = Department of the Interior; NOAA = National Oceans and Atmospheric Administration.

Subsidies, Compensation, and Public Works

36. Agricultural Conservation Program
37. Clean Lakes Program (EPA)
38. Colorado River Salinity Control
39. Conservation Loans and Easements
40. Conservation Reserve
41. Environmental Easement Program
42. Emergency Conservation
43. Emergency Watershed
44. Endangered Species Conservation (DOI)
45. Farmland Protection
46. Flood Control
47. Forestry Incentives
48. Forestry Stewardship Incentives
49. Great Plains Conservation
50. Integrated Farm Management
51. Integrated Pest Management
52. National Estuary (EPA)
53. Nonpoint Source (water quality) (EPA)
54. Rural Clean Water Program
55. Range Improvements (DOI, Bureau of Land Management)
56. Small Watershed
57. Water Bank
58. Water Development and Management (DOI, Bureau of Reclamation)
59. Wetlands Conservation (DOI)
60. Wetlands Reserve

SOURCES U S Department of Agriculture, Economic Research Service, Natural Resources and Environment Division, "Agricultural Resources and Environmental Indicators, " *Agricultural Handbook No. 705,* Washington, DC, December 1994, and Jeffrey A Zinn, "Implementation of Resource Conservation Programs Enacted in the 1990 Food, Agriculture, Conservation and Trade Act, " memorandum to Congress, Congressional Research Service, Jan 31, 1992

Appendix 4-3: USDA Conservation Expenditures, by Activity and Program Fiscal Years 1983-1995

APPENDIX 4-3: USDA Conservation Expenditures, by Activity and Program, Fiscal Years 1983-1995[1]

Activity/program	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994 enacted	1995 enacted
							$million[1]						
1. Technical assistance, extension, and administration:													
Soil Conservation Service (SCS) programs—													
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	502.6	500.5
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	8.9
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	28.4	28.8
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
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	83.5	55.9
Subtotal SCS	412.8	403.5	414.7	399.3	435.7	469.6	487.9	499.8	538.5	596.8	643.9	634.7	604.6
Agricultural Stabilization & Conservation Service (ASCS) programs—													
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	9.7	5.0
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	4.9	1.5
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	0.0
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	0.0
Forestry Incentives Program (FIP)	1.3	1.3	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.3	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
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
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	7.7
ASCS salaries & exp., 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
Subtotal ASCS	44.3	48.7	46.1	63.3	84.0	81.4	03.3	95.6	99.2	104.3	99.6	93.1	77.0
Extension Service (ES) conservation	15.9	16.0	16.4	16.3	15.7	18.1	19.8	23.5	29.4	31.1	31.1	33.8	33.8
Forest Service (FS) programs	14.4	9.7	9.8	9.5	10.0	10.8	13.0	19.2	47.4	56.5	60.7	62.5	68.1
Subtotal Tech. asst., ext., and admin.	487.4	477.9	487.0	488.4	545.4	579.9	624.0	638.1	714.5	788.6	835.3	824.1	783.5
2. Cost sharing for practice installation:													
ASCS programs—													
Agricultural Conservaiton 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	95.0
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	3.0
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	14.1	4.3
Emergency Cconservation 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	0.0
Forestry Incentives Program (FIP)	11.3	11.1	11.5	9.8	10.7	10.6	11.0	10.2	12.4	11.5	11.2	11.5	6.0
Rural Clean Water Programj (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
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	5.3	7.0
Subtotal ASCS	204.2	202.0	197.5	169.1	436.7	493.0	377.6	340.3	242.7	249.0	276.3	246.1	115.3

(continued)

APPENDIX 4-3 (Cont'd.): USDA Conservation Expenditures, by Activity and Program, Fiscal Years 1983-1995[1]

Activity/program	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994 enacted	1995 enacted
							$ million[1]						
FS Stewardship Incentives Program (SIP)	0 0	00	00	00	00	00	0 0	00	199	0 8	178	179	183
SCS Great Plains Conservation Program (GPCP)	12,2	123	125	115	114	118	122	129	164	162	164	164	6 3
Subtotal Cost-sharing	2164	2143	2100	1807	4481	5048	3898	3532	2790	2660	3105	2804	1399
3. Public works project activities (SCS):													
Emergency Watershed Protection	225	220	5 0	797	148	135	100	949	200	700	731	2480	1250
Flood Prevention (operations)	227	9 9	139	191	115	113	128	160	128	214	238	229	0 0
Resource Conservation and Development (RC&D)	144	9 7	8 5	77	72	70	67	4 2	5 7	6 5	2 6	4 6	40
Small Watershed Program (operations)	160.6	876	880	808	827	834	837	817	826	896	1013	1069	141
Subtotal SCS public works projects	220.2	1291	1154	1873	1162	115.2	1132	1968	121.1	1875	2008	3824	1431
4. Rental and easement payments (ASCS):													
Conservation Reserve Program (CRP)	0.0	0.0	0 0	0 0	4100	7601	11621	1393.7	15901	16125	15100	17292	1739.0
Water Bank Program (WBP)	88	8 8	8 8	8 4	8 4	8 4	90	122	131	171	171	74	00
Wetland Reserve Program (WRP)	0.0	0 0	0 0	0 0	0 0	0 0	00	0 0	0 0	0 0	4 4	47.3	630
Subtotal rental and easement payments	88	8 8	8 8	8 4	4184	7685	1171.1	14060	16032	16296	1531 5	17839	18020
5. Conservation data and research:													
Agricultural Research Service	635	637	637	624	593	605	659	736	736	739	743	767	760
Cooperative State Research Service	279	296	328	313	310	331	345	406	50.6	497	517	512	432
Economic Research Service	5 0	7 7	5 4	40	4 0	31	30	4 6	5 5	58	6 3	5 0	40
Forest service (forest environment research)	197	204	203	239	282	293	31 1	353	407	390	418	420	422
National Agricultural Library (water quality)	0 0	00	0 0	0 0	0 0	0 0	0 0	0 3	0 3	0 3	0 3	0 3	03
SCS programs:													
River basin surveys	164	156	149	14.2	121	121	121	123	128	133	133	135	130
Soil surveys	514	535	548	543	582	677	682	681	698	726	72.6	739	726
Plant materials centers	3 8	40	41	3 9	4 6	4 9	5 0	7 2	7 9	81	81	8 9	81
Snow surveys	3 8	39	4 0	3 8	50	5 4	55	5 4	5 6	5 7	5 7	5 8	58
Subtotal SCS	755	770	778	762	797	900	908	930	960	996	996	1021	99.5
Subtotal conservation data and research	1916	1984	2000	1978	2022	2160	2253	2473	2667	2683	2740	2773	2652
6. Conservation compliance and sodbuster (ASCS & SCS) (expenditures are included in other programs listed above):													
Total	1,1244	1,0285	1,0212	1,0625	1,7303	2,1843	2,5234	2,8414	2,9845	3,1400	3,1521	3,5481	3,133.7

[1] Derived from material provided by the Off Ice of Budget and Program Analysis (OBPA) USDA.

SOURCES: U.S. Department of Agriculture, Economic Research service "Agricultural Resources, Cropland, Water, and Conservation Situation and Outlook Report, " Agricultural Report 30, May 1993, and U.S. Department of Agriculture, Economic Research Service, Natural Resources and Environment Division, "Agricultural Resources and Environmental Indicators," *Agricultural Handbook 670,* December 1994