Targeting Environmental Priorities in Agriculture: Reforming Program Strategies

EXECUTIVE SUMMARY

Substantial evidence indicates that agricultural activity has led to major water quality, wildlife, and soil quality problems nationwide. The damages associated with each type of problem vary widely, depending on how production practices affect an area's natural resources. In certain geographic areas, the stress on the environment from farming or ranching is severe. At this writing, a number of federal programs have been designed to ameliorate these problems. However, although they single out some general problems, such as highly erodible lands, these programs generally miss opportunities for larger payoffs by not focusing on specific geographical areas and issues that require special attention.

To achieve the greatest returns on tax expenditures, federal programs must be targeted to "priority" areas and successfully apply low-cost approaches. More effective targeting conserves budget resources for taxpayers, diminishes unnecessary program burdens on farmers, and keeps more land in production to serve consumer and trade interests. Reserving costly land retirement programs for cases of true incompatibility between production and environmental objectives will save expense. More emphasis on spreading low-cost or even profitable technologies that improve environmental health will not only save government expense but will give a greater chance of using private incentives to build enduring solutions. Moreover, relying on programs that emphasize low-cost approaches will spread scarce tax dollars over more priority areas.

One major impediment to better targeting has been incomplete science and national information bases. To overcome these data deficiencies, OTA has assessed the efficacy of assembling an expert panel that would use the most complete scientific information available to identify priority areas. *The expert panel process proved feasible and effective, identifying priority areas within which program targets could be refined with state and local input.*

The geographic distribution of priority areas identified for water quality, wildlife habitat, and soil quality confirms that different regions are vulnerable to different types and intensities of problems. For instance, surface water pollution from agrichemicals is more serious in the Corn Belt and Great Lakes regions than in the Southeast. The loss of wildlife habitat is a critical concern in the Prairie Pothole region, but wind erosion is the major difficulty in the Texas High Plains.

A key finding of the expert panel was the considerable overlap of many priorities in several geographic areas. Large sections of the Corn Belt, Plains states, Lower Mississippi Valley, and some Atlantic estuaries, emerge as areas offering multiple potential environmental benefits if targeted by programs. For example, restoring riparian buffers along streams in the Corn Belt would not only contribute to water quality goals, but restore wildlife habitat as well. The overlap of priorities also reinforces the notion that government programs must attempt to address entire agroenvironmental systems, rather than focus on individual components such as soil erosion. Federal programs must continually reflect the fact that water quality, wildlife habitat, and soil quality are interrelated in agroecosystems.

Identifying environmental priorities for agriculture is a first step to more cost-effective programs. The next is to approach these priorities in ways that maximize opportunities to attain environmental quality objectives, maintain profitable production, and reduce the budget burden.

- *First, government can use education and technical assistance programs to promote the adoption of "complementary" technologies that simultaneously enhance environmental quality and maintain acceptable profits.* Proven examples include integrated pest management and soil nutrient testing, a form of precision farming. Many other technologies are emerging that show considerable promise of preserving profitable production and achieving environmental objectives. Incomplete information, perceived risks, and other factors may hamper the spread of complementary technologies without public assistance. Education, technical assistance efforts, and minimal one-time subsidies could overcome these mostly management-related barriers.
- *Second, government can encourage farmers to use other management technologies involving cost, such as construction of livestock waste facilities, through economic incentives or disincentives.* The choice between using an incentive or disincentive depends on the nature of the environmental risk, legal liability, cost burden, and ease of monitoring, among other factors. Regardless of the approach chosen, the goal is to keep resources in production but in an environmentally-acceptable manner.
- *Third, program planners should bear in mind that programs used to conserve land through long-term retirement, such as the Conservation Reserve Program (CRP), are cost effective only when agricultural production is fundamentally incompatible with achieving environmental objectives.* Otherwise, shifts to different technologies that permit continuing commercial production are preferable.

These approaches bear directly on developing and implementing conservation and environmental legislation for agriculture. As an example, legislation could require the use of targeting procedures to maximize environmental benefits for tax expenditures. Using such an approach, re-enrollment in the CRP would not be limited to existing contract holders, but would be open to all owners of eligible lands based on environmental merit and cost. Further, the expert panel process of identifying priority targets could be used by federal agencies in program implementation. Periodic review and updating of the priorities would be necessary as science yields new insights about environmental problems. A second layer of targeting within the priority areas could be undertaken by state and local parties who have more precise knowledge of agriculture and environmental relationships in their regions. Finally, federal agricultural research and agroenvironmental programs could be linked, so that the development of technologies to achieve both production and environmental objectives could be accelerated.

AGROENVIRONMENTAL QUALITY: PRESENT AND FUTURE DIRECTIONS

In a preceding report, OTA summarized scientific evidence detailing the many interactions between agricultural and environmental systems (64). Based on a review of the existing literature and consultation with national experts (table 1), OTA concluded that certain agricultural production activities lead to detectable and sometimes profound changes in water quality, wildlife habitat, and soil quality.[1] The changes are not always detrimental to these resources, or to the health of humans or other living things that depend upon them. However, sufficient evidence is available to show that degradation of water, wildlife, and soil resources due to agriculture is prevalent on a

TABLE 1: Agriculture and Environment: What We Know and Don't Know

We Know:	We Don't Know:
■ *Current data, while incomplete, highlight important themes.* National trends in environmental quality have not been monitored regularly, particularly with respect to agriculture. Yet, studies by federal and state researchers offer some mutual corroboration.	■ How to fully assess *the interaction of environmental systems and agricultural systems*. This is primarily due to low investment in related scientific research. ■ The *potential for technologies* to enhance environmental quality along with productivity. Private markets and public programs provide inadequate incentives for such innovation.
■ *Agriculture is the primary source of pollution in surface waters nationwide.* This pollution is real, extensive, and not yet controlled. Seasonally, in certain regions, surface water pollution levels exceed drinking water standards.	■ Temporal and geographical *patterns in surface water quality*, due to incomplete monitoring. ■ *Full implications of agricultural pollution* found in surface water on human or environmental health, because related science is still evolving and has not been emphasized.
■ *Residues from fertilizer and pesticides are in groundwater of almost every state.* In cropland areas, nitrate levels in groundwater exceed drinking water standards nearly three times more often than under any other land use. Pesticide levels that violate drinking water standards have been found in many states in areas where these chemicals are used heavily.	■ Temporal and geographical *patterns in quality of groundwater*, due to incomplete monitoring. ■ *Full implications of agricultural pollution* found in groundwater on human or environmental health, because related science is still evolving and has not been emphasized.
■ *Soil erosion has declined by 33 percent nationwide during the last decade*. Erosion, however, is only one aspect of soil quality. Other aspects include organic matter, microbial activity, compaction, salinity, electrical conductivity, and contamination.	■ Key *trends in soil quality*, besides erosion. Related science is still evolving, and monitoring of many quality attributes has not been systematic. ■ *Full implications for environmental health*. Related science is still evolving and has not been emphasized.
■ *Agricultural development is the primary cause of diminished wildlife habitat nationwide.* Loss of habitat is a chief cause of species loss. Cropland and rangeland cover almost half of the nation. Maintaining mosaics of grass and other kinds of habitat within farm regions can sustain regional species.	■ Full spectrum of farming/wildlife interactions. Research and monitoring tend to focus on certain species or certain regions. Science related to agroecological systems is evolving. ■ Full implications of technologies on wildlife viability and potential for technology innovations to increase compatibility between agriculture and wildlife. Private markets and public programs offer inadequate incentives for such innovations.

SOURCE: Office of Technology Assessment, 1995.

[1] In the report, *Agriculture, Trade and Environment* (91), OTA determined that knowledge of agroenvironmental quality in the U.S. is hampered by the lack of understanding of agricultural and environmental systems and how they interact, by incomplete and unsystematic monitoring of agroenvironmental conditions, and by the absence of science-based criteria for evaluating the implications of conditions—particularly in terms of long-term ("sustainable") environmental or human health. The public agricultural research system has predominantly focused funding and resources on improving production to the detriment of understanding agroenvironmental issues and discovering technologies that simultaneously achieve production and environmental health.

national scale. These "agroenvironmental" problems are particularly acute in many places.

Agriculture's role in determining environmental quality can be quite substantial, because conditions generated on individual farms tend to spread beyond the farm gate. For example, sediment, fertilizer residues, or pesticides transported off the farm in field runoff can make streams, rivers, lakes, and reservoirs unsuitable for drinking, for fish habitat, or for swimming and other recreational activities. Agroenvironmental effects that are not contained within the individual farms where they are generated can cause local, regional, national, and, in some rare cases, even international changes in environmental quality.

Even as agroenvironmental science evolves, the evidence suggests that it is possible to employ the best science to help identify or target key agroenvironmental priorities. These priorities can provide insight to policymakers as they seek to focus related policy and programs. *In this report, the "priorities" refer to areas or categories of effects where potential environmental benefits associated with agriculture were assessed to be greatest. The benefits can come from ameliorating existing damages, or from protecting against future degradation.* The selection of priorities relied on expert scientific assessment of available evidence. Leading scientists for selected environmental subjects identified the highest priorities for OTA review (see box 1). The scientists were instructed to consider environmental, economic, and social factors but not restricted to a fixed set of criteria or standards because of incomplete science and data.

Rationales for Federal Role in Agroenvironmental Quality

Public surveys reveal broad support for protection of the nation's environmental quality, including those resources affected by agriculture (73). Farmers report interest in adopting practices that are profitable, protect the health of farm families and workers, prevent land or water contamination, and avoid environmental damages that could result in lower land values, litigation, or regulation (26). Public attitudes and consumer behavior favoring reduced use of farm pesticides may be a factor driving the dramatic growth in retail markets for natural and organic foods since 1990 (52,64). It is not surprising, therefore, that more than 60 percent of the public favors increased federal spending on agricultural natural resource conservation, and an additional 20 percent wants current levels maintained (97).

Ultimately, the extent and type of federal response boils down to political decisions taken by Congress. However, by considering the reasons for federal involvement in agroenvironmental management, it may be possible to help identify the situations and types of problems most amenable to national responses. Analysts have discussed three reasons: 1) the need to manage "transboundary" problems; 2) the ability to gain economies in research, technical assistance, and technology development that benefit not just one, but many states; and 3) the federally legislated responsibility to provide certain "public goods"[2] on a national basis (52).

Transboundary Problems

Agroenvironmental problems begin locally, as agricultural systems affect surrounding environmental resources such as water, air, soil or wildlife. These problems may, however, cross state and national boundaries. If individual or collective state action is expensive or impossible, federal action may be required to manage such transboundary problems effectively. Federal responses can range from direct intervention in issues of safeguarding public health, to facilitating collaboration among states on issues that cannot be successfully resolved by any one state.

Perhaps the most commonly cited example of a transboundary effect is agricultural runoff from

[2] Such public goods are benefits available to all citizens in equal quantity and quality. The intended provision of healthful drinking water to all citizens under the Safe Drinking Water Act exemplifies a national public good.

BOX 1: Using an Expert Panel for Environmental Targeting

OTA reached three major findings after conducting a comprehensive review of the evidence about U.S. agroenvironmental conditions (64):

- Agriculture exerts broad, significant effects on the nation's water, wildlife, and soil resources.
- Published data on agroenvironmental conditions are incomplete and not a federal priority.
- Existing science and data suggest that agroenvironmental conditions are geographically diverse and particularly intense in some areas.

The first finding establishes that agricultural production significantly interacts with environmental systems, resulting in "agroenvironmental" conditions. The second implies that programs that attempt to deal with the range of agroenvironmental interactions will have to proceed without complete scientific information. A great deal of information is available, however. Policies designed to remediate or prevent damages to environmental health may have to rely on a combination of published data supplemented with subjective expertise. The third finding suggests the need for some type of problem-based, geographical targeting to ensure that the highest agroenvironmental priorities are addressed. Otherwise, program efforts could miss opportunities to produce the most valuable environmental improvements. In the face of continuing budget pressure, the rationale for targeting becomes increasingly compelling. Expected levels of funding simply will not permit blanket coverage of all agroenvironmental conditions in all regions. In addition, to the extent that agroenvironmental improvements may pose significant costs for some farmers, targeting can control the scope of those costs and, furthermore, permit public efforts to focus on helping farmers in high-priority areas make needed transitions at the lowest cost.

To counteract the lack of complete science to identify agroenvironmental priorities, OTA convened a group of leading scientists to examine 10 major environmental quality dimensions related to agriculture: soil quality, surface water quality, groundwater quality, water conservation, wetlands, rangelands, rural landscapes, plant diversity, insect diversity, and wildlife habitat (see appendix C). The exercise proceeded on the premise that leading scientists embody the most comprehensive information because they can draw together the best of existing scientific data with experience and insight. They can use all available published literature and augment those data with expert judgment of emerging evidence to assess the relative significance of environmental conditions. Overlap in priorities associated with different subject areas represented by the scientists, e.g., water quality and wetlands, was common (see appendix B). Indeed, the overlap of subject areas was considered desirable in light of scientific uncertainty about the elements of agroenvironmental quality. Such overlap also emphasizes that effectively managing the dynamic interaction of components within agroenvironmental systems will require multidisciplinary approaches.

The principal purpose of the exercise was to determine the feasibility of identifying geographically-based priorities for each subject area represented on the panel. The panelists had a simple but challenging task: draw up a list of the 10 highest priorities that exhibit the most severe problems and potential benefits based on the best science. The size of the geographic area was not restricted, but panelists were asked to be as precise as possible, in keeping with the objectives of targeting. (Large areas inherently diminish targeting efficiency, unless the environmental or conservation problem in question applies in equal measure throughout the area.)

(continued)

BOX 1: Using an Expert Panel for Environmental Targeting (Cont'd.)

The exercise resembled a Delphi process of soliciting expert judgment, then sharing it with other panel members and OTA staff, and then feeding it back to the panelists for possible revision. The initial session was held in August 1994, with a second meeting in May 1995, for making refinements. Each panelist was asked to take environmental, economic, and social criteria into consideration in making the selections, but was not required to adhere to a fixed procedure. Panelists were encouraged to consult with peers around the country to draw together the best data from both published and unpublished sources. A majority of panelists each contacted from 5 to 30 peer scientists to incorporate their views in the prioritization. Thus, the panel's priorities reflect a broad range of professional input. Further, the panelist findings received peer review.

A major project goal was to extract as much expert judgment as possible from the panel members without imposing constraints on their decision processes, thus encouraging innovative approaches. A potential disadvantage of this strategy is the use of different criteria, weights, and standards by each member and the potential inconsistency of their results. However, imposing a standard decision protocol for all panelists when faced with varying degrees of science across categories would either make the exercise infeasible or force artificial choices. In particular, the absence of economic benefit values for most of the environmental improvements precludes benefit-cost comparisons across subject areas.

Several findings emerged from the exercise:

- It is possible to identify agroenvironmental priority areas/regions by using existing data augmented by expert scientific judgment. In some instances, however, the priorities do not fall into neat geographical boundaries and are better described as categories, e.g., riparian wetlands.
- This national-level selection of priorities should be augmented by a companion process using local and regional expertise to define specific priority areas within the larger target areas. This refinement is also likely to help determine which program strategies may fit best with local conditions and incentives.
- The geographical priorities for several subject areas overlap, suggesting the potential for overlap among programs aimed at individual aspects of agroenvironmental quality.
- In the process of selecting priorities, weaknesses in science and data become apparent. For instance, the relationship between agriculture and insect diversity is little understood, despite efforts to advance pest management technologies. Revealed weaknesses help define research and monitoring needs.
- Understanding the problems and their causes within these priority areas gives general guidance about program strategies that might be employed, but broad geographical targeting is not an adequate basis for developing precise program strategies.

SOURCE: Office of Technology Assessment, 1995.

fields into streams and rivers. Some of the pollutants contained in runoff may settle on the originating farm, but monitoring clearly shows that waterborne pollutants travel across farm, county, state, and even national borders. *The boundaries of agroenvironmental systems are not constrained by private property lines or political borders*—yet the power to control pollutants that affect agroenvironmental systems largely rests with individual farmers on the lands they manage. Unfortunately, problems occurring outside private or political boundaries—"off-site" effects—are normally not considered by farm operators making routine management decisions.[3]

When effects arising from crop or livestock production move off the farm but stay within local or state jurisdiction, then local or state initiatives may be able to ameliorate any problems. But when effects cross state borders, individual states are not necessarily capable of resolving them or of finding low-cost solutions. For instance, states in the Lower Mississippi River region affected by hundreds of thousands of tons of fertilizer and pesticide residues from Corn Belt runoff (23,24), are not able to directly alter the behavior of farmers in Iowa, Illinois, Indiana, Missouri, Ohio, and other states contributing to the pollution. Federal programs, however, may serve as a broker between the parties, and innovate a solution. If state cooperation proves infeasible, the federal government may have to impose a solution.

If formal cooperation or collaboration with foreign governments is needed to respond to effects that cross national borders, some form of federal participation is mandatory, because the federal government retains authority for entering international agreements. Again, the type of federal action can vary from empowering states to respond individually or collectively, to fostering international scientific dialogue on the nature of the problem, to promoting technology research, development, and exchange, to signing binding international agreements. The Montreal Protocol, which controls the use of ozone-depleting substances by signatory countries around the world, is an example of the last type of action.

Economies in Research, Technology Development, and Technical Assistance

Historically, Congress has given federal agencies responsibility to conduct agricultural and environmental research, develop agricultural technologies, and implement technical assistance for conservation and environmental improvement. Evaluations of commercial benefits indicate that the research and technology development programs have generated large rates of returns, in the range of 20 percent (3). Because the research and technology programs have been oriented primarily to increasing output, analyses of environmental benefits and costs generally have not been performed.

These federal research, technology development, and technical assistance capacities, if applied to agroenvironmental management, may result in "spillover effects" that benefit more than one state. They may also enjoy some economies of scale over individual state efforts if large amounts of staff or equipment would need to be duplicated state by state. Possible examples include agroenvironmental monitoring (especially of transboundary effects), better understanding of how regional agroenvironmental systems function (again, especially in cases where effects cross state borders), insights into the biological health implications of farming activities affecting many regions, and technology development that adapts to the growing need for farmers to achieve production and environmental objectives simultaneously. Not only can this basic information be used freely in designing and implementing federal, state, or local programs,

[3] Some efforts have been made to internalize transboundary effects into farm planning, largely through voluntary education, technical assistance, and subsidy programs to implement practices that lower pollution generation and movement (91). Less often, direct regulation of the causes of these effects has been authorized as with permits for wetlands alteration and controlling effluent from confined animal facilities to water resources.

but federal expertise could be used to help state and local agencies or private firms tailor research, technology, or technical assistance to meet specific regional concerns and goals.

Federal research, technology development, and technical assistance have typically been generated in close partnership with states and local governments. The federally established Land Grant University system exemplifies a federal-state partnership approach that provides federal funding to states. Research and technology development related to agroenvironmental concerns has been conducted by the Agricultural Research Service (ARS) units located in the universities and enhances these partnerships. Technical assistance programs offered by the U.S. Department of Agriculture's (USDA) Natural Resources Conservation Service (NRCS) and the Extension Service (ES) may also achieve cost efficiencies that can be shared with farmers across the country. Both efforts are run in partnership with state and local governments.

Some federal research programs are not conducted cooperatively with states but are designed to gain cost economies in collecting and disseminating information of use to the agricultural sector. USDA's Economic Research Service maintains detailed records about farm characteristics, commodity prices, trends in input use, environmental indicators, and trade statistics. The federally funded Appropriate Technology Transfer for Rural Areas[4] center (ATTRA), serves as a clearinghouse for conservation and production information that may interest farmers in many states.

Whether existing programs or new programs achieve cost efficiencies in providing agroenvironmental services that are not attainable by state and local efforts depends on the situation. Each case must be evaluated individually. However, federal research, technology development, and technical assistance efforts may serve some unique functions in collaborating with state and local governments.

Federally Designated Environmental Public Goods

Through legislation, Congress has defined precedents for federal responsibility in providing certain national public goods related to environmental quality. The passage of national legislation in the early 1930s that established federal programs and agencies to stem soil erosion, and their continuing reauthorization, exemplifies such a public good designation. The Safe Drinking Water Act, the Clean Water Act, the Endangered Species Act, the Great Lakes water quality and national estuary restoration programs are only a few of the more recent actions that raise certain public environmental quality goals to the level of federal law.

Agriculture, along with other industries, is required to meet environmental standards in concert with these laws. Although the specific kinds of public goods protected by federal law may change over time, Congress has repeatedly reserved the management of a set of environmental quality issues for federal responsibility and leadership. Any change in the issues requiring public good protection remains with Congress.

State and Local Roles

The cases delineated above outline rationales for federal agroenvironmental programs. Nonetheless, they do not define the relative roles of federal, state, or local governments in implementing the programs. The appropriate balance of leadership and funding in identifying and responding to environmental problems is ultimately a political question. The answer depends on issues beyond the scope of this report.

In a dialogue about agricultural management and the environment, a group of farmers, scientists, environmental interest groups, government agency staff, and agribusiness shared the view that a shift away from federal programs and toward state efforts was preferable for managing agroenvironmental issues (35). When prefer-

[4] ATTRA is operated by the National Center for Appropriate Technology and funded by the U.S. Fish and Wildlife Service, Department of the Interior.

ences favoring a shift in agroevironmental leadership to the states are considered against trends in public surveys that favor continued, and even increased, federal funding for agroenvironmental management, some tension becomes evident. Clearly, when federal leadership is exercised in identifying potential national agroenvironmental priorities, the eventual program targets must be selected with meaningful state and local involvement. Moreover, even if Congress indicates that federal programs are needed to address some priority issues (such as transboundary effects), state, local, and private initiatives may be encouraged within those programs to develop cost-effective, enduring solutions to specific problems.

The initial targeting of priority areas described in the following section is intended to improve the cost effectiveness of whatever federal programs Congress deems necessary. It does not imply that federal responses are appropriate in all cases, nor that federal programs should be the exclusive or major approach. Delegating responsibility and funding to state and local governments could be the principal program strategy in resolving an identified priority.

IDENTIFYING AGROENVIRONMENTAL PRIORITIES

Available evidence underscores the importance of three factors in determining the scope and severity of agriculture's effects on environmental quality in the United States. First, agricultural production covers about half the nation's lands leading to the possibility of widespread effects, but concentrates environmental pressure in certain areas. Second, the quality of environmental resources varies across the country—not only in terms of their productive capacity, but also in their ability to assimilate pollution and adapt to changes brought about by agricultural practices. The degree or intensity of agriculture's effects on environmental resource quality will likely correspond to these differences in adaptability. Third, agricultural production technologies have been developed and applied without systematic consideration of their environmental implications, and frequently without being tailored to match regional or local agroevironmental vulnerabilities. Consequently, agriculture's effects on the quality of environmental resources can be prevalent and, in susceptible pockets, particularly intense. Places where the effects are intense are logical priority areas.

Several efforts have been made to identify particularly susceptible areas over the past 20 years. USDA is charged with carrying out an assessment every 10 years of natural resource conditions on nonfederal lands under the Resource Conservation Act (98). The RCA analysis models physical, biological, and economic systems to forecast possible natural resource conditions over the next 50 years. These forecasts can highlight areas expected to be under high stress. A second national study has estimated the geographical distribution of agroenvironmental conditions and susceptibilities using existing databases, physical and biological models of agroenvironmental relationships, and limited economic data (27). The resulting database helps identify how agriculture's environmental performance might change under alternative programs, including targeting schemes. Other studies have focused on particular environmental subjects, such as regional vulnerability to groundwater contamination (32). Although these studies add important information to the policy dialogue, their model analyses are limited by incomplete agroenvironmental data.

To ameliorate the problem of data deficiencies, OTA worked with a panel of leading scientists to identify agroenvironmental priority areas as noted above (see box 1). A central finding emerged from the exercise: *It is possible to use an expert panel to identify agroenvironmental priority areas and especially relevant when existing science and databases are incomplete.*

The conclusions of the expert panel, combined with analysis performed by OTA, indicate that agriculture's effects on the environment can be divided into three general categories: water quality, wildlife habitat, and soil quality. These three categories provide an umbrella for considering the many aspects of dynamic agroenvironmental systems. For instance, a full assessment of water quality related to agriculture would encompass surface water, groundwater, wetlands, atmospheric moisture, water conservation, and their interactions. Habitat quality could incorporate plants, insects, and wildlife dimensions as well as dynamic issues such as biodiversity. Soil quality might encompass erosion, chemical and physical attributes of soils, soil as a habitat for microbial life forms, and soil as a buffer for water quality. Regrettably, the available science is not sufficiently developed to fully consider all of these dimensions and their systemic relationships.

This report consequently focuses on the subjects for which scientific evidence about the connection between agriculture and environmental quality is most complete:

- surface water quality;
- wildlife habitat; and
- soil quality.

In OTA's judgment, this trio of categories covers the major set of agroenvironmental priorities. Also, they overlap with or incorporate some of the priorities from the seven other subject categories covered by the expert panel: range (grazing) lands, wetland and riparian areas, water conservation, groundwater quality, plant diversity, insect diversity, and rural landscapes. These overlaps suggest interrelationships among the categories that emphasize the importance of managing entire agroenvironmental systems—a major theme of this report.

However, the priorities for the three categories should not be interpreted as covering all environmental dimensions related to agriculture, only those for which OTA judged the information to be sufficiently complete at this point. The priorities for the seven other categories presented in appendix A provide additional, albeit incomplete, information that should be incorporated into a full assessment of agriculture's environmental performance. For example, the priorities for range (grazing) lands, water conservation, and groundwater add agroenvironmental dimensions relevant to the western U.S. that are only minimally captured by the three selected categories. OTA recommends continued development of the subject areas covered in appendix A and their full inclusion in further targeting processes.

Finally, air quality should also be added as a separate environmental category in future assessments. The major traditional air quality problem associated with agriculture, wind erosion causing dust storms, was covered under soil quality. However, more recent air quality concerns related to agriculture, including odors emanating from large confined animal facilities, carbon sequestration and pollution damages to crops, need to be systematically incorporated. Although some of these types of problems may be dealt with at the local or state level, others can become extensive enough to require the involvement of several states and the federal government.

The common themes that emanate from analyzing priority problems for the three categories, and, indeed, the expert panel process as a whole, offer numerous lessons for identifying environmental priorities in agriculture. An overarching insight from the process is that the agroenvironmental effects interact in systems: a change in soil quality, for instance, likely has implications for water and wildlife habitat as well. Therefore, in targeting agroenvironmental priorities, it is important to identify the *causes* of the problems and not focus on observed symptoms.

Whether the priorities identified here—or, indeed, whether any agroenvironmental priorities—warrant public action is a political, not a scientific, decision. Scientists can alert policymakers to agricultural activities or conditions that may pose real environmental risks and the systematic relationships that tie them to their sources. But policymakers must weigh those risks and decide how best to expend public resources. Processes that join science and policymaking are currently immature, and yet the need for closer links between them is likely to increase as population and production pressures place more stress on environmental resources. Assuming agriculture's contribution to chronic national environmental problems persists, as it has in the case of nonpoint surface water pollution,[5] cost-effective programs are unlikely to be developed without applying much more sophisticated environmental and social science.

Agriculture and Surface Water Quality

Common production practices on many farms can and do induce changes in water quality. These changes may manifest themselves directly in surface water quality or quantity, with indirect effects spreading throughout the hydrologic system. Agricultural pollutants—particularly sediment, nutrients, pathogens, insecticides, and herbicides—are commonly found in surface waters around the country (15,23,25,67,79,96, 101). Aggregate data indicate that agriculture is the primary cause of surface water quality impairment nationwide (67,101). Evidence shows that although concentrations of common agricultural pollutants in surface water may have declined since the 1980s, 71 percent of U.S. cropland remains in watersheds where at least one agricultural pollutant exceeds standards for recreation or ecological health (80).

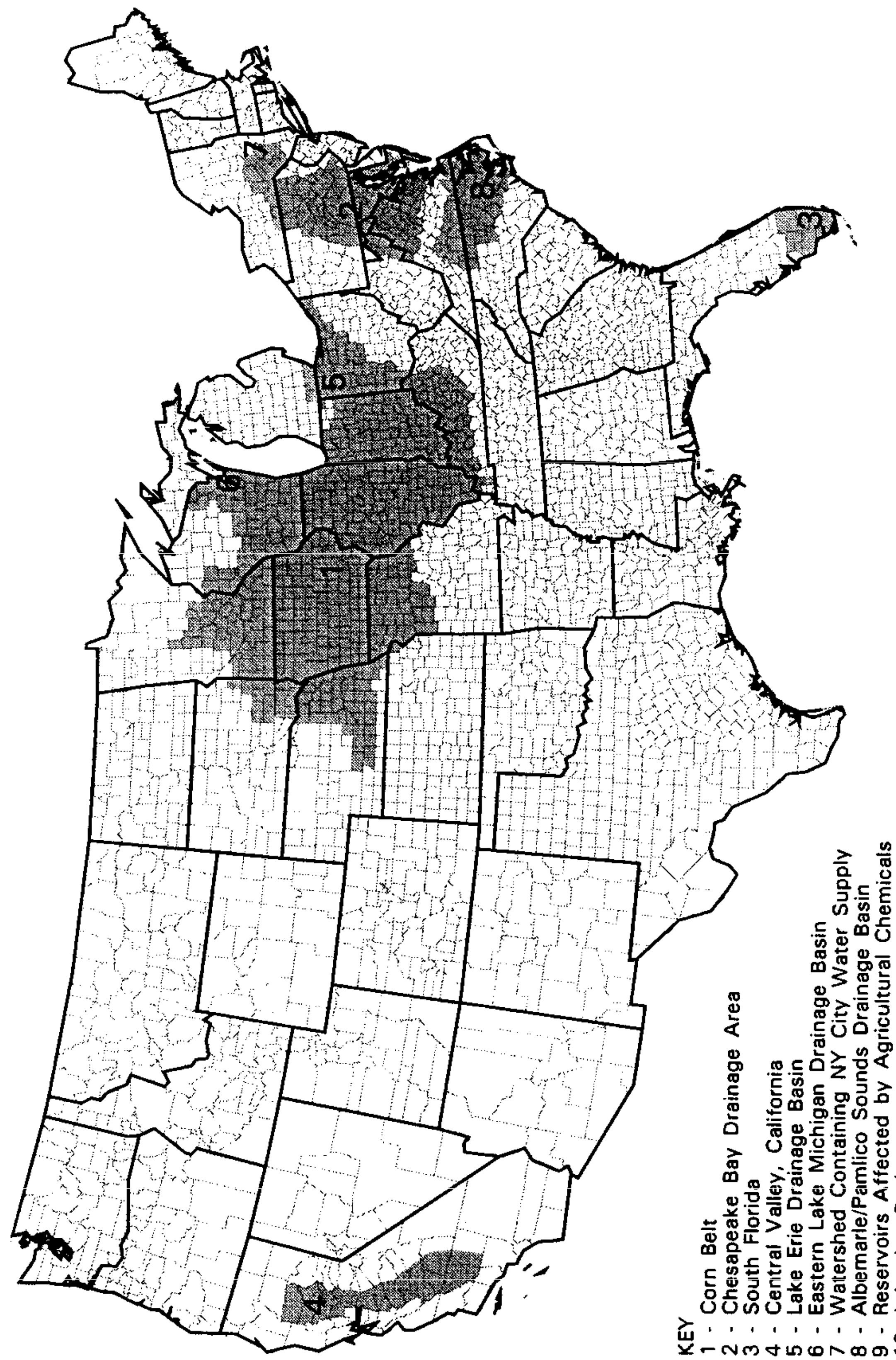
Findings

Working with the expert panel, OTA identified eight geographic areas and two general categories in which surface water quality is severely degraded or in need of special protection (figure 1 and table 2). These priorities were selected according to two basic criteria: that agriculture is a major source of large documented pollution (implying significant potential benefits), and that the agricultural industry will necessarily be involved in reversing degradation or ensuring future protection (77). Considering these criteria, the expert panel and OTA gave preference to sites that have high commercial or ecological value. Overall, the priorities highlight opportunities to remedy significant damages to drinking water supplies caused by agriculture; to target links between poor surface water quality and degraded wildlife habitat; and to protect commercial and other regional economic services provided by surface waters.

Impairment of surface water is of particular concern in the Corn Belt, where fertilizer and pesticide residues are widespread and highly concentrated in many streams, rivers, and lakes. Of all cropland in the upper Midwest, 87 percent is located in basins that violate criteria for acceptable water quality (81). Concentrations of nitrate in some streams exceed EPA drinking water standards. Excessive nitrate in drinking water has been linked to methemoglobulemia (“blue baby syndrome”) (29) and, clinically, to cancer-causing compounds in humans (48). High phosphorus levels create favorable conditions for eutrophication, a condition of excessive algae growth that impairs recreational uses and degrades fish habitat (79). In many basins, concentrations of bacteria from livestock waste are very high (79). Finally, herbicides, particularly atrazine, have been detected at levels that exceed EPA drinking water standards in many streams during spring and summer months (24).

Pollutants from Corn Belt agriculture have significant impacts elsewhere in the Mississippi drainage basin as well. Sediment and chemicals that originate in the Corn Belt converge in the Mississippi River and flow southward. Both drinking water and aquatic habitat quality are compromised all the way down the Mississippi River, with hundreds of thousands of tons of waterborne agricultural contaminants ending up in Louisiana’s Gulf Coast estuaries (24). The impact of these contaminants on aquatic life and the function of the Gulf’s estuarine ecosystems is not well documented at this time. However, the known detrimental effects of agricultural pollution on other estuaries, combined with the high commercial and ecological value of estuaries, provide a basis for concern. The Mississippi River and drainage area was also identified as a priority for wetlands and riparian areas (40).

[5] For example, diffuse agricultural runoff has been a nettlesome aspect of nonpoint water pollution control for 20 years, and now stands as the primary impediment to achieving national water quality goals (38).



SOURCE: Office of Technology Assessment, 1995.

TABLE 2: Surface Water Quality Priorities

Priorities and Justification	Links to Agriculture
Area 1: Corn Belt/Mississippi Drainage Basin ✧●♠✶ Prevalence of agricultural fertilizer and pesticide residues in regional streams degrades regional sources of drinking water. Also, these pollutants migrate through the Mississippi River to Gulf Coast estuaries.	Chemical use in the watershed that drains to the basin and proximity of fields and livestock operations to streams are chief agricultural links. Movement of runoff may be facilitated by drainage structures.
Area 2: Chesapeake Bay Drainage Basin ●♠✶♥ Degradation of the nation's largest estuary causes declines in wildlife and losses to commercial fishing operations. Nutrients from agriculture have historically been a primary cause of eutrophication damages.	Fertilizer use and dairy farming in the watershed that drains to the basin are the primary agricultural sources of nutrients that promote eutrophication.
Area 3: South Florida/Everglades Drainage Basin ✶ The Everglades and Florida Bay are adversely affected by nutrient inflows and by inadequate water flow to maintain diverse wetland function.	Nutrient residues in runoff from sugar plantations and dairy farms promote eutrophication. Drainage and flood control that benefits agriculture changes water flow.
Area 4: Central Valley, California ♦✶♠ High levels of pesticide and fertilizer residues degrade aquatic habitat in the San Joaquin River, Sacramento River, and Suisan Bay.	Chemical use is the primary link. Irrigation drainage flows facilitate the movement of runoff through the watershed.
Area 5: Lake Erie Drainage Basin ✧●✶♠ Eutrophication of Lake Erie degrades aquatic habitat. Lake Erie gets the largest loadings of agricultural nutrients of all Great Lakes	Fertilizer use on regional farmlands is associated with extremely large loadings (total amounts) of phosphorus entering the lake in runoff.
Area 6: Lake Michigan Drainage Basin ✶✧♠ The long residence time of water in Lake Michigan (about 100 years) increases susceptibility to degradation by accumulated pollutants. Municipal water supplies to Green Bay and Milwaukee, Wisconsin, and the role of Lake Michigan in wildlife habitat are key concerns.	Runoff containing fertilizer and pesticide residues from croplands, nutrients and bacteria from livestock operations, and sediment have been linked to agriculture.
Area 7: Catskills Watershed ✶ Efforts to protect the New York City water supply from pollutants includes "whole farm planning" for the watershed. A test case for watershed management.	Runoff related to dairy and other farms is at issue. The manner in which conflicts over land use are resolved and the degree of success reached in water quality protection may make this case a model for other regions.
Area 8: Albemarle/Pamlico Sounds Drainage Basin ● Runoff of agricultural chemicals substantially impairs the quality of aquatic habitat.	Polluted runoff, linked to chemical use, degrades water quality.
Area 9: Slow-recharging Midwestern Reservoirs Reservoirs contain high levels of herbicides, phosphorus and nitrate, which degrade aquatic habitat and human drinking water supplies.	Fertilizer and pesticide residue runoff can converge in reservoirs. Herbicides can accumulate to levels that exceed drinking water standards year-round.
Area 10: Irrigation drainage areas Irrigation flushes heavy metals and salts held in arid soils into waterways that influence aquatic and wetland habitats.	Irrigation may be incompatible with high surface water quality here. Water diversions for agriculture may make problems worse by reducing surface flows that could dilute toxins.

♣ overlaps with surface water quality priorities
♦ overlaps with water conservation priorities
● overlaps with soil quality priorities
✶ overlaps with wetland and riparian priorities
✧ overlaps with wildlife habitat priorities
♠ overlaps with groundwater priorities
♥ overlaps with rangeland quality priorities

The Chesapeake Bay, which supports many commercial fishing activities, recreational uses, and ecological functions, is significantly impaired by eutrophication caused in part by the drainage of agricultural nutrients (residues from fertilizer and livestock manure).[6] Indeed, livestock waste problems make this drainage basin both a surface water quality and rangeland/pasture priority area (74). In the Chesapeake Bay, the largest estuary in the United States and one of the largest in the world, 30 years of declining fish, oyster, and to a lesser extent, shellfish populations have been linked to agriculture. The chief link is the annual influx of millions of pounds of nutrients that, through eutrophication, reduce the dissolved oxygen that is crucial to the propagation of many aquatic species (4,34). These ecological damages translate into direct economic losses to commercial and sport fishing of as much as $16 million per year (30). The value of non-commercial environmental losses has not been calculated.

The National Oceanographic and Atmospheric Administration estimates that of all U.S. estuaries, the Albemarle-Pamlico Sounds receive the largest loadings of hazardous agricultural chemicals (62). Nutrient residues, primarily from agriculture, are also among the highest in the nation (53). As already mentioned, excessive nutrients in estuaries dramatically reduce the quality of aquatic habitat and productivity. The Sounds comprise the second-largest estuary in the country.

Accumulation of agricultural nutrients that promote eutrophication is also a problem in Lake Erie, and has implications for aquatic habitat and recreational activities. The total amount of nutrient residues reaching the Great Lakes coastal zone is the second—highest in the nation, exceeded only by loadings reaching the Gulf of Mexico. However, when considered in terms of per unit drainage area, the Great Lakes area leads the nation in the amount of nitrate, phosphorus, and sediment reaching its coastal zone. Lake Erie receives the greatest amount of phosphorus runoff of all five Great Lakes (79). Even though not all of these pollutants are due to agricultural activity, water quality targets set jointly between the United States and Canada will not be met without effective phosphorus control from agricultural producers (6).

Eutrophication is also a concern, but not the only concern, relating agriculture to the quality of water in southern Lake Michigan. Accumulation of numerous agrichemicals, ranging from phosphorus to DDT, places the drinking water and aquatic services of Lake Michigan at risk. Because it takes nearly a century for water in Lake Michigan to be replaced naturally (54), the lake is particularly susceptible to contamination by pollutants that persist in water and accumulate over time. Even though annual amounts are small compared with those in Lake Erie, a chronic inflow of agricultural pollutants can add up to significant problems because the lake is used as a primary drinking water source by millions of people and supports multimillion-dollar commercial and sport fishing industries. Some problems associated with water quality in Lake Michigan, such as contaminated fish, can be dealt with only by issuing fish consumption advisories in Great Lakes states. Drinking water supplies for the cities of Green Bay and Milwaukee, Wisconsin, may be at particular risk from agricultural pollution of Lake Michigan because conventional water treatment processes can not remove all agricultural pollutants (47).

Midwestern reservoirs, such as Perry Lake, Kansas, are also prone to accumulated herbicide runoff because they recharge very slowly: previous seasons of herbicide runoff have not been flushed out before a new season of runoff enters the reservoir. Thus, low-concentration, chronic influxes of pesticides to these water bodies can

[6] Eurtrophication is a process in which fertilizer residues such as phosphorus and nitrate, entering water bodies in agricultural runoff, enhance the growth of aquatic algae. This excessive growth creates “blooms” of vegetation that use up dissolved oxygen on which fish and other organisms depend. Sediment accumulation, also connected with runoff, may simultaneously cloud water, elevate water temperature, impede gill function, and smother hatching sites.

accumulate to amounts that exceed EPA drinking water standards year round (table 3). Because midwestern reservoirs are key sources of drinking water, recreational swimming, and fishing, accumulated agrichemicals can pose a significant risk to human health as well as wildlife.

Protection of the Croton and Catskills-Delaware watersheds that supply New York City's drinking water is emerging as an important example of the relationship between agriculture and surface water quality. Daily, these two watersheds produce 1.2 billion gallons of water of such high quality that, historically, no filtration has been needed. Progressive development of lands in the watershed has prompted regional EPA officials to explore the need for a filtration system to ensure safe drinking water. New York City officials prefer to prevent pollution through watershed management, which includes a program of "whole farming planning." Two aspects of this case make it an important test for watershed management as a means of enhancing compatibility between agriculture and water quality. First, will watershed management, without water treatment, adequately protect drinking water quality? Second, can the interests of local, rural farmers and of urban drinking water users be reconciled through a watershed management approach?

A combination of water quantity and quality dimensions is at issue in the degradation of the Everglades, making it both a surface water and wetlands priority (40,77). Residues of fertilizers used in the sugar fields of south-central Florida and pollutants from dairy livestock waste have

TABLE 3: Atrazine Concentrations in Water Samples From Selected Midwestern Reservoirs During Winter Months, 1990–92

Reservoir	Sample date	Atrazine concentration* (μg/l)
Illinois		
Carlyle Lake outflow	1-3-92	2.3
Lake Decatur outflow	1-8-92	.2
Rend Lake spillway	1-2-92	.6
Lake Shelbyville outflow	1-8-92	1.1
Lake Springfield at Sugar Creek	1-30-92	2.5
Lake Springfield at Spaulding Dam	1-30-92	4.0 *
Iowa		
Coralville Lake	2-21-92	.2
Corydon Reservoir	winter, 1992	10.0 *
Rathbun Reservoir	—12-90	3.7 *
Rathbun Reservoir	2-20-92	2.8
Red Rock Reservoir	2-12-92	.2
Saylorville Lake	2-12-92	.1
Kansas		
Perry Lake	2-3-91	3.9 *
Missouri		
Long Branch Reservoir	—12-90	2.0
Smithville Reservoir	—12-90	3.6 *

* Exceeds EPA drinking water standards for atrazine of 3μg/l, where μg/l,= micrograms per liter.

* NOTES: Atrazine concentration determined by GC (gas chromatography) or ELISA (immunoassay); —, no data;

SOURCE: D.A. Goolsby, et al. "Persistence of Herbicides in Selected Reservoirs in the Midwestern United States: Some Preliminary Results", Goolsby, D.A., L.L. Boyer and G.E. Mallard, eds., in *Selected Papers on Agricultural Chemical in Water Resource of the Mid Continental United States,* U.S. Geological Survey Open-File Report 93-418 Denver, Colorado, 1993.

been implicated in the eutrophication of the Everglades. Eutrophication has led to the decline of numerous plant and animal species native to the Everglades ecosystem. An additional concern is the presence of mercury in the water, at concentrations that have prompted fish consumption advisories. The source of the mercury is believed to be dried peat in drained agricultural soils. Finally, competition for available water in the Everglades persists among agricultural, municipal, flood control and ecological uses. This competition reduces water flows to the Everglades and can increase the concentration of pollutants draining into the Everglades. Agriculture is not the only source of problems with surface water and associated natural habitat, but its role is nonetheless significant. Agricultural activity affects the viability of this internationally unique ecosystem, and the industry is likely to be a necessary partner in any solution.

The California Central Valley and Gunnison/Uncompahgre irrigation districts further illustrate how convergence between water quantity and quality dimensions can exacerbate environmental sensitivity, causing surface water and wetlands problems (40,77). Irrigation can flush naturally occurring toxins out of arid soils and into drainage flows that move downstream. From drainage flows, metals and soil salts are washed into streams, rivers, and wetlands, where they risk harming or killing[7] aquatic life and migratory waterfowl, as well as other life forms in the food chain. Testing of fish and waterfowl in some of these irrigated areas reveals high levels of boron, cadmium, selenium, copper, mercury, and zinc (11). The toxic metal selenium, the accumulation of which was implicated in the now-infamous demise of the Kesterson National Wildlife Refuge, a waterfowl nesting area in California, would have remained sequestered in soil without irrigation.

Lessons for Targeting Water Quality

Three lessons from these findings can guide federal, state, and local efforts in identifying water quality targets. The weight of scientific evidence shows the crucial importance of managing plant cover on and around fields; pesticides and fertilizer; and livestock manure (either as a fertilizer added to crops or as a waste product of livestock operations). In general, the following three aspects of agricultural production are critical to determining what effect agriculture has on surface water quality.

Some common agricultural pollutants resist degradation once they enter water bodies. Scientists do not know how long it takes for certain commonly used pesticides to degrade once they enter surface water. Evidence shows that atrazine, for example, can remain in large lakes and reservoirs for the months or even years it may take for water volume to be replaced naturally. Consequently, it is important to detect risks to drinking water and aquatic habitat early, when correction and prevention are most feasible. It is also wise to seek technologies that prevent pollution from getting into water in the first place. For instance, as already noted, removing herbicides from drinking water is beyond the capability of most water-treatment technologies.

Agricultural pollutants have a tendency to travel once they are waterborne. Therefore, assessing the vulnerability or actual degradation of water quality associated with agriculture may entail inspecting fairly extensive drainage systems. For example, pollution concentrations near a single farm may be too low to trigger concern, but pollutants transported through streams and rivers from many farms can accumulate to significant amounts at some terminal drainage points. The most dramatic example of this phenomenon occurs in the Mississippi Drainage Basin as noted above, where a “soup” of herbicides, insecticides, nitrate, and sediment builds up to

[7] Lethal risks connote increased mortality (death); nonlethal risks may include behavioral or developmental problems and reproductive failure.

hundreds of thousands of tons by the time it reaches the Gulf Coast estuaries of Louisiana.

Surface water, groundwater, wetlands, and water conservation conditions are interrelated. The movements of pesticides between groundwater and surface water are well documented (105). In Colorado, fertilizer residues flushing out of groundwater enter the South Platte River (49). The excessive concentration of salts in western irrigation drainage, which ultimately degrades aquatic habitat, is partly caused by the reduced surface water flows that result when groundwater and rivers are tapped to supply irrigation water (20). In the Northern High Plains, the relative lack of surface water flows, combined with the flushing action of irrigation and intensive chemical use, makes infiltration of pollutants to groundwater much more prevalent (42). These examples reinforce the theme of seeking the sources of water quality problems, not simply targeting symptoms.

Agriculture and Wildlife Habitat

Grasslands or wetlands that are retained within agricultural regions can provide ideal habitat for numerous species of wildlife. In the past four decades, however, changes in agriculture have resulted in the conversion of grasslands and wetlands to crop production, tillage of larger fields, less crop diversity, fewer rotations among crops, and greater dependence on fertilizers and pesticides. The degree to which these broadly characterized trends occur in agriculturally dominated regions varies, of course, and the role of agriculture in affecting the quality and distribution of wildlife habitat is much more significant in some regions than in others.

The changes brought about by crop cultivation and grazing have enhanced habitat for some species but diminished habitat for others. However, the overall patterns and trends showed population declines, even in ring-necked pheasants, cottontail rabbits, bobwhite quail, ground-nesting birds, and other species that are well adapted to agricultural land uses (17,28,72,84). Species that depend on grassland habitat experienced more precipitous declines due to isolation and fragmentation of pockets of grassland remaining (37,75).[8] Losses in the diversity and quality of aquatic habitats and the elevated presence of agrichemicals in aquatic ecosystems are also related to these trends (63,76).[9]

Recently, populations of pheasant and other wildlife species have increased significantly as a direct result of long-term land set-asides, principally under the CRP. However, it should be noted that this conservation approach did not increase the long-term compatibility between commercial agricultural and protection of wildlife. The increase in habitat and wildlife populations afforded by CRP lands can be ensured only by continuing rental payments or long-term easements.

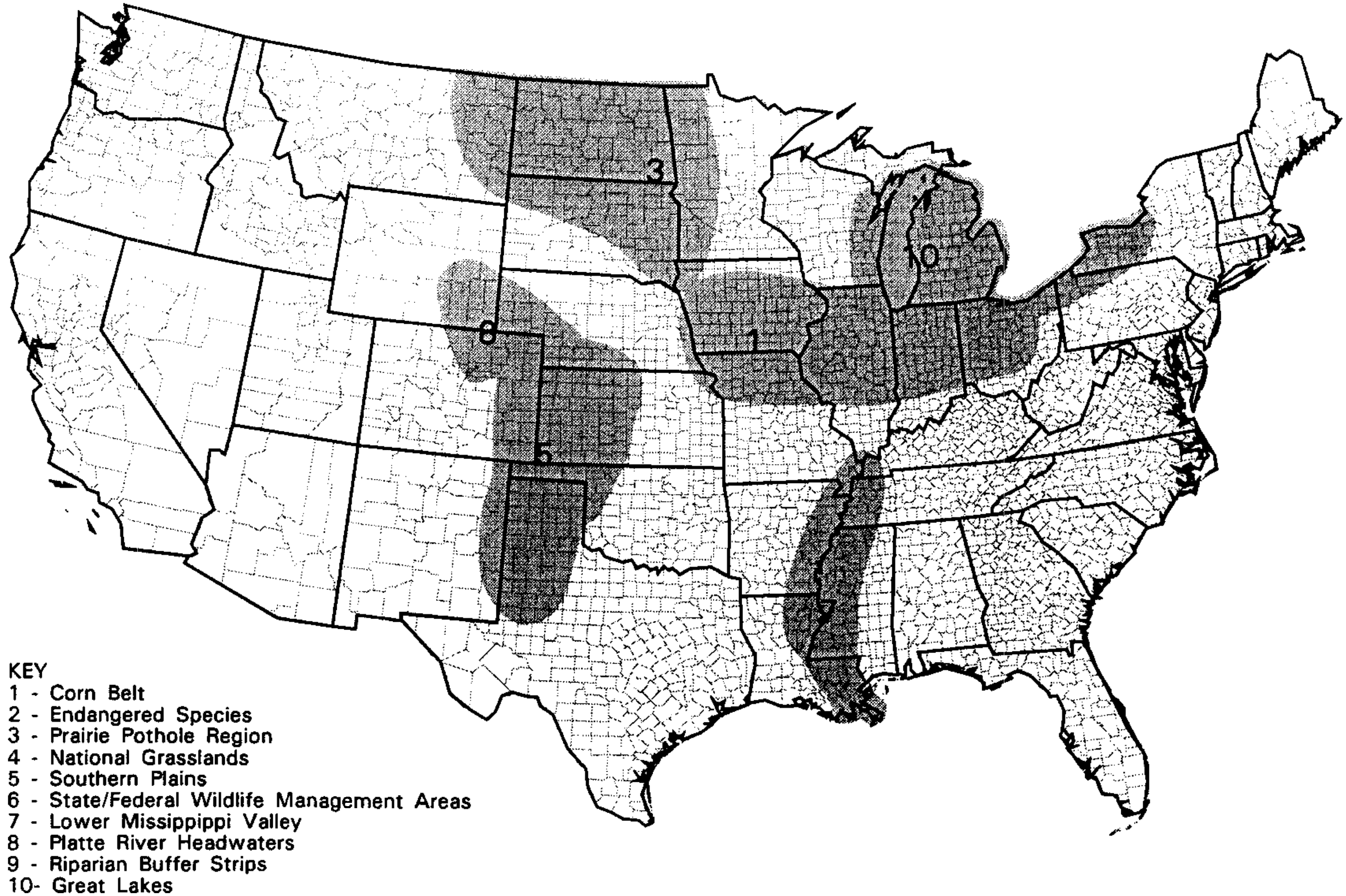
Findings

As in the case of water quality, OTA targeted 10 priority areas where agriculture has major effects on the quality and distribution of wildlife habitat (figure 2 and table 4). Four of the selections (items 2, 4, 6, and 9) represent general cate-

[8] The conversion of 30 percent of short-grass prairie and 99.9 percent of native tallgrass prairie in the Great Plains states, much of this to intensive crop production, has resulted in declines of many wildlife species. At least 55 grassland wildlife species in the U.S. are listed as threatened or endangered as a direct result of this habitat loss, and 728 are candidates for listing. Several species whose habitat needs include large tracts of native grasses have already become extinct (75).

[9] For instance, sediment accumulation and chemical exposure may degrade habitat close to farmed lands. EPA estimated that in the 1980s, one to two million birds died every year through exposure to the pesticide carbofuran, and FWS determined that nearly 20 percent of endangered or threatened species in 1988 were listed, in part, because of pesticides (100). Nutrients, sediment and herbicides carried in runoff to surface waters promote changes in water quality and surface flows that reduce dissolved oxygen, impair gills, smother hatching sites or diminish the food supply for aquatic herbivores, and chronic, low-level concentrations of pesticides have been linked to reproductive failure and developmental abnormalities in fish and other aquatic organisms (12,55,86). Bioaccumulative pesticides which concentrate along the food chain have led to documented developmental, behavioral, immunological and reproductive impairments, particularly in sensitive species of fish, birds and mammals (12).

FIGURE 2: Wildlife Habitat Priorities



SOURCE: Office of Technology Assessment, 1995.

TABLE 4: Wildlife Habitat Priorities

Priorities and Justification	Links to Agriculture
Area 1: Corn Belt ♣●✶♠	
Common species (including ducks, pheasants, and songbirds) in severe decline have been restored by CRP, but are vulnerable to resumed production on set-aside lands.	Polluted runoff impairs water habitat. Cropping practices disturb nesting sites during breeding and fledging seasons. Field patterns eliminate stream buffers and long-term cover needed for nesting and protection from predators.
Area 2: Endangered Species/Habitats	
Species viability is at risk where grassland and aquatic habitats are diminished.	AS ABOVE. Some species are particularly sensitive to changes brought about by agriculture.
Area 3: Prairie Potholes ♣●✶♥	
A key breeding ground and migration site for many animals, waterfowl and grassland birds are vulnerable to habitat modification if production resumes on set-aside lands.	Grassland and wetland habitats are converted to fields. Resulting land use practices leave bare ground in winter, disturb nesting sites during breeding and fledging seasons, and eliminate long-term cover.
Area 4: National Grasslands	
The layout of prairie preserves does not fully support declining nongame birds and other grassland species they are intended to protect.	Preserves are fragmented by agricultural activities within their perimeters. Most prairie wildlife requires large, unbroken tracts of habitat.
Area 5: Southern Plains ♦●♥	
Restoration of declining wildlife in the Plains, as a result of CRP, is vulnerable to a resumption of production on set-aside lands.	Cultivated agricultural production may be incompatible with wildlife gains made through CRP.
Area 6: State and Federal Wildlife Management Areas	
Nesting success and survival of managed species would improve if habitat areas were larger and buffered from agricultural activity around them.	Existing refuges are hemmed in by intensive agriculture around their perimeters.
Area 7: Lower Mississippi Valley ●✶	
A chief winter habitat for waterfowl, shore birds, and nongame birds. Habitat quality affects reproductive success in the spring. Loss of 80 percent of bottomland hardwood habitat and degraded water quality diminishes habitat quantity and quality.	Extensive conversion of forest and wetland areas to cropland, straightening of natural streams, and migration of pesticides, fertilizer and sediment from the Corn Belt combine to diminish wildlife habitat in this region.
Area 8: Platte River Headwaters ♦●✶♠♥	
An important remnant of short-grass prairie, habitat losses continue to cause declines in both population and diversity of birds, mammals and fish.	Conversion of grasslands to cropland, eradication of prairie dogs (a “keystone” species which supports other species), and fragmentation of residual grassland areas diminish availability of habitat.
Area 9: Riparian Areas	
Streams, rivers, wetlands that receive farm runoff (sediment, fertilizer residues, pesticide residues, bacteria from livestock waste) are degraded.	Fields are cultivated too close to streams, which makes it easy for field runoff to enter streams and , ultimately, be transported through watersheds. Improperly managed livestock manure also enters streams.
Area 10: Great Lakes basin ♣✶	
Agricultural pollutants carried in runoff pervade tributaries and lakes from which millions of people consume drinking water and fish. Loss of aquatic habitat reduces spawning stock and diversity of fish preferred for sport and commercial catches.	AS ABOVE. Some species are particularly sensitive to changes brought about by agriculture.

♣ overlaps with surface water quality priorities
♦ overlaps with water conservation priorities
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✧ overlaps with wildlife habitat priorities
♠ overlaps with groundwater priorities
♥ overlaps with rangeland quality priorities

gories that include multiple locations. Overall, the choices of wildlife priority areas were based on several criteria: areas where agriculture is associated with the loss of unique habitats for declining species; where the ability of habitats to sustain viable populations of common species is a concern; where protecting wildlife habitats is integrally related to local or regional economic viability; and where beneficial policies and land uses already in place could be strengthened (2). The main emphasis in selecting wildlife priority areas was on enabling ecologically viable communities to co-exist with agricultural land uses. Although priorities were generally keyed to relatively large geographic regions, the problems or potentials observed are not uniform or equivalent across the entire selected region. More precise identification of priority sites (for instance, counties or drainage basins) can best be provided by state or federal biologists familiar with unique regional issues and priorities.

Admittedly, geographic regions that were not included in the 10 priority areas are of concern because they provide important wildlife habitat. California's Central Valley, for example, contains critical wintering habitat for migratory birds and declining species. However, residential/industrial development in this region means that agricultural changes will not necessarily enhance habitat substantially. Declining stocks of salmon in the Pacific Northwest are also an issue of national importance. However, agriculture is only one of many factors impinging upon salmon habitat (others include logging; dams on major rivers and tributaries; commercial, subsistence, and recreational fishing; and urban and industrial development). Further, the science defining the relative roles of these factors is incomplete.

The Corn Belt is the most intensively farmed region in the country. A shift to large fields with minimal diversity among crops has caused a regionwide loss of habitat diversity. Greater dependence on synthetic fertilizers to maintain high crop yields, and on herbicides and insecticides to control pests, has increased contamination of surface waters and reduced the supply of plants and insects that many birds eat. Removal of fencerows, shelterbelts, wetland, and vegetated riparian zones has eliminated permanent, year-to-year cover that is critical to game and nongame species. The net effects of these changes in land use—fewer kinds of wildlife species and a decreasing ability of the landscape to support common wildlife species—may appear insignificant at the farm level, but are striking in a large, intensively cultivated region.

Major impacts on river systems and riparian areas occur in the Great Lakes drainage basin due to channelization (that is, the straightening of streams) and agrichemical contamination of tributary surface waters. Drastic reductions in aquatic habitats and fisheries have been observed in Great Lakes ecosystems. Coastal wetlands and marshes have been lost or severely degraded. Channelization and agrichemical- and sediment-laden runoff from agricultural fields have degraded the quality of aquatic habitats, resulting in loss of spawning habitats and numerous changes in water characteristics that affect fish populations in tributaries as well as the Great Lakes themselves.

The Lower Mississippi Valley is the major winter and migratory area for many of North America's waterfowl and shorebird populations. The region suffered major losses of habitat in recent decades due to conversion of wetlands and bottomland forest to agricultural production, and remaining wetland quality has been reduced by runoff of agricultural pesticides, fertilizers, and sediment. The quality of habitat within this region affects the physiological fitness of wintering birds and their reproductive success during the following breeding season. Sedimentation and agricultural chemical runoff reduce the quality of coastal wetland ecosystems and estuarine habitats, which are essential for reproduction in coastal fisheries. The Lower Mississippi was also identified as a wetland and riparian priority on the basis of diking, drainage, cutting of bottomland woodlands, and channelization (40).

Nationwide, implications for improvement in surface water quality and habitat are associated with riparian areas of stream and river systems, as noted by three expert panelists (2,40,77). Extensive channelization of river systems has eliminated or severely degraded riparian habitats. Quality, availability, and productivity of aquatic habitats has been reduced by as much as 90 percent in some midwestern river systems. Improved riparian vegetation and buffer strips can reduce sediment and nutrient concentration in agricultural runoff by more than 90 percent (21), providing benefits to aquatic and wetland associated wildlife. Enhancement of riparian habitats could benefit migratory birds, freshwater and anadromous fisheries (fish that spawn in fresh waters but travel to salt water, for instance, salmon), and game species. More vegetated riparian areas also improve upstream flood storage capacity.

The Prairie Pothole region is a critical breeding and migratory area for all kinds of migratory birds and waterfowl. Approximately 50 percent of North America's duck population is bred in the Pothole region (31). Most of the region's temporary wetlands, important to shorebirds and pairing of waterfowl, have been converted to farmland. But wetlands alone cannot produce ducks, and retention of relatively large blocks of grasslands adjacent to or near wetlands is essential to maintaining populations of waterfowl and upland bird species.

The eastern portion of the Prairie Pothole area contains highly erodible croplands that are now enrolled in the CRP. Shifting from crop production to grazing could provide a commercially viable alternative that also maintains the permanent groundcover needed for wildlife (74). Wildlife habitat in the western fringe of the Prairie Pothole region is being diminished by the spread of leafy spurge, a noxious nonindigenous weed that is dominating native grassland/rangeland plants. This change in plant mix can severely reduce the availability of forage for many native wildlife species (74).

Reduction of native short-grass prairies in western states is associated with the decline of many species. In the Platte River headwaters, despite the retention of an important remnant of short-grass prairie, populations of mountain plover, lark bunting, swift fox, prairie dogs, and several kinds of fish have declined drastically (2). Moreover, the loss of "keystone species" such as the prairie dog, which have largely been exterminated because they have conflicted with agricultural operations, has direct ramifications for the viability of other species, including the burrowing owl, mountain plover, and numerous species of raptors, including wintering bald eagles (2,75).

Because so much habitat has been lost due to agriculture in the Plains, and because much of that lost habitat was grasslands, wildlife habitat restored by CRP-protected grasslands in the Southern Plains is considered a high agroenvironmental priority. Increases in populations of pheasants and other small game have had positive effects on rural economies in this area. The same phenomenon pertains to other grassland areas. Pheasant hunting is worth $70 million annually in South Dakota alone (70), but the region where pheasant hunting is popular stretches from North Dakota to the Texas Panhandle, and from Eastern Colorado to Iowa. Although the status of game species does not indicate the availability of habitat for all species, and particularly not for land animals that require large expanses of prairie or forest, the status of pheasants is a barometer for the availability of habitat for game and nongame species that thrive in the fragmented, "edge-rich" environment carved out by the interspersion of crop cultivation and grassland.

National Grasslands (special areas designated for management purposes) provide habitat for declining game and non-game species that require large tracts of grassland not edge habitats. The majority of these protected grasslands are fragmented by farmed lands within their boundaries, however, and so their effectiveness is limited. Even though grazing can complement many habitat/wildlife management objectives, introducing non-native grasses on grazed lands within National Grassland boundaries has negative effects on wildlife associated with grassland habitats.

Improving habitat associated with state managed wildlife and recreation areas is a priority because most state areas are heavily used by the public and isolated within intensively farmed regions. Efforts to increase the size and critical mass of these sites in producing wildlife, by providing suitable vegetative cover on cropland adjacent to these management areas, would enhance populations of game and nongame wildlife and also benefit land for public use. Lands adjacent to management areas need not be open to the public to provide environmental and recreational benefits. Areas managed by the state are a higher priority than areas managed by the federal government, because they are distributed more extensively across the nation.

Although increasing emphasis is being placed on protecting habitats for communities of species rather than individual species, protecting specific endangered species has a long history. Science indicates that protecting endangered species goes hand-in-hand with protecting their habitats. The causes of habitat decline for endangered species varies across the nation, but loss of grassland cover, greater dependence upon agrichemicals, loss of wetland and riparian areas, competition for water that flows in streams and rivers, and land conversion are key among them.

Lessons for Targeting Wildlife Habitat

Is it possible to maintain a highly productive agricultural system in a way that sustains viable wildlife habitat in rural areas? Lessons for identifying priority targets related to agriculture and wildlife reflect extensive scientific evidence that specific kinds of farming technologies and land use patterns, not all, are detrimental to habitat protection.

Preserving wildlife means preserving and restoring long-term grassland, wetland, and aquatic habitats. Since the 1950s, farmers have moved more toward maintaining larger, contiguous fields. This trend fragments and minimizes natural habitats. But studies show that adequate long-term cover is the critical factor in enabling wildlife to breed successfully. By comparison, seasonal cover created by annual set-aside programs is ineffective (8). Indeed, field studies show that the availability of adequate cover is even more important than food or water in determining habitat quality in many areas dominated by agriculture.

It is estimated that about 4 to 6 percent of the land in agricultural regions, if established in long-term grassland cover of sufficient quality, could support abundant and diverse wildlife (2). Establishing long-term plant cover on approximately 2 million acres of riparian zones[10] that are currently unprotected in agricultural areas could make a significant contribution to the quality of riparian, aquatic, and wetland habitat (44).

The configuration of habitats determines which kinds of species benefit. The way cover is arranged across a landscape determines how productive wildlife will be and which species will benefit most. For example, a combination of grassed waterways, riparian buffers, and small parcels of grassland would provide good habitat for ring-necked pheasants in the Corn Belt, but would not support upland nesting waterfowl in the Great Plains. Upland birds like the Baird's sparrow, blue-winged teal, and prairie chicken require larger expanses of unbroken grassland cover.

In planning to protect habitat, the use of "barometer" species that can represent the habitat needs of communities of species to be protected may help to more clearly define the objectives of habitat protection. Tracking the success of barometer species over several years can also help evaluate the success of habitat protection programs.

Water quality is critical in determining the quality of wildlife habitat. The quality of the water that animals live in, drink, or draw food from can affect their immediate health, their ability to reproduce, and even their species' long-term viability. The health of many species in the food chain, particularly top predators, may be

[10] This amount is equivalent to one-half of one percent of existing cropland and about 5 percent of the acreage now enrolled in CRP.

severely affected by the progressive diminution or contamination of plant and animal populations upon which they depend for food.

Preventing runoff of agricultural pollutants into waterways can help to maintain high water quality, which in turn affects wildlife food chains. As already stated above, management of plant cover, of pesticides and fertilizer, and of livestock manure on farms are three aspects that are critical to the interaction between agriculture and surface water quality. Retaining riparian zones and floodplain areas rather than converting them to cropland serves not only water, wetlands and wildlife priorities, but reduces flood damages as well.

Agriculture and Soil Quality

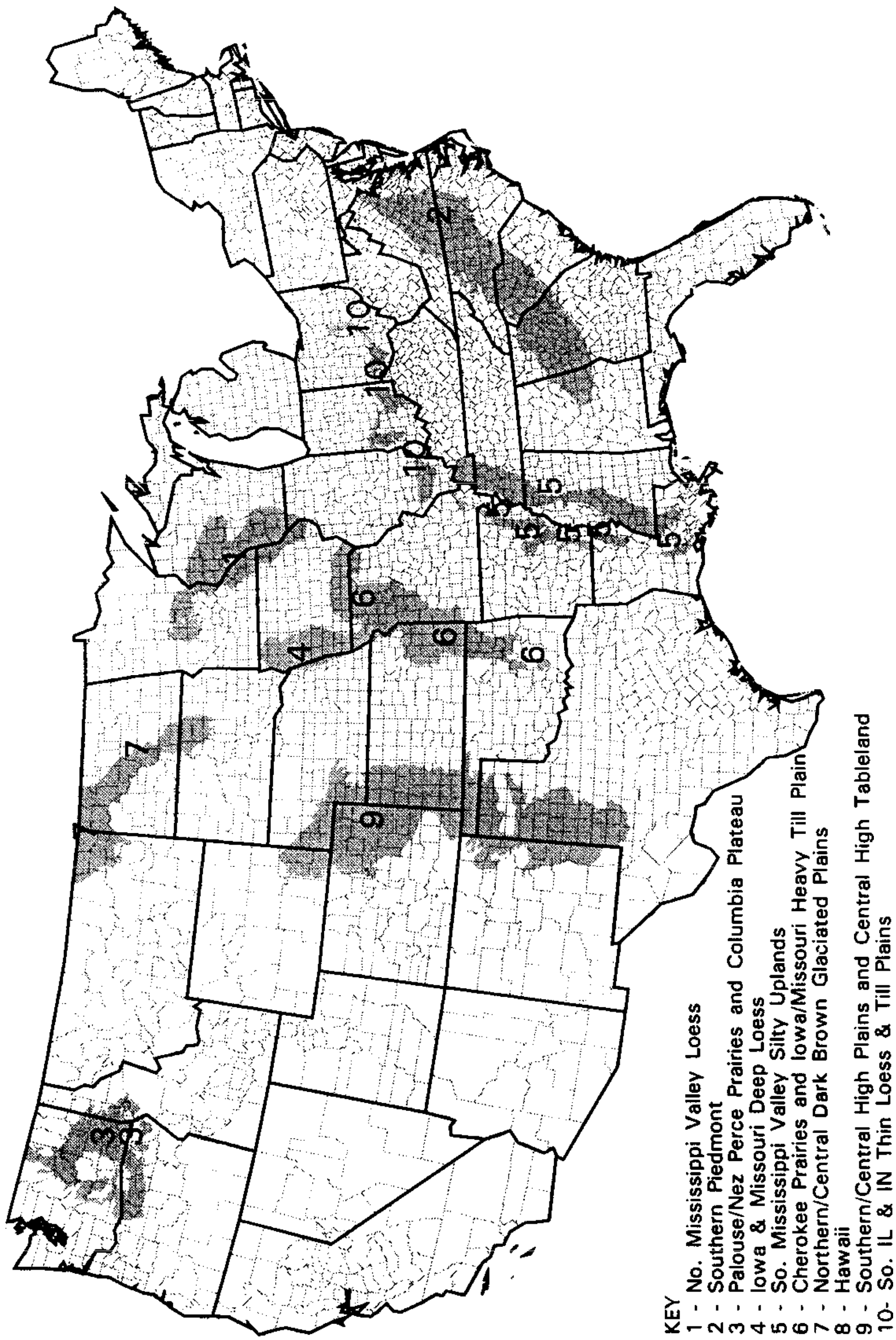
Agriculture's role in determining soil quality is, in some ways, more difficult to describe than its role in water quality and wildlife habitat. Given the complexity and spatial variability of soils, scientists are still looking for a way to describe soil quality more completely. At this writing, the term "soil quality" encompasses many quantitative attributes such as microbial density, organic content, electrical conductivity, acidity, soil structure, chemical contamination, and infiltration rate in addition to qualitative aspects such as smell, color, and texture (55). Soil quality can also be assessed in terms of its capacity to perform productive and environmental roles, such as the capacity to promote the growth of plants; to regulate the infiltration and surface movement of water within a watershed; and to act as a buffer for water and air quality by sequestering and degrading carbon, agricultural chemicals, and organic wastes.

How agricultural production affects these attributes or capacities can be described, but not accurately measured. Heavy machinery or animal stocking rates can make soil more compact, in contrast to the loosely aggregated soil structure that is most conducive to water infiltration and healthy root growth. Irrigation can increase soil salinization, because irrigation water contains salts that are then deposited on the soil surface. Because many agrichemicals adhere to soil particles, intensive use of pesticides and fertilizers can contaminate soils. Changes in tillage practices, in the use of agrichemicals, or in the mix of crops grown can change the microbial and organic content of soils, leading to changes in productive and ecological capacities. Aside from these relatively well-known effects, it has been more difficult to document comprehensively how agriculture changes soil quality.

Findings

Soil's vulnerability to erosion and to changes in other aspects of quality (such as salinity, compaction, acidification) in response to agriculture varies across the country (33), depending upon innate soil characteristics and management practices. Because there are only incomplete data on these variables, the severity of erosion-related problems served as the primary criterion for selecting soil quality priorities (41). OTA also considered other forms of environmental degradation related to erosion, including offsite problems such as damage from sedimentation in surface waters, wind erosion, and groundwater leaching of nitrates and pesticides. Figure 3 shows the geographical distribution of the priority areas and table 5 briefly describes each one.

The geographical configuration of the Northern Mississippi Valley Loess and Southwest Wisconsin Sandy Outwash area contributes to problems with erosion and water quality. The southern section of this area, for instance, is made up of a thin mantle of rich soil over fractured limestone. Steep slopes and deeply incised stream channels lead to severe water erosion and surface water degradation. The innate tendency toward erosion is exacerbated by the fact that about 60 percent of the area is covered by cropland, much of it dedicated to corn. In the northern part of the area, intensive vegetable production predominates, and farmers make liberal use of nitrogen fertilizers, pesticides, and manure. Deep and coarsely textured soils on gently rolling landscapes are highly susceptible to leaching, and so agrichemicals are rapidly transported to groundwater. The topography and soils are also conducive to severe wind erosion, and airborne dust is common in sandy areas.



SOURCE: Office of Technology Assessment, 1995

TABLE 5: Soil Quality Priorities

Priority Areas and Justification	Links to Agriculture
Area 1: Northern Mississippi Valley Loess and Sandy Outwash ♣✶✧♠ Severe water and wind erosion degrade soil. Agrichemical leaching to groundwater is a significant concern.	Steep slopes, permeable soils, poor manure management, and intensive use of agrichemicals and irrigation raise the chance of groundwater degradation.
Area 2: Southern Piedmont ♣ Water erosion and soil compaction reduce productivity. Agrichemical leaching to shallow groundwater occurs.	Steep slopes, concentration of row crops that do not protect soil, and cropping on marginal soils induce erosion and water quality problems.
Area 3: Palouse and Columbia Plateau ✶♠♥ Wind erosion creates fugitive dust in the air. Water erosion is associated with impaired surface water. Groundwater is also a concern.	Steep slopes, intensive chemical (fertilizer) use, a fallow cropping sequence that removes ground cover, and cultivation on marginal soils are factors.
Area 4: Iowa and Missouri Deep Loess ♣✧ Water erosion leads to build up of sediment off-site. Poor surface and groundwater quality are also concerns.	Steep slopes, silty soil, concentration of row crops, and intensive chemical inputs are primary causes of quality conditions.
Area 5: Southern Mississippi Valley Silty Uplands ✶✧ Water erosion leads to build-up of off-site sediment.	Steep slopes, silty soils, and concentration of row crops influence conditions.
Area 6: Iowa and Missouri Heavy Till Plains; Cherokee Prairie ♣✶✧ Soil productivity is degraded by water erosion and soil compaction.	Sloping soils and concentration of row crops increase water erosion.
Area 7: Northern and Central Glaciated Plains ♥✶✧ Wind erosion and off-site dust degrade air quality. Conservation of water in soils is a concern.	Cereal-fallow cropping rotations expose soil to wind. Depletion of organic matter and cropping on marginal soils exacerbate quality problems.
Area 8: Hawaii ♠ Extreme water erosion results in surface degradation. Agrichemical leaching is also observed.	Intensive cropping on steep slopes, including heavy tillage and harvesting equipment and intensive agrichemical use, created conditions of soil and water degradation. Heavy rainfall typical of the area exacerbates erosion.
Area 9: High Plains ♠✧♦♥ Conservation of water in soils is a concern. Dust from wind erosion degrades air quality.	Lack of adequate crop residues, in part due to inclusion of a fallow rotation, exposes soil to erosion. Cropping on marginal soils and extensive cotton production in southern high plains increases soil degradation.
Area 10: S. Indiana and IllinoisThin Loess ♣✧ Soil productivity is reduced by water erosion and soil compaction. Surface and groundwater quality are also concerns.	Concentration of row crops is the primary cause of soil quality problems.

♣ overlaps with surface water quality priorities
♦ overlaps with water conservation priorities
● overlaps with soil quality priorities
✶ overlaps with wetland and riparian priorities
✧ overlaps with wildlife habitat priorities
♠ overlaps with groundwater priorities
♥ overlaps with rangeland quality priorities

Much of the Southern Piedmont consists of small farms and some woodlands, although urban encroachment is increasing. Soil compaction and water erosion are major problems in areas where soybeans, corn, cereals and cotton are grown. Soil compaction reduces root growth and impedes infiltration of surface water. Contamination of surface and shallow groundwater with agrichemicals also occurs. Poultry waste management makes some areas in the Piedmont a rangeland/pasture priority as well (74).

Steep slopes and medium-textured soils planted with cereal crops make the Palouse and Nez Perce Prairies extremely vulnerable to erosion. Wind and water erosion occurs on both medium- and coarser-textured soils; water erosion occurs primarily during spring thaws, from melting snow. Surface and groundwater quality are impaired by the combination of shallow soils and heavy application of nitrogen fertilizers. Riparian grazing in this area creates rangeland conditions that are also a high agroenvironmental priority linked to water quality.

Deep loess soils and steep slopes make the Iowa and Missouri Deep Loess Hills extremely prone to erosion. Although corn and soybeans are grown intensively on these soils, the favorable natural productivity conditions of the deep loess can result in only moderate productivity losses from erosion if nutrient levels are maintained with fertilizers. However, erosion transport to offsite waters causes severe sedimentation problems and delivers agrichemicals that migrate and accumulate in downstream rivers, wetlands, and estuaries.

Steep slopes and water erosion also cause major environmental problems in the Southern Mississippi Valley Silty Uplands, which border the Mississippi River, and in the Southern Illinois and Indiana Thin Loess and Till Plains area. Erosion of the thin layer of soil that is typically found in these areas brings significant economic problems, in the form of lost productivity, as well.

In the High Plains, cotton is grown on sandy soil in the south. It leaves little residue to protect the soil from erosion in the off-season. Other major crops in the region include winter wheat, grain sorghum, and corn. Wind erosion is often severe, leading to soil damage and dust in the air. Projections are that as many as 30 “dusty” days may occur each year. Currently, a sizable portion of this land is in the CRP and is classified as “highly erodible land” (HEL) by USDA. The high erodibility of High Plains soils is exacerbated by the types of crops planted and the manner in which they are grown. Using this area as rangeland may provide a commercially viable and environmentally preferable alternative; it would both maintain ground cover and prevent erosion (74). Given the limited rainfall in this area, retention of soil moisture and efficient water use also affect soil quality. The chief source of water in the High Plains is the Ogallala aquifer, and withdrawals from the aquifer for irrigation of local crops (for instance, cotton) are the primary cause of falling water tables (20).

More than half of the Northern/Central Dark Brown Glaciated Plains is used for dryland crop production, mostly cereals. Some of the drier parts of the area are allowed to lie fallow. Soils are deep and medium-textured. Wind erosion is a major problem, and there is occasional water erosion. Saline seeps are common because water moving through the soil accumulates salt, then reappears on the surface of the lower slopes. Effective storage of water in the soil during the fallow period is of utmost importance. Currently, a considerable amount of land in this priority area is enrolled in the CRP. The most highly erodible lands in this area were also designated a priority for rangeland conservation (74).

In the corn, soybean, sorghum, and cereals region of the Cherokee Prairies and Iowa and Missouri Plains, soils are subject to water erosion that is sufficiently severe to create gullies. This runoff carries sediment and agrichemicals to surface waters. Drinking water wells in this area have also been polluted by agricultural pollutants. The soils are relatively unsuitable for agricultural production, and erosion promotes further loss of soil productivity.

Portions of Hawaii are rapidly becoming urbanized, but some farmland—dedicated to sugar cane and pineapple—still exists. Farms on low mountain slopes and coastal plains are extremely susceptible to water erosion, however, which creates off-site sedimentation. These tropical soils are deep and permeable, which facilitates transport of agrichemicals to shallow groundwater.

Lessons for Targeting Soil Quality

The relationship between soil erosion and water quality is very direct, especially near steep slopes. Sediment washed from farm fields into rivers, streams, or wetlands reduces water quality by increasing "turbidity" (cloudiness) and by transporting fertilizer and pesticide residues into water bodies. Farming on steep slopes where erosion control is extremely difficult emerged as a serious issue relating soil and water quality. Sedimentation of waterways from erosion can make water unsuitable for drinking, recreation, and aquatic habitat, and can make flood control more difficult. Notably, six of the 10 priorities were chosen in part because of steep slopes and surface water quality concerns.

Despite dramatic national improvements in controlling soil erosion, it is still a priority in certain areas. Trends show that significant improvements in controlling soil erosion have occurred on a national scale since the 1930s. Nonetheless, soil erosion remains a conservation issue. Wind erosion in the western Plains is still a problem, and about 120 million acres of the nation's cropland are vulnerable to soil losses that exceed rates of soil creation (91). Those levels are considered unacceptable by USDA.

Existing data on soil conditions do not permit targeting based on soil quality. Soil data collected by federal agencies, most notably by the Natural Resources Conservation Service (NRCS, formerly the Soil Conservation Service or SCS) pertain almost exclusively to soil erosion. Indicators for soil quality and for the various production, ecosystemic, and environmental capacities that stem from soil quality have not been developed. However, research shows that soil quality is important for producing agricultural crops and forage as well as for unique environmental functions such as cycling carbon and nutrients, partitioning water on the land surface, and buffering air and water from the effects of land uses. In this context, soil degradation means that the soil's capacity to perform any of its productive, ecosystemic, or environmental roles is reduced. Developing and maintaining soil quality that supports these functions will require more than simply minimizing erosion.

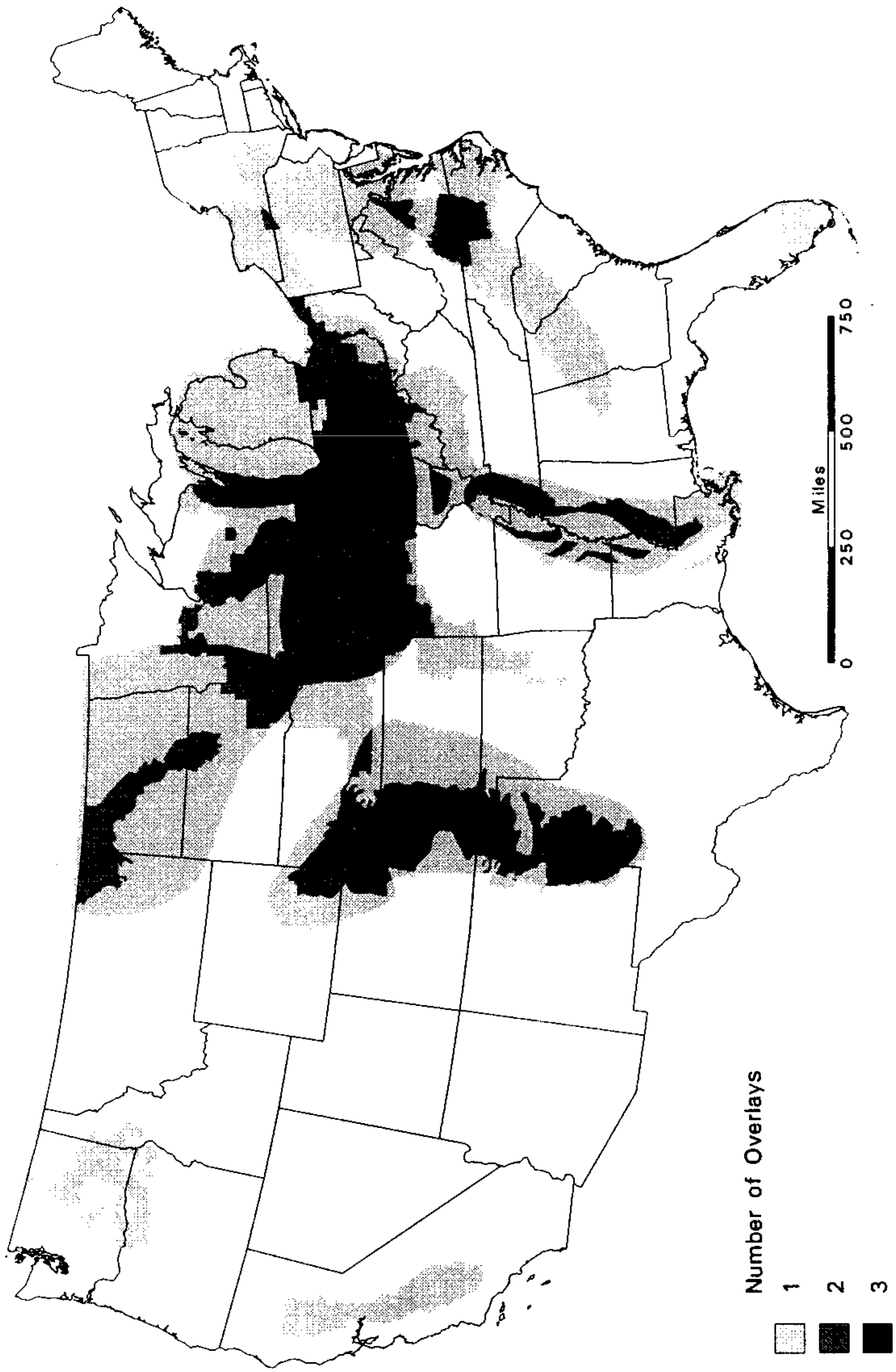
A shift in emphasis from preventing soil erosion to protecting soil quality, an idea gaining support within the scientific community, could lead to some fundamental changes in research, technology development, and programs. For instance, research on managing soil quality would focus heavily on how to regenerate or enhance soil functions (such as the ability to absorb and filter water; the capacity to hold nutrients and sequester carbon; and the ability to support biological activity by plants, earthworms, insects, and microbial life). Determining the eligibility of soil quality priorities for various agroenvironmental program responses would not be triggered simply by erodibility measures, but by a more complete assessment of present and potential characteristics of soils. For instance, in particular areas, some cropland may be so marginal in productivity that it might be more cost-effective to devote attention and resources to richer, more productive soils.

ENVIRONMENTAL PRIORITIES AS PROGRAM TARGETS

OTA's findings strongly illustrate that agroenvironmental priorities seldom involve just one dimension of environmental quality (see appendix B). Rather, it is very common for soil erosion to be systematically connected to water quality, habitat or both. Water quality is virtually always connected to some habitat or human health consideration, and also typically reflects the condition of soils (55). Figure 4 shows how closely the priorities overlap in many cases. The darkest areas are those with the greatest number of overlapping priorities. When surface water, soil and wildlife habitat are considered jointly, large areas

FIGURE 4: Environmental Priority Overlaps

Overlays Include: Surface Water Quality, Soil Quality, Wildlife



SOURCE: Office of Technology Assessment, 995.

of the Corn Belt, Atlantic estuaries, Lower Mississippi Valley and the Great Plains contain the most priorities. The overlapping of priorities suggests possible patterns and interconnections among many agroenvironmental conditions.

The darkest areas may well be the highest-priority areas in agriculture, and thus the highest-priority targets for agroenvironmental programs. The types of land, water, and biological resources in the priority areas help portray the character of agriculture and potential environmental problems. A detailed analysis of the areas was not feasible given the length of the project. Box 2 and appendix D describe some land types in the priority areas. Approximately one-third of U.S. cropland, pasture, and rangeland is in areas with two or more overlapping priorities. These areas are dominated by the Corn Belt and large

BOX 2: What's in the Priority Areas?

Agroenvironmental conditions in the priority areas reflect the scale and intensity of agricultural production and the character of environmental resources. A detailed analysis of the production and environmental bases was not possible given time constraints. OTA recommends such an analysis be conducted to more fully understand the priority areas and their agroenvironmental systems. As a preliminary step, the amounts of some major types of lands in the surface water quality, wildlife, and soil quality priority areas are given in appendix D.

Cropland, pasture, and rangeland uses total nearly 525 million acres in counties wholly or partially covered by all priorities. The figure represents nearly 50 percent of the U.S. total, which confirms that important agroenvironmental problems are broadly spread across the nation. Not surprisingly, the majority resides in the Corn Belt and Plains states. It is imperative to bear in mind that not all, or even a majority, of the croplands, pasture, and rangeland in the priority areas are linked to serious environmental problems. Indeed, only a very small portion, such as 5 to 10 percent, may be critical to improved management.

Over 23 million acres of forested and non-forested wetlands occurred in counties wholly or partially covered by all priority areas, about 25 percent of the total in the lower 48 states. Dominant areas of wetlands fall in the Lower Mississippi Valley, Northern Plains, Corn Belt, and southern Florida.

In a separate study, about 2 milllion acres of riparian buffers were identified for priority attention to remedy nonpoint water quality problems related to agriculture (44). Counties in the OTA priority areas encompass two thirds of those potential riparian buffers. They are spread throughout the country, but concentrated in the Corn Belt and Northern and Southern Plains regions.

Counties in the priority areas also hold just over 27 million acres of lands enrolled in the Conservation Reserve Program, or about 75 percent of the total. No inference can be made as to the location of present CRP enrollment lands vis a vis lands key to solving citical environmental problems in the priority areas. The existing CRP regional distribution indicates agriculture has already set aside sizeable capacity to address the environmental problems via long-term set aside if targeted appropriately.

When multiple overlaps of priorities are considered, the relevant land use and environmental scales shrink as portrayed in figure 4. For areas where two and three priority criteria are satisfied, total cropland, pasture, and rangeland fall to about 350 million and 40 million respectively. The Corn Belt and Plains states retain their dominant positions. Wetlands in priority counties decline to about 5.3 million and 300,000 acres. The Great Lake states, Lower Mississippi Valley, and Northern Plains account for large parts of the totals. Finally, priority areas identified for two of three environmental dimensions accounted for nearly 725,000 acres of riparian wetlands, mostly in the Corn Belt and Southern Plains, and the three overlap region captured about 153,000 acres, virtually all in the Corn Belt.

SOURCE: "Land Use, CRP Contarcts, and Riparian Buffers by Geographic Region: A GIS Approach," by John G. Lee and Stephen B. Lovejoy, L&L and Associates, West Lafayette, Indiana, July 1995.

areas of the Great Plains, presumably reflecting the heavy concentration of agricultural production in those regions. Other important areas include watersheds and river basins flowing into two Atlantic estuaries and the Lower Mississippi region. The priority designations do not imply that all farmlands in the area are generating or incurring environmental damage and need program attention. Indeed, only small amounts of farmland may require intensive treatment.

For example, the areas with more than one priority designation contain only about 724,000 acres of riparian buffer acres needed to protect streams and rivers from water pollution (43,44)[11]. Most of those acres are in the Corn Belt and Southern Plains regions. Similarly, only about 5.4 million acres of forested and unforested wetlands are in areas with more than one priority designation. The areas with two or more priorities currently include 16 million acres of CRP lands. This amount of land represents ample capacity to protect the riparian buffers and wetlands if reenrollment is reconfigured to those types of priority lands where production and environmental protection are incompatible.

Without intimate knowledge of the dynamics among soil, water, and wildlife dimensions of an agroenvironmental priority, it is difficult to design programs that protect or restore agroenvironmental health. In response to growing awareness of the importance of system dynamics, concepts such as “whole-farm management” and “ecosystem management” have begun to generate interest among scientists as well as among policymakers (88). *Yet, despite some philosophical movement toward a more holistic view of agriculture and its relationships with the environment, most policies and programs still focus on discrete components of agroenvironmental systems rather than the systems themselves. For example, most conservation programs for agriculture deal exclusively with soil erosion. Although other programs deal with water quality issues, and even habitat, virtually none offer farmers support for managing whole farming systems.*

One way of shifting the focus of conservation toward entire systems is to target policy and programs to “agroecosystems” instead of to individual system components. The concept of an agroecosystem (figure 5) shifts the emphasis more clearly toward acknowledging that farms, beyond supporting cultivated vegetation and domesticated animals, also affect nutrient cycling, hydrologic flows, soil and water quality, and wildlife habitat. An agroecosystem covers the area most directly sustaining the environmental and productive functions of farms. Conversely, it includes the area in which most environmental side-effects of production—such as sediment deposition, modification of wildlife habitat, or changes in water quality—are likely to be detected. Thus the concept is important to guide of research and monitoring agroenvironmental conditions. When agroecosystems are the focus for programs and policies, on-farm conservation and productivity concerns, as well as off-farm environmental conditions, are addressed in the same effort.

To guide program implementation and evaluation, it is important to identify measurable attributes of agroecosystems. Unfortunately, there a lack of agreement among scientists on those attributes and the underlying relationships that tie them together. Thus program strategies designed and implemented separately will likely miss opportunities for gaining complementary environmental objectives or avoiding possible conflicts. An objective of future program design should be to create effective mechanisms to ensure that individual programs take into account natural environmental interactions of agroecosystems. The “special area management” approach implemented under the Coastal Zone Management Act offers one model that has achieved some success in drawing together diverse program efforts (10).

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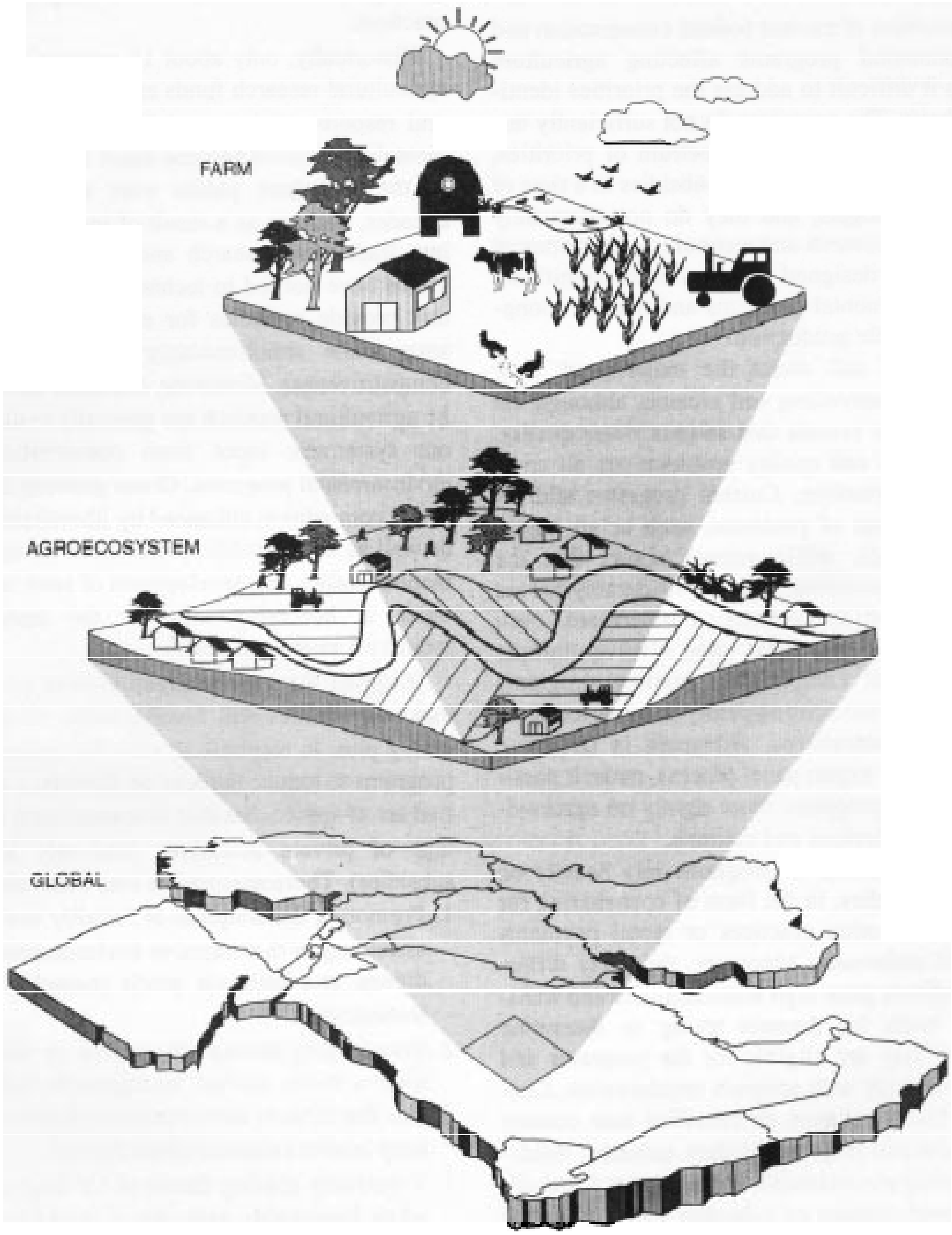
[11] All areas selected as surface water quality, wildlife habitat, or soil quality priorities contain over two thirds of the 2 million acres of the identified riparian buffers but contain just about one half of the nation's farmland.

FIGURE 5: Agroecosystem



The term "agroecosystem" indicates that farms do more than produce cultivated vegetation and domesticated animals. Farms 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 Prcgram (EMAP), *1992 Agroecosystem Pilot Project Plan* (EPA/620/R-93/O10), January 1993.

DEVISING STRATEGIC PROGRAMS FOR AGROENVIRONMENTAL PRIORITIES

The structure of current federal conservation and environmental programs affecting agriculture makes it difficult to address the priorities identified above. The programs do not sufficiently target programs to the full spectrum of priorities; they rely predominantly on subsidies in a time of shrinking budgets, and they do not adequately emphasize research and technology development specifically designed to ameliorate significant agroenvironmental problems and maintain long-term profitable production.

Programs still direct the majority of their funding to controlling soil erosion, although the latest science reveals that serious water quality, wildlife, and soil quality problems are all environmental priorities. Current programs address general classes of problems, such as all highly erodible lands, while science shows that the severity of problems varies considerably across the class and the country. Furthermore, even though priority problems often involve multiple environmental components, existing programs generally do not systematically account for agroecosystem interactions. Advances in targeting, including the expert panel process, make it possible to focus programs more tightly on agroenvironmental priorities and systems.

A large number of programs rely heavily on federal subsidies, in the form of cost-sharing for new conservation practices or rental payments for land retirement. Moreover, the many different programs pose high administrative and transaction costs for farmers trying to determine whether they are eligible for the programs and how to comply with program requirements. Continued heavy reliance on subsidies runs counter to current and projected budget cutbacks. Asidefrom being unsustainable in the current fiscal climate, over-reliance on subsidies does not lead to the effective use of public funds, particularly when private incentives exist to adopt beneficial practices.

Historically, only about 10 percent of federal agricultural research funds are committed to natural resource topics, even though agroenvironmental issues have become much more important to the American public over the past three decades. Perhaps as a result of inadequate funding, traditional research and development programs have not led to technological innovations that provide remedies for environmental problems while simultaneously maintaining farm competitiveness. Moreover, decisions about public agricultural research are generally made without systematic input from conservation and environmental programs. Given growing international competition enhanced by liberalized trade, as well as strong public preferences for environmental quality, the development of such technologies is becoming vital to the agriculture industry's long-term health.

Bridging the gaps between current programs and new realities will involve more refined targeting plus, in response to calls for streamlining programs to reduce burdens on farmers, a simplified set of approaches that take maximum advantage of private incentives (and rely less on subsidies). These approaches could include:[12]

1. Promoting the adoption of "readily available" technologies that improve environmental conditions and maintain profit (complementary technologies[13]).
2. Encouraging through incentives or disincentives a move toward management technologies that achieve environmental objectives and keep land in commercial production.
3. Voluntarily retiring farmland for long periods when foreseeable agricultural production and

[12] This categorization of strategies pertains directly to actions on private lands, and not the installation or maintenance of public works, such as flood control structures.

[13] OTA has previously outlined the concept of complementary technologies as those that enable farmers to improve environmental quality while maintaining acceptable profits (91).

desired environmental performance are incompatible.

The first and second approaches should be backed up by a vigorous public/private technology research and development program aimed at addressing agroenvironmental priorities while continuing profitable production (91). The remainder of this report describes each approach in general and then illustrates its application to selected surface water quality, wildlife, and soil quality priorities. Other analysts have used similar classes to characterize the different categories of practice (technology) profitability (46).

All of the strategies could be implemented under the guidance of whole farm natural resource management plans. Such plans would incorporate considerations of soil quality, water quality, and wildlife habitat into the farm's production system on an integrated basis using the best science. The construction and implementation of the plans would draw heavily on the farmer's expertise to capitalize on his/her intimate knowledge of the farm's natural resources (52). Public agencies could assist in a variety of roles, providing information on applicable environmental objectives, the functioning of agroenvironmental systems, and the economic and environmental performance of technologies. The efficacy of the plans would be limited by incomplete understanding of the dynamic aspects of production-environment interactions. The fusion of private and public resources gives the best chance of achieving coordinated environmental objectives, private conservation goals, and sustaining a competitive farm operation. The composition of the plans would depend on specific on-farm and off-farm environmental objectives, coupled with the farmer's personal and production goals, and so would vary by farm and by region.

Spreading Complementary Technologies

The term "technology" covers the various inputs—labor, information, machinery, water, chemicals, soil, plants, animals, insects and other biological resources—used to produce food, fiber, and other agricultural products. Implicitly, it includes the management scheme whereby those inputs are combined into practices comprising the overall production system. The rapid growth of U.S. agricultural productivity during this century has been fueled by a series of technological advances, from the advent of mechanical cultivation, to synthetic fertilizer, to hybrid seed, to chemical pest controls. These technologies have propelled unprecedented growth in crop and livestock production, yielding large returns to crop and livestock producers and consumers. But the application of these technologies has also resulted in environmental degradation. Prominent examples include wind erosion and wildlife habitat destruction from cultivating grasslands, sediment runoff clogging roadside ditches, streams and rivers, and fertilizer and pesticide residues flowing into water resources.

Unlike traditional technologies stimulated by yield-enhancing or cost-savings rewards from the market, "complementary technologies" would *by design* enable farmers to enhance environmental quality while maintaining farm productivity and profitability.

> 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 (91, p.100).

Shifting to institutions that stimulate the development of technologies guided both by production and environmental objectives will require changes from the status quo research and agroenvironmental management approaches. The private sector now has few incentives to develop and promote complementary technologies in agriculture. Market forces have "induced" agricultural technology innovation that reduces the need for relatively expensive purchased inputs, such as land and labor. The private market costs of these inputs are effective signals to conserve expenditures by substituting less expensive inputs. However, the costs of many agoenvironmental problems—such as degraded water quality or diminished wildlife habitat—are not generally or fully reflected in market prices or costs when the damages affect resources off the farm. Similarly, when agricultural practices benefit off-farm environmental resources, farmers may not be able to collect those benefits, as for habitat benefiting migratory wildlife. Consequently, there is little impetus for technological innovation that ameliorates these environmental costs, or enhances off-site benefits.

One function of public policy is to provide signals that help attain social goals that are not expressed clearly in the marketplace. However, public policy has not addressed the barriers to developing and adopting complementary technologies. Although public cost-share subsidies may encourage farmers to adopt some technologies to reduce pollution, subsidies do not generally provide incentives to integrate production and environmental goals into a unified technological approach from the outset. Efficient regulation may expand the market for complementary technology, insofar as the regulatory restrictions translate into market incentives for cost-effective, environmentally sound alternatives (65). However, environmental regulation has not been widely used in agriculture, compared with other industries (91). In some cases, it may not be the most desirable approach for stimulating development and use of complementary technologies.

Federal research funds have generally not been directed to environmentally related topics nor to targeting innovations that enhance the compatibility between production and environment. Since the 1970s, about 10 percent of the work done by federal and state research institutions has been dedicated to natural resource topics, compared with more than 60 percent related specifically to production of crops and animals (94). How much of the 10 percent of research monies devoted to natural resource issues concerned complementary technologies is unknown.

As long as agricultural technologies are designed specifically for one purpose—and that purpose is typically yield enhancement—agricultural production and environmental quality are independent goals that may, at times, actually compete with each other. Indeed, production-related technologies that are not explicitly designed to achieve environmental goals will at best accidentally improve environmental quality, and at worst cause significant degradation. Most likely, the present disconnect between production and environmental technology development produces both improvements and degradation, but in an unpredictable fashion. For instance, given a situation in which water quality goals require a reduction in nitrogen applications but nitrogen-dependent crop varieties dominate cropping patterns, an inherent conflict between production and environmental goals emerges. This conflict may in fact increase on-farm costs associated with conservation management, and so slow the adoption of conservation practices.

During the past three decades, a few agricultural technologies have emerged with the power to increase profit yet reduce environmental damage caused by farming in some situations. Integrated pest management (IPM) and conservation tillage (CT) may be among the most recognizable examples currently in use. IPM uses scouting and other management information to better target a range of chemical and non-chemical treatments to control pest problems in an economically and ecologically sound manner (see box 3). IPM often lowers pesticide applications and associated costs (13).

Conservation tillage is defined as any tillage and planting system that (a) leaves at least 30 percent of the planted soil surface covered by crop residue to reduce soil erosion by water, or (b) leaves at least 1,000 pounds of residue per acre during critical periods when soil erosion by wind is a primary concern. On the heels of the 1970s energy crisis, the CT revolution reduced labor, fuel, and machinery costs, and maintained or increased yields in many areas. It also significantly reduced erosion and polluted runoff. The effects of CT on groundwater and wildlife are not fully understood.

These two production practices or systems generally satisfy the criterion for complementary

BOX 3: Integrated Pest Management as a Complementary Technology

Integrated Pest Management (IPM) uses enhanced information and multiple tactics, drawn from a variety of production methods, to manage pest populations in an "economically efficient and ecologically sound manner" (60). Some of the strategies used as part of an IPM approach to pest control are scouting and monitoring for insects, development of crop varieties with resistance to specific pests, pheromone traps which lure insects to traps, changes in tillage and crop mix, use of sterile insects or release of natural predators and biologically based pesticides.

IPM programs are typically tailored to specific crops and, correspondingly, to specific kinds of pests. Very few IPM programs have been developed for livestock, but many have been designed for crops. Cotton and its most severe pest, the boll weevil, have been the primary target for IPM innovations. Other crops, including soybeans, tobacco, fruits, corn and flowers are among the 30 or more agricultural crops that have been managed using IPM concepts.

Economic Performance: Review of 61 farm-level evaluations of the economic performance of IPM (13,60) showed that *this approach generally leads to increased profitability over conventional approaches*. Lower pesticide use, lower production costs, lower risk, and higher profits to producers were commonly observed. While surveys indicate that over half of the nation's fruit, nut, vegetable and major field crops are managed with IPM, barriers to wider adoption persist; for example, "inadequate knowledge of available IPM alternatives, too few crop consultants to deliver IPM services, and the higher managerial input necessary for IPM implementation" may slow adoption in certain regions or for certain crops (102).

Environmental Performance: There are many practices that can feasibly be included in an IPM system, but surveys indicate that the bulk of IPM users rely predominantly on conventional pesticides (102). Although IPM-users manage pesticides more strategically than non-IPM users, it should be noted that *more strategic or efficient use of pesticides does not necessarily mean a reduction in the total amount of pesticides applied*. Rather, it means that pesticides use is tailored to monitored pest levels. Therefore, environmental benefits from reduced pesticide use should not be assumed in all IPM systems.

The diversity of methods used by IPM practitioners, and the absence of complete research about the effects of these practices on water quality, soil quality or wildlife makes general conclusions very difficult. The use of pesticides and other pest control methods on IPM-grown crops can be subjected to the same scrutiny applied to their use in any production regime: what inputs are being used, where are they being applied, when, and how? In addition, some consideration might be given to the ecological effects of introducing predatory or other pest control organisms into agroecosystems. The actual environmental effects of these introductions may never be fully anticipated *a priori*.

SOURCE: Office of Technology Assessment, 1995.

technologies of maintaining profit while improving environmental performance. However, each technology involves different degrees of profitability and different levels and types of environmental effects, depending on the farm and natural resource area in question. Crop and livestock enterprises, machinery, management experience, soil type, climate, and many other factors determine whether, and to what extent, certain technologies benefit both agricultural producers and the environment.

As noted above, environmental regulation, which can stimulate the search for and adoption of such technologies, has not been widely applied to agriculture. Pesticide registration is the major exception, so the development and adoption of IPM may have been affected. However, U.S. pesticide regulation may have stymied the development of more environmentally benign pest controls (54). Conservation compliance, a form of quasi-regulation that requires agricultural program participants to implement conservation practices on highly erodible lands, has accelerated the adoption of CT (96). But it is doubtful that the narrow focus of conservation compliance on erosion control fully exploited the possible environmental gains from conservation tillage technology. Thus the full potential of CT and IPM to simultaneously achieve production and environmental objectives simultaneously likely has not been realized and will not be achieved under current programs.

Future Program Needs

Complementary technologies hold considerable promise in agriculture, but only if research and agroenvironmental management programs are redirected to encourage their development and application. Despite inadequate incentives, several classes[14] or families of technologies with great potential to meet agricultural and environmental goals simultaneously are gaining attention. In addition to IPM and CT, other possible candidates include precision farming which covers soil nutrient testing (see box 4), management-intensive or rotational grazing, biotechnology, and organic farming, among others.

The success of these technologies depends on sufficient management expertise. For example, research on IPM indicates that successful application depends on improved knowledge of pest populations and a wide range of cost-effective control methods (59). But that finding largely covers management for production objectives only. Adding environmental considerations would raise the level of management required to yet another degree. Similar considerations apply to implementing CT in diverse farm and resource settings to ensure full environmental benefits are achieved. These two cases illustrate that achieving production and environmental objectives are not automatic outcomes of using the technology. Rather, they depend on proper application, and that successful application depends heavily on management training and expertise.

How could program reforms be made to hasten the full development and adoption of such complementary technologies? A first step would be a joint public-private review of such technologies by crop or livestock enterprise and by region. All parties would simply be informed about what is available or about to be developed. Table 6 lists some preliminary and elementary considerations in conducting such reviews.

The unique combination of production and environmental conditions comprising agroecosystems requires that the reviews be conducted on a state and local basis, to take advantage of regional and local knowledge of farming systems and environmental responses. Experience with IPM and CT, for example, suggests that neither of these technologies is likely to be a “silver bullet” for all farming and environmental situations. Indeed, indiscriminate general endorsement and application may worsen either environmental or profit conditions. A second, longer-term step would reorient public agricultural research funding and incentives to support the development of technologies simultaneously serving production, profit, and environmental objectives (91).

Once complementary technologies are identified and developed, they could be adopted in a cost-effective manner through voluntary education and technical assistance programs to build needed management expertise. In the past, funding for federal agroenvironmental programs has been allocated primarily to retiring land and implementing structural solutions, such as building terraces. In order to increase management

[14] IPM, CT, and many other classes of agricultural technologies actually cover multiple specific technologies that apply to different types of farms and natural resource situations. For example, CT includes no-till, ridge-till, mulch-till, and many other variants of reduced tillage. Similarly, IPM covers a variety of approaches to particular crops, pests, and regions. The same diversity will emerge for new technologies to best adapt to farm-specific and resource-specific requirements. This observed diversity supports program approaches that permit flexibility in designing and implementing agroenvironmental practices and systems, rather than specifying generic best management practices.

BOX 4: Precision Farming as a Complementary Technology

Precision farming (also called "site-specific," "variable rate" or "prescription" farming) refers to a set of technologies designed to enable farmers to adjust fertilizer and pesticide use to variations in soil properties from point to point across their fields. Different parts of a single field may contain very different levels of nutrients and degrees of pest problems, and site-specific technologies allow farmers to discern these differences. So far, the approach has primarily been used to manage fertilizer application more efficiently.

Variable rate technologies are presently available in a range of applications, including soil testing devices, yield monitors, and tractors outfitted with receptors for retrieval of satellite information. All variable rate technologies depend on data, typically from censuses or soil probes or surveys, and effective information-management practices are critical to successful implementation. Information management can, in some cases, mean that as a farmer becomes more aware of field characteristics, gradual adaptations can occur in farm planning. In some applications of variable rate farming, soil data is integrated with satellite-supported global positioning systems (GPS) and computer-supported "expert systems" software to produce rigorous, computer-driven input applications at every point in a field. The latter is the application most commonly dubbed "precision farming" but the term is really broader.

Economic Performance: Variable rate farming is designed to maximize profits by increasing the efficiency of input use. The balance between production costs and revenues is the key to profitability, not increasing yield. In other words, *the goal of this approach is not to grow more, but to grow smarter.* The profitability of variable rate farming has not yet been documented thoroughly. USDA analysts note that "[g]iven the newness and limited application of precision farming, analyses of the costs and benefits are only beginning to become available." (95).

Farmers in Pennsylvania reduced their fertilizer applications on corn by about one-third when using pre-sidedress soil nitrogen testing and achieved a modest increase in profit of $3.70 to $13.50 per acre (51,78). The findings corroborate those for a similar analysis of Iowa farmers (5). These concrete economic gains have encouraged gradual adoption of soil testing in some states.

Precision farming systems may be most advantageous in the production of crops that require a lot of fertilizer, herbicide, or insecticide because it is on these crops that rigorous efficiency could allow farmers to pare down their use of purchased inputs. Reduced use means budget savings. Yet, in its fullest application, precision farming could require an investment of up to $250,000 in equipment and support services (95), and it is not yet clear whether these costs will be sufficiently offset by the benefits of precision technology (i.e., reduced input expenditures or increased yields) to make it widely profitable.

Environmental Performance: Increased input efficiency could reduce the total amount of agrichemicals used on farms, and this could reduce the total amount of pollutants available for contamination of soil or for leaching into groundwater and runoff into streams. However, *increased efficiency does not necessarily mean a reduction in the overall amount of inputs applied*. Rather, increased efficiency means that doses are calculated to minimize inaccurate application at individual sites. When these individual doses are summed, the total amount applied may or may not be less than the amount applied without variable rate technologies.

Even when total amounts do decline under precision farming regimes, actual environmental effects depend not only on how much is used but also on what compound(s) are used and where, when, and how they are applied (71). Scientific research suggests that predicting environmental effects based solely on input levels may not be possible. For instance, if application of pesticides or fertilizer is concentrated near stream banks (riparian areas) or on very porous soils that filter chemicals swiftly into groundwater, then *environmental effects may change very little even though total chemical usage might have declined.* In short, the mechanisms by which inputs applied with precision methods interact with environmental quality must be taken into account to determine the actual effects caused; total amounts applied are not adequate information.

SOURCE: Office of Technology Assessment, 1995.

TABLE 6: Reviewing Agricultural Technologies for Complementarity

General Considerations	Specific Considerations
What is the technology?	Which management skills and equipment does it use? Are they readily available from the private sector or public programs? Is the technology targeted toward a particular kind of farm?
What is it designed to enable farmers to do?	What can farmers do better with this technology? What evidence exists to confirm its promise in particular settings?
What do we know about the profitability of this technology (compared with the most likely alternative)?	Compared with the profitability of the most likely alternative technology, what are costs, benefits, and risks of adopting the technology in different farming regions, for different kinds of agricultural enterprises? What kinds of transition costs can be expected from shifting to the technology?
What do we know about the environmental implications of this technology (compared with the most likely alternative)?	What effect does use of the technology have on water quality, soil quality, air quality, and wildlife habitat quality? Can these effects be compared with those associated with the most likely alternative technology used in that region, on that crop, under similar environmental conditions?
Given these findings, will this technology support local, state, and federal production and environmental objectives?	Have specific economic and environmental performance objectives been articulated for the sector? How will the technology enhance or detract from agriculture's capacity to achieve its dual performance goals?

SOURCE: Office of Technology Assessment, 1995.

expertise (knowledge of natural resource systems, technology application skills, and so forth), these programs will likely have to be reoriented significantly. Some short-run costs, mostly for management training, will likely be incurred as production technologies change. Ultimately, the economic benefits stemming from these technologies should provide farmers with natural incentives to use them.

The "on-farm" research emphasis of the Sustainable Agriculture Research and Education (SARE) program may serve as a model for helping farmers and ranchers evaluate and adapt complementary technologies to their local agroenvironmental systems (90). Bringing farmers and ranchers into the research process ensures that the findings will be relevant to their particular situations, and that scarce research program resources are used efficiently. To overcome farmers' and ranchers' fears about yield loss or offset some expenses for new equipment, some subsidies may be required initially. But many of these technologies primarily require new forms of management, so equipment subsidies should not constitute a major expense.

Shifting Management Practices through Public Incentives or Disincentives

Complementary technologies may not be available for some agroenvironmental problems, and therefore some cost must come from public or private budgets. In such cases, a form of public incentive (such as subsidy payments or cost sharing for practices, property tax or income tax breaks, or preferential terms on federal credit) or some type of disincentive (such as regulations, taxes, or conditional eligibility for agricultural program payments) is required to induce farmers and ranchers to change their land or water management practices. However, unlike land retirement, the goal remains to continue commercial production while achieving the environmental objectives.

The decision to use incentives or disincentives is political. Technical or economic analysis can make the choices clearer by providing estimates of the type and degree of risk, the extent and duration of damages, which groups are most affected, and other consequences. For example, if an environmental problem threatens human health significantly, regulation could be the most effective way to minimize exposure and ensure public health. In situations where the risks are less significant or scientifically uncertain, or where the practices lead to environmental benefits not required by law, incentives may be preferred. Eventually, policy makers must decide whether farmers require incentives (compensation) to achieve the environmental objectives, or whether they must attain certain levels of performance without public assistance. Most federal agroenvironmental programs aimed at altering agroenvironmental management practices rely on incentives rather than disincentives.

Changes in management practice can take the form of a shift in production inputs, such as reduced irrigation water use; a change in the cropping enterprises, such as increased crop rotations to reduce pesticide applications; or some combination of changes in input and enterprise. An extreme change might be a switch from cultivated crop production to continuous hay or grass production—in effect a CRP-like conversion that allows commercial forage use. In some cases, these changes could be viewed as short-term approaches to resolving environmental conflicts that also trigger public and private efforts to develop complementary technologies. However, whenever human or environmental health is strongly threatened, continuing disincentives (such as registration of pesticides) may be necessary to guard against excessive risk.

One of the greatest challenges in this strategy is to convert a wide array of existing incentive programs into a streamlined, consolidated effort that targets national priorities. More than 60 years of programs to treat specific problems has resulted in a pastiche of unintegrated efforts. Such a piecemeal approach not only reduces the feasibility of focusing program resources on high-priority problems, but also likely confuses farmers seeking public assistance about which program best fits their needs, and raises their costs in finding an appropriate program for their needs. Those higher costs discourage not only participation, but the adoption of new practices.

If agriculture's minimum environmental performance guidelines within each agroenvironmental priority area were clarified, it would be easier to determine when incentives or disincentives should be used. At least one state, Vermont, is attempting to implement uniform general codes of agricultural practice expected of all producers—in effect a form of required minimum standards (104). Beyond that minimum standard, the public is obligated to provide financial assistance (cost sharing) if further environmental improvements are desired. Applying the uniform minimum standards approach implies that farms in the entire state are required to satisfy the minimum codes of practice which may appear to run counter to the notion of targeting. Conceivably, some minimum level of effort by all farms may be considered necessary if, for example, surface waters statewide are considered a priority target. Determining minimum requirements for agriculture, whether in a priority area or statewide, would also reduce uncertainty for farmers and public agencies in implementing land management practice programs through incentives or disincentives.

A new approach to reducing uncertainty is to allow farmers to satisfy all applicable regulatory requirements by implementing and maintaining a certified total farm resource plan. Termed "environmental compliance," the approach helps farmers to avoid existing and potential agroenvironmental regulatory burdens by constructing and implementing individualized farm plans that suit their particular operations and meet public environmental responsibilities (52). Many unanswered questions remain—how to achieve multiagency agreement on the criteria and standards for the plan, whether plans should come from public agencies or the private sector or both, who shall do the monitoring of environmental performance under the plan, and resolving potential conflicts with existing environmental statutes. The environmental compliance plan could be a substitute for incentive programs providing cost-sharing, or a supplement. The Vermont program referred to above, for instance, operates in tandem with a subsidy program to defray some costs for practices beyond the minimum levels.

Retiring Farm Land from Commercial Use

The last program strategy is to encourage voluntary retirement of environmentally sensitive land from commercial production for long periods (10 years or more). Such a strategy essentially acknowledges that in certain cases, normal crop or livestock activities and acceptable environmental quality cannot coexist. Given large annual rental costs averaging $50 or more per acre, this strategy should be reserved for priority cases of greatest environmental value and where enrollment ensures long-term environmental protection. Preserving critical wetlands that could yield water quality, wildlife, and flood control benefits may be one example.

The federal government has implemented two major farm land retirement programs during this century: the Soil Bank (SB) from 1958-1972 and the CRP from 1986 to the present day (91). More than 28 million acres have been covered by the SB and more than 36 million acres by the CRP—nearly 10 percent of the nation's cropland. The SB was aimed primarily at supply management; the CRP combined supply control with erosion control objectives. Thus neither was or has been driven primarily by environmental considerations. Both programs solicited voluntary enrollments of eligible lands through annual rental payments paid over mostly 10-year contracts and cost sharing for conservation practice establishment.

A third land retirement effort, the Wetland Reserve Program (WRP), was initiated by the 1990 farm bill. Its enrollment target is 975,000 acres by 2000. The WRP was established to provide landowners with an opportunity to voluntarily return converted or farmed wetlands to wetland condition. Landowners must sign a permanent or long-term easement that restricts agricultural use of the land but permits compatible hunting, fishing, or recreational uses. Enrollees receive easement payments and cost-sharing for restoration expenses. Less than 100,000 acres have been enrolled to date despite offers from landowners to enroll nearly 600,000 acres during the bidding process.

Important lessons have emerged from these program experiences to inform future land retirement initiatives. *Of principal relevance to this analysis, several studies have determined that CRP enrollments could have produced significantly higher environmental benefits by more effective targeting of environmental priorities* (61,68). Better environmental performance is not inconsequential to considerations of program extension or renewal. Although the CRP has produced sizable environmental benefits, a recent comprehensive assessment of CRP evaluations concludes that "it is unlikely from a social welfare standpoint that the CRP produced benefits sufficient to cover its costs" (14). Moreover, with the exception of wildlife benefits, most assessments have not used ground-level monitoring to definitively determine whether environmental improvements, such as water quality, have actually taken place.

Any renewal or new version of a land retirement program should begin with all eligible lands, previously enrolled or not, equally competing for enrollment on the basis of environmental priorities and cost. CRP enrollment procedures after the 1990 farm bill guided by an environmental benefit index indicate rudimentary targeting information substantially improved potential environmental performance (61). However, this targeting procedure only applied to about 3.5 million acres, and not the 33 million enrolled prior to the 1990 farm bill. Regional analyses demonstrate that both higher environmental performance (see box 5) and lower rental costs may be reasonably expected. Thus, a simple renewal of existing CRP enrollments would fall substantially short of maximizing the environmental cost-effectiveness of long-term land retirement.

SB experience and surveys of CRP participant intentions indicate the majority of enrolled lands (probably two-thirds or more) will return to pro-

BOX 5: Targeting CRP in the Prairie Pothole Region

The Prairie Pothole region, about one-fourth of which dips down from Canada into the Dakotas, was identified in the expert panel exercise as an environmental priority for agriculture. On the North American continent, no region produces more ducks than the Prairie Potholes of the Northern Great Plains. Indeed, more than 50 percent of the ducks living in the U.S. and Canada were born in the Prairie Potholes (31). Ducks, deer, mink, and fox are among the wildlife that depend on this combination of wetland and grassland habitat.

Fields of wheat lie in close proximity to these wetlands, and many sporadic wetlands have been converted to farm fields over the course of this century. Approximately 6.2 million acres in the Prairie Pothole region are presently enrolled in the Conservation Reserve Program (2), which pays farmers to take land out of production for up to 10 years. These acres were enrolled primarily to control soil erosion, not to benefit wildlife. Yet, unexpectedly wildlife benefits have occurred.

If acres in the Prairie Pothole region are enrolled in a renewed CRP, is it possible to target the acres that most strongly protect native waterfowl (or other wildlife) habitat? Researchers working in the Prairie Pothole region demonstrated that waterfowl productivity can be enhanced and land rental expense lowered (69). Scientists integrated GIS with a variety of wetland and wildlife data developed by the federal Fish and Wildlife Service and National Biological Service as well as some presented in published literature. While their work is in progress, current results show that even a downsized Conservation Reserve Program, if retargeted, could reap substantial benefits to five duck species (mallard, northern pintail, gadwall, blue-winged teal, and northern shoveler) and to the North American Waterfowl Management Plan.

The approach, moreover, can be applied to other wildlife objectives. The targeting exercise could also be framed to integrate soil and water quality priorities with wildlife objectives. Savings in land rental expense may or may not occur in other cases. The targeting exercise could also be framed to integrate soil and water quality priorities with wildlife objectives.

SOURCE: Office of Technology Assessment, 1995.

duction after their contracts expire (96). The 10-year contracts with annual rental payments convey the notion of temporary set-aside. Only lands planted to trees can likely be considered under protection beyond contract expiration (1). In some cases, the return to crop production may not induce significant environmental damages if production developments have created opportunities for complementary technologies. Advancements in conservation tillage, for example, likely offer the potential for many CRP acres to return to production without risk of significant erosion and related damages. However, for enrolled lands on which continuing erosion or wildlife habitat protection is desired, either renewable contracts or easements are required. As noted above, the WRP largely avoids the risk of reconversion to cropland by using voluntary permanent or long-term easements where commercial production and wetland protection are deemed incompatible. These instruments can avoid some costs of multiple retirement episodes for such lands, including administration, practice establishment, and farm enterprise transition expenses.

Federal land retirement programs can cost less and still significantly contribute to long-term environmental protection. Effective mechanisms to ensure that rental payments do not exceed comparable market values, as used for post-1990 CRP enrollments, are already in place. Contracts that permit limited uses offering some commercial returns, such as haying or grazing that do not disturb nesting periods, offer the potential to lower rental payments by the amount of the commercial return. Other possible commercial opportunities include industrial crops and selling hunting privileges or other recreational services. However, the commercial uses must conform to environmental performance guidelines. Again, the WRP permits compatible uses such as hunting and fishing. Finally, provisions to allow states to contribute matching funds for land retirement that would have large state and local benefits could extend the influence of limited federal funds.

Surface Water Quality Illustration

The Corn Belt was chosen as one of the top 10 surface water quality priority areas. The primary challenge facing the region is to decrease the fertilizer, pesticide, and animal waste pollution entering streams and rivers. This pollution not only contaminates drinking waters downstream as far as the Lower Mississippi but degrades wildlife habitat as well. It stems from various agricultural practices, including fertilizer and pesticide application rates, tillage management, crop selection, and fragile lands management.

Given the complex relationships between agricultural practices and water quality, any solution to the problem will likely involve applying all three of the strategies described above. Potential program responses set out here are only illustrations of possible applications, however. Area and site-specific analyses of the agroecosystems, watersheds and farms are necessary to formulate appropriate management strategies. For example, researchers in Indiana and Wisconsin have demonstrated the potential of geographical information systems technology to improve targeting of the sources of key water quality problems to guide cost-effective programs (see box 6).

Complementary Technologies

The high potential of using soil nutrient testing to decrease nitrogen fertilizer applications has been mentioned in box 4. IPM also offers the potential to reduce pesticide applications, thereby decreasing runoff and leaching problems while saving money. The CT family of technologies have a sound track record of increasing profits and reducing erosion and surface water runoff. These approaches are excellent examples of potential complementary technologies that should receive vigorous education/technical assistance (ETA), and perhaps be eligible for minimal cost-sharing to overcome initial adoption barriers.

Before broad ETA initiatives can be launched, however, programs of applied research and systematic evaluation to enhance their complementary potential are probably necessary. For example, evidence about CT's effects on water quality are extensive, but the results are not as uniform as the evidence on soil quality. A large body of evidence shows that, in many parts of the country, CT improves surface water quality because it reduces erosion runoff of sediment and agrichemicals to streams (96). However, in other cases, the benefits of reduced surface runoff under some forms of CT have been offset by increased groundwater contamination (7). The principal message from these differing results is that CT's environmental performance is site- and farm-specific. It depends upon how the changes in tillage affect the buffering and assimilative capacities of the soil, in combination with shifts in the amount and type of agrichemicals used and how they are applied, and the hydrological characteristics of the field and farm in question.

The profit and environmental performance of these technologies will vary by specific farm and resource conditions, and therefore local expertise is required to judge applicability. For example, if increased infiltration under CT occurs where extensive drainage tiling systems empty easily into surface waters, negative effects on surface water quality will likely ensue. Although the current forms of these technologies can alleviate sources of surface water pollution, their full potential requires further research and development explicitly incorporating environmental quality objectives.

Other Management Practice Shifts

Although complementary technologies may alleviate a significant portion of the water pollution

BOX 6: Targeting System Management Within a Watershed

The importance of managing whole systems emerged as a key lesson in the exercise for identifying water quality priorities. Although conceptualizing systems remains a challenge, one approach to system management gaining interest in many parts of this country is “watershed management.” Watershed management often begins with the objective of protecting water quality in local or even regional drainage areas, but the interrelationships between water quality and wildlife health are generally acknowledged, too, as are links between soil erosion and water quality. By integrating an awareness of these and other aspects of environmental quality, watershed management is indeed an example of system management.

Yet, is it feasible to manage entire watersheds or indeed any “whole” systems? Can these managment efforts be implemented strategically and cost-effectively?

One way of increasing the feasibility and cost-effectiveness of watershed management is by targeting program efforts more carefully to sources of key problems. University researchers in Wisconsin and Indiana have demonstrated that Geographical Information Systems (GIS) and other modeling tools can help environmental managers visualize how water systems behave and, furthermore, enable them to target crucial links between agricultural land uses and water quality (45,66,103). These experiments have shown that it is possible to link different land use options (for example, different crop rotations or tillage practices) to the amount of soil that will enter nearby streams and, moreover, to the implications of that runoff for water quality (103).

Scientific evidence is quite clear that what happens to small streams that receive drainage from farm fields can directly affect the quality of a whole watershed. While some of these streams may not even run during some seasons of the year, and while many small streams and drainage flows may seem insignificant to larger watershed quality, pollutants from them merge and accumulate in rivers, lakes and wetlands. Riparian buffers, 50 to 100 foot widths of grass or other vegetation planted between farm fields and streams, have been proposed as a kind of land use change that may significantly improve watershed quality. Research demonstrates that such buffers do indeed trap soil particles and fertilizer residues making their way from cropland and grazing land.

The Conservation Reserve Program has made riparian buffers (also called “filter strips”) eligible for enrollment to promote erosion control (1985) and water quality improvement (1990). Voluntary adoption has not ensured that riparian buffers are placed in watersheds where they will do the most for water quality. Experiments in Wisconsin and Indiana suggest that information technologies could almost certainly help target riparian buffers more strategically for water quality improvement. Whether GIS approaches to targeting these approaches are the most cost-effective way to manage watersheds or other environmental systems in all cases is not clear. The cost of data collection, the challenge of making GIS more accessible to users, and the difficulty inherent in attributing the environmental benefits associated with its use are barriers that have not yet been fully overcome.

SOURCE: Office of Technology Assessment, 1995.

sources from agriculture, some dimensions of the problem will likely require changes in management practices that are currently not profitable. For example, continuous corn-soybean rotations may not produce enough crop residue to retard runoff effectively with profitable CT technologies. Under current commodity programs, participants risk losing program payments if they use less corn in their rotations and more grass or legumes. Increased flexibility in commodity program plantings through commodity program reform may induce more crop diversity, including hay and forages that provide erosion control and wildlife benefits (18). Moreover, it lowers government commodity cost exposure and gives producers more flexibility in responding to global food markets.

A second management practice likely requiring public incentives or disincentives is the establishment of grassed waterways or other structures on steeply sloping lands that result in excessive erosion and runoff despite CT practices. Although the grassed waterways are installed voluntarily by some others may need some incentives to cover part of the expense of construction and seeding. If the cost-sharing is restricted to only high-priority watersheds within the Corn Belt, the cost exposure could be limited. The practices also provide erosion productivity savings (thus giving some incentives for sharing costs by the owners) and wildlife benefits from permanent grass cover.

Intensive agricultural livestock operations often generate large amounts of waste per unit area, and have the potential to contaminate surface waters through precipitation runoff and excessive discharge. Although low-cost or even profitable grazing systems offer some hope of ameliorating these problems in certain areas (see box 7), the common approach has been to build manure management structures. Capital-intensive structures, such as lagoons for holding wastes, are often used to shift application patterns to seasons with less chance of runoff and contamination, but they involve significant capital costs. Agricultural conservation programs historically have shared some of the costs of constructing these types of structures, much as public funding was used to match local waste water treatment plant construction. In surface water quality priorities around the Great Lakes and the Corn Belt, public incentive programs could help ameliorate surface water quality damages from livestock wastes. Waste effluents from some confined animal feeding operations, generally exceeding certain size limits, are already regulated as point sources under the Clean Water Act and require technology and discharge standards. However, a review of the evidence indicates that enforcement varies widely by state, and some states provide cost-sharing incentives to complement the regulations (91).

Long-Term Land Retirement

Scientific assessments indicate that riparian buffer strips can effectively filter most of the sediment, fertilizers, and pesticides carried in runoff from crop fields and livestock sources (21,55). These filterstrips must be maintained in a suitable cover for extended periods to provide continuing water quality protection. If, as often is the case, they involve removing land from crop production for riparian area restoration, owners will not likely voluntarily convert the areas and will likely resist regulation to establish them. Virtually all of the surface water quality priorities identified by OTA, including the Corn Belt, involve excessive cropland runoff carrying sediment and agrichemicals into streams, rivers, reservoirs, and lakes. They are therefore candidates for buffer strips and long-term protection. In addition to water quality benefits, most of these riparian areas provide flood protection by increasing upstream storage capacity and increased wildlife habitat for terrestrial and aquatic species.

Most of the native grasslands of the Corn Belt have been converted into cultivated crop production or improved pasture. In steep cropland areas, or where the concentration of row crop production is particularly intense and could lead to excessive erosion and chemical water pollution, damage can be reduced by establishing large contiguous blocks of grasslands. The CRP established these types of grasslands, but not in patterns to maximize the potential for reducing water pollution or promoting the most valuable wildlife habitat. Cropland retirement secured by long-term contracts or easements on selected priority lands offers multiple environmental benefits.

Wildlife Illustration

The Corn Belt and several areas in the Great Plains were selected as wildlife priorities largely because they suffer from progressive destruction of their grass cover. Whether these areas are hay fields in diversified farming operations, perma-

BOX 7: Management Intensive Grazing as a Complementary Technology

Management Intensive Grazing (MIG) (also known widely as “rotational grazing” or “intensive rotational grazing”) refers to livestock systems that replace dependence upon animal confinement and mechanically harvested and handled or purchased feed with an emphasis on allowing livestock (usually cows) to graze on a series of enclosed pastures. *The central feature of these systems is careful management of the interaction between herds and pasture quality.* When the vegetation remaining in one area of pasture (paddock) can no longer support the herd, it is fenced off and allowed to recover over a 2–4 week period while the animals are rotated to a new paddock. The number and size of paddocks and the length of the rest period between grazings vary depending on the number of animals and the type of pasture vegetation.

Economic Performance: *Case studies, primarily of dairy farms, indicate that management intensive grazing technologies are profitable.* The USDA SARE program reports that $3.75 in benefits can be returned for each $1 invested by dairy farmers (99). On both large and small dairy operations, profitability can increase after switching to an intensive grazing system (50,59), due largely to a significant reduction in operating costs. Profits can average $120–150 per cow (19). Although a thorough analysis of the economic performance of management intensive grazing is lacking, available evidence indicates that good management is the single most important factor is establishing a profitable grazing system.

Environmental Performance: It should be noted at the outset that while substantial research has been conducted on many aspects of rotational grazing, *no comprehensive attempt has been made to compare the environmental effects of pasture-based and confined feeding livestock operations.* Some considerations of the effects of MIG on soil, water, and wildlife quality may be made, nevertheless.

Conversion of cropland to pasture can reduce localized demand for pesticides and fertilizers. Corresponding risks of soil or water degradation may, by inference, decline correspondingly. Well-managed pastures may experience little soil compaction since animals are moved regularly, and a successfully managed rotation ensures continuous, perennial plant cover that can reduce soil erosion. MIG systems are not without risks to soil quality, however, especially during spring when soils are muddy.

Water quality problems can stem from sediment, manure and pathogens introduced by livestock trampling stream banks and wading in waterways. By providing a water source in each paddock to alleviate these concerns (50), graziers may need to consider whether stationary water sources encourage soil compaction and overgrazing around the water source. Manure management, especially during winter, is also a consideration. Rigorous comparison between MIG and confined systems regarding nitrate leaching to groundwater and other aspects of water quality is lacking.

MIG may be more compatible with protection of wildlife habitat than confined systems, primarily because pasture offers a more complex habitat for insect, birds and mammals than does a field planted to one or two crops. The actual mix of vegetation maintained on grazing lands will have a significant impact on wildlife, however. If the majority of grasses planted as forage are not native to the area, their value to local wildlife may be reduced and/or they may overrun and outcompete native plants (74). The amount of land dedicated to grazing would also affect the quality of habitat.

SOURCE: Office of Technology Assessment, 1995.

nent riparian areas along streams, grass strips in erosive portions of fields, or fencerows or windbreaks, they can provide critical wildlife habitat for food, nesting, and security from predation. In some areas, they will also trap water runoff that carries pesticides, fertilizer, and sediment to rivers and streams and destroys aquatic habitat. The program challenge is to develop private and public incentives that will restore natural grassland habitats, and that will withstand economic pressures for conversion back to cropland when crop prices jump abnormally high for short periods.

Complementary Technologies

Because more grass or natural habitat is crucial to better wildlife health, complementary technologies for wildlife are difficult to find. Generally, switches from cultivated crop enterprises to hay or natural grasses mean lost profits. Some analyses suggest, however, that increased crop diversity, including forages, could lead to steady or increased profits while improving environmental performance (18). Validating these modeling estimates on the ground is not feasible under current commodity program and technology conditions.

Another possibility of joint production-environment advantage is management-intensive (rotational) grazing as explained in box 7. This shift in enterprises essentially adds more grass or hay cover in the crop rotation. In some areas, research shows the change to this practice preserves or increases profits while reducing water pollution and enhancing wildlife cover (36). Extensive research on its applicability in wildlife priority areas has not been conducted.

Other Management Practice Shifts

Two of the top 10 wildlife priorities—riparian buffer strips and the Great Lakes—involve establishing grass buffer strips along rivers, intermittent streams, and drainage ditches, with special emphasis on grassed waterways in the upper reaches of drainages. These buffers also likely provide improved water quality and water storage for potential floods. Although maintaining some of the buffers may require land rental or easement acquisition, some types such as the grassed waterways in upper drainages and field buffers have been traditional venues for cost sharing.

Another possibility is to establish conservation headlands, a practice that ensures the outer edges of fields are not sprayed with pesticides, to promote greater plant diversity, cover, and food sources. Preliminary research in Europe has shown that establishing these headlands in a 20 foot border around arable crop fields increases the abundance of forbs (herbs other than grass) and insects, leading to improved reproduction of ground nesting birds (83). Some incentive would likely be necessary to induce farmers to adopt the practice. If the headland practice is coupled with integrated pest management, there may be a potential, in some situations, for improving wildlife habitat value while maintaining or increasing profits. In those cases, the practice becomes a complementary technology. The Great Plains and Corn Belt may be good trial areas. However, the overall applicability to U.S. farming systems or environmental performance in the selected priority areas has not been widely investigated.

The construction of holding ponds to catch sediment and agrichemical runoff is another practice traditionally receiving cost-sharing incentives. Such holding ponds and other controlled drainage practices improve aquatic habitat by decreasing the amount of pollutants entering rivers and streams. They may have some use in areas where complementary technologies are not available and inadequate funds exist for long-term set-asides. However, the structures require year-round maintenance (58) and removal of sediment to maintain their interception of pollution flows. Research has demonstrated that controlled drainage utilizes water more efficiently, and, in some areas, this increases crop yields by 10 percent (22); this provides substantial private incentive for implementation.

Long-Term Land Retirement

As explained previously, agricultural practices have diminished significant amounts of natural habitat over time, and, until the CRP, wildlife species that depend on agricultural habitat were declining substantially across the country. Broad scientific evidence indicates that long-term cover is the key to recovering and maintaining many wildlife species native to regions that are dominated by agriculture (2).

All wildlife priorities identified by OTA require the establishment of long-term grass, tree, or wetland cover. Examples include the establishment of native grasses on highly erodible Corn Belt croplands, of wetland protection in the Prairie Potholes, of large contiguous blocks of grasslands in the Plains states for game and nongame species, of bottomland hardwood plantings along the Lower Mississippi Valley, and of riparian buffer strips in the Great Lakes region. The creation of long-term natural cover often leads to erosion control, water quality, or other environmental benefits, as noted in the overlapping designations on the wildlife priority table.

Soil Quality Illustration

Soil quality priorities, as noted earlier, overlap with many water quality priority selections and other subject areas. Accordingly, they are good cases to search for program solutions that emphasize system approaches that integrate multiple environmental dimensions.

Complementary Technologies

With the exception of priority 8 (Hawaii), the first potential solution for the soil quality priorities involves improved tillage practices, reflecting the fact that there is further potential to expand CT in those areas. Although CT technology was introduced in the early 1980s, some operators may still benefit from learning about its economic and environmental consequences for their farms. This approach might be especially appropriate for treating soil erosion problems on farms that have not been subject to conservation compliance requirements and therefore have not implemented a conservation plan. The wider application of CT technologies should be screened for increased groundwater quality risk due to greater water and agrichemical infiltration. Further research and development may yield new CT technologies that better meet surface water and groundwater quality objectives.

Organic farming systems offer another possible complementary technology approach for improving soil quality (see box 8). Although commercial applications of these systems cover small acreages in the U.S., research has documented that they can yield economic returns comparable to conventional systems. Their environmental performance is not extensively documented as the box text explains.

Other Management Practice Shifts

Several opportunities are available for incentive programs to improve soil quality. In four of the top 10 priority areas (1, 4, 5, and 6), OTA identified short-term set-asides with companion technology development as a potential solution. Those set-asides would likely be accomplished with incentives in the form of land rental payments. Commercial use could be permitted on these set-aside lands that satisfies environmental requirements. Also, treating soil erosion problems often requires the construction of costly grassed waterways, windbreaks, and other structural measures. Federal and state incentive programs have provided funding to operators to defray part of such costs since the 1930s. These measures would likely be eligible for cost sharing under an incentives package for soil quality in the priority areas. An alternative to incentive approaches would be to require minimum practices to retain eligibility for agricultural program payments (compliance mechanisms).

Long-Term Land Retirement

Considerable advances in the family of CT technologies over the past decade will likely allow many CRP lands to return to profitable production and meet environmental objectives. However, resumed production on some CRP lands will cause continuing, significant on-site productivity losses and off-site damages under cultivation. OTA identified areas in the Southern Piedmont (2), the Palouse and Columbia Plateau (3), the Iowa and Missouri Heavy Till plain (6), the Northern/Central Plains (7), and the Southern and Central High Plains and Tablelands (9) as priorities where long-term set-asides were likely necessary for those marginal croplands. Long-term set-asides of the most vulnerable lands also provide other significant environmental benefits including better water quality, wildlife habitat, and water conservation in the Plains states.

BOX 8: Organic Farming as a Complementary Technology

Organic farming systems are characterized by technological methods that rely on crop rotations, crop residues, composted animal manure, legumes, green manure, mineral-bearing rocks, mechanical cultivation and biologically-based pest controls. These methods avoid the use of synthetic fertilizer, pesticides or growth regulators. Organic technologies are designed to "maintain soil productivity and tilth, to supply plant nutrients, and to control insects, weeds, and other pests (93)." In the 1990 Farm Bill, the intent to develop federal standards for the marketing of organically-grown products was codified in the Organic Foods Production Act ("OFPA") of 1990 (87). Although standards have not yet been established, the OFPA stipulates that certification will only apply to products grown on land managed in accordance with accepted organic methods for 3 years or more. In the current absence of federal standards, accepted organic practices are defined and certified by state and/or "third-party" independent associations.

Economic Performance: Preliminary studies showed that yields per acre were generally equivalent to or slightly less than yields on conventional farms, and that production costs averaged 12 percent lower than those associated with conventional methods (92). *A recent review of economic research on the subject indicates that the profitability of organic production methods competes favorably with conventional methods in many regions of the country* (9). Broader adoption of organic technologies might face barriers similar to those described in the case of IPM: inadequate knowledge of alternatives, lack of adequate technical assistance, and the costs of management. The absence of programmatic incentives for adoption might also be a factor. Finally, attitudes that organic methods are old-fashioned and out-of-date, or that organic farming is a philosophy rather than a set of technologies may also pose barriers to adoption.

Environmental Performance: *Environmental benefits related to organic production are commonly inferred from the fact that synthetic pesticides and fertilizers are avoided while naturally-derived inputs are typically used.* As has been discussed elsewhere in this report, the environmental effects of agriculture can not be determined simply from the amount of one or a few inputs used. When considering the environmental performance of organic technologies, consideration should be given not only to what inputs and practices are avoided, but also to what inputs and practices are implemented. In short, environmental effects are mediated through processes that involve *what* inputs are used, *how* they are used, and *where* and *when* they are used. Among the issues that may be considered are effects on soil quality, water quality, and compatibility with wildlife habitat.

While yield comparisons are numerous, adequate comparisons of the environmental effects of organic and conventional production technologies have not been made. For example, a recent GAO study indicates that improperly stored livestock waste is a significant source of surface water impairment caused by agriculture (89). Do management methods on organic and conventional farms differ in the tendency to leach nitrate into groundwater and allow nutrient runoff to enter streams? Comparisons could also be made between the environmental effects of organic and other pest control methods. A preliminary attempt to compare integrated pest management, conventional and organic pest control methods on apples in New York state indicated that organic methods exert the most detrimental environmental effects because of the frequent use of sulfur (39). This study has met with both interest and criticism (85). The absence of additional studies makes it difficult to evaluate the results.

SOURCE: Office of Technology Assessment, 1995.

CONCLUSIONS AND POLICY IMPLICATIONS

Better targeting of strategic federal program approaches to agroenvironmental priorities could yield more benefits and preserve budget resources. Current conservation and environmental programs for agriculture do not focus on priorities as a rule. As a result, they cannot selectively apply program strategies—profitable complementary technologies, public incentives or disincentives for other management practices, or long-term retirement—based on a target problem.

Improved targeting of priorities and application of strategic programs also implies the opposite approach to implementing uniform programs across the country. More precise application of programs helps lower unnecessary costs to agriculture, reduces program burdens on farmers, and helps sustain the essential elements of agroenvironmental health. Focusing programs on priority targets would likely keep more land in production to serve consumer and trade interests.

The expert panel approach developed by OTA proved feasible and effective in identifying agroenvironmental priority areas in cases where existing databases are incomplete. If the approach is adopted, it could be repeated periodically to ensure that the most current science and data are used to monitor changes in environmental conditions and other factors influencing priorities. The national expert panel exercise needs to be augmented with regional, state, and local input to further refine the priority areas within the national selections.

The findings have direct implications for developing and implementing conservation and environmental programs in agriculture. *First, legislation could direct the use of targeting procedures to maximize environmental benefits for tax expenditures.* For example, opening the re-enrollment of the Conservation Reserve Program to all lands based on environmental merit and cost enables taxpayer funds to achieve the greatest net benefits. Restricting re-enrollment to existing contract holders likely locks in what appears to be a socially unprofitable program for another 10 years.

Second, the expert panel process of developing priority areas could be incorporated into program implementation. Drawing on leading scientists to inform the priority selections is crucial to the success of the process. Further, the priority area guidelines developed in this assessment can be revised periodically as science advances and as regional, state and local expertise is consulted.

Finally, to accelerate the development and adoption of technologies that will sustain privately profitable production and achieve environmental objectives, agricultural research programs must be solidly interlinked with agroenvironmental programs. Existing research and conservation programs are largely disjoint. To induce effective collaboration, program incentives must reward research and technology *achievements* that contribute to production and environmental objectives using whole farm system approaches. More involvement of the private sector will be necessary to attain the full potential of complementary technologies, not only due to limited government budgets, but also because private involvement will help guide and adapt technology innovations.