Agriculture and Water Quality

by
Anna Barrios
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Abstract

We may have become an urban nation, but we remain an agricultural land. Nearly 70 percent of the United States, exclusive of Alaska, is held in private ownership by millions of individuals. Fifty percent of the United States, 907 million acres, is cropland, pastureland and rangeland owned and managed by farmers and ranchers. The responsibility for stewardship of the land lies in the hands of about 4.7 million individuals. This means that the care of 50 percent of the United States is in the hands of less than 2 percent of it's citizens (USDA, Dec. 1996, p. 7). The extent and importance of agriculture in the United States means that it is impossible to accurately assess the health of the land without a special focus on agriculture.

While much of agriculture's environmental impact can be assessed within an individual field or farm ownership, there is much that cannot. The continued domination of agricultural land use, combined with the growth and dispersal of people into suburban and rural areas, means that the quality of the nation's environment and the sustained productivity of the land depends more than ever on how people relate to the land. How America's farmers and ranchers use and manage their land is, therefore, key to producing the nontraditional agricultural commodities that people value and to maintain healthy, stable landscapes and watersheds. Moreover, the continuing dispersal of urban and suburban residents into rural areas virtually guarantees heightened interest among the newcomers in agriculture's environmental performance (USDA, Dec. 1996. p.20).

While agriculture does have some very serious effects on the natural environment, with a strong commitment from landowners and proper policy in play these effects can be mitigated (USDA, Dec. 1996. p.22-23). Because too much of an agricultural input in the wrong place can cause water quality degradation or other environmental problems, management practices and systems have been developed that can sustain yields and protect the natural resources that produce them. As producers, farmers must consider the relative merits of permanent practices that have high capital costs versus those that have lower capital costs but require careful continuous management. It is important to encourage farmers to act as responsible stewards of the land. While agricultural commodities are in surplus, the farmers' essential services of land stewardship are in deficit. The marketplace does not recognize and reward farmers for sound management of agriculture land, yet such services are in great demand by the public and necessary to sustain the future prosperity and livability of many of our nation's communities.

Agriculture and Water Quality

We may have become an urban nation, but we remain an agricultural land. Nearly 70 percent of the United States, exclusive of Alaska, is held in private ownership by millions of individuals. Fifty percent of the United States, 907 million acres, is cropland, pastureland and rangeland owned and managed by farmers and ranchers. The responsibility for stewardship of the land lies in the hands of about 4.7 million individuals. This means that the care of 50 percent of the United States is in the hands of less than 2 percent of it's citizens (USDA, Dec. 1996, p. 7). These areas produce traditional commodities for the market place: corn, soybeans, oats, hay, milk, beef, wool, Christmas trees and more (USDA, Dec. 1996, p. 5).

Today, each acre of cropland produces nearly three times what was produced on that same acre in 1935. This dramatic productivity increase has made food prices lower for Americans than for any other industrial country. Exports of agricultural commodities reached $56 billion in 1995 – 7 percent of our export total that year. But farmers and ranchers are capable of producing much more than just food and fibers. Through care and stewardship of the land, farmers can produce safe drinking water, clear-flowing streams and scenic landscapes (USDA, Dec. 1996. p. 7). Most of the water we use falls first on our nation's farms and ranches, where it is portioned by soil into surface water, groundwater and vapor that reenters the atmosphere through plants (USDA, Dec. 1996. p.6). To be more specific, nearly 88 percent of the water that falls on the United States as rain or snow each year falls on private land before it reaches our lakes and streams and groundwater aquifers (USDA, Dec. 1996. p. 8).

The extent and importance of agriculture in the United States means that it is impossible to accurately assess the health of the land without a special focus on agriculture. Across the expansive and diverse landscape, Americans produce at least 200 different crops. Amidst this diversity, however, four crops – hay, wheat, corn and soybean – account for about slightly more than half of the total value of all farm sales. Major fiber products include timber, cotton, wool and hides. While much of agriculture's environmental impact can be assessed within an individual field or farm ownership, there is much that cannot. Few farms are large enough to encompass the entire landscape or watershed, and even those farms that are exceptionally large are ecologically linked to neighboring land, including nonagricultural land (USDA, Dec. 1996. p.19). The continued domination of agricultural land use, combined with the growth and dispersal of people into suburban and rural areas, means that the quality of the nation's environment and the sustained productivity of the land depends more than ever on how people relate to the land. How America's farmers and ranchers use and mange their land is, therefore, key to producing the nontraditional agricultural commodities that people value and to maintaining healthy, stable landscapes and watersheds. Moreover, the continuing dispersal of urban and suburban residents into rural areas virtually guarantees heightened interest among the newcomers in agriculture's environmental performance (USDA, Dec. 1996. p.20).

Among the 2 million farms, the number of farms in both the small and large ownership categories has increased, while the number of mid-size farms has dwindled. This increasing pattern of small ownership in many rural areas means a dramatic increase in the "edge effect" as urban land use patterns press into rural ones. Rural homesites and "ranchettes" increasingly mix with prime farm and forestland. The conflicts that develop between rural residents and agriculture make commercial production more expensive and difficult. Increasing taxes, regulations and land prices often lead farm and forest landowners to give up and sell out (USDA, Dec. 1996. p.22).

The increasingly complex mix of urban and rural land uses has natural resource impacts that extend well beyond land use competition. Urbanization brings streets and rooftops that run stormwater directly into drains and drainageways instead of filtering it naturally through the soil. There are new pollutants as well, such as oil leaked from automobiles or chemicals leached from suburban lawns. Watersheds where the maintenance of healthy conditions formerly depended on the land stewardship of a few dozen agricultural managers, now often rely on the actions of hundreds of small landowners, making the task of developing effective, cooperative efforts all the more difficult and necessary. This is not to say that agriculture does not have some very serious affects on the natural environment as will be discussed in the following sections, but with a serious commitment from landowners and proper policy in play these effects can be mitigated (USDA, Dec. 1996. p.22-23).

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The status of the nation's water resources (river, lakes and estuaries) is assessed by states and Native American tribes in accordance with section 305(b) of the Clean Water Act. Water quality is defined by each state and tribe for each water resource, based on the state or tribe's determination of the waters beneficial uses (swimming, fishing, supporting aquatic life, etc.). In the 1994 assessment, states and tribes reported on 17 percent of river miles, 42 percent of lake acres and 78 percent of estuarine square miles. Of the river miles assessed, about 64 percent were found to be of good quality, with no identified use impairments. Thirty-six percent of the assessed miles suffered from use impairments caused by one or more sources. Agriculture was found to contribute to impairment in 60 percent of the impaired river miles, equivalent to 22 percent of the total assessed river miles (USDA, Dec. 1996. p.40).

One of the major sources of water impairment from agriculture is the sediment, often with nutrients or chemicals adsorbed to the soil particles, that enters streams and rivers as a result of soil erosion. While eroded soil may not move directly into waterways, there is a direct water quality benefit when America's farmers and ranchers reduce the amount of soil that moves off their land. Concentrated animal production sites are of particular environmental concern because of the potential for nutrient and bacterial contamination of water resources as well as odor problems affecting neighboring communities. Industrialization of the livestock production sector, spurred by economics of size and new production and processing technologies, has produced livestock concentrations and geographic shifts unprecedented in the United States. Parts of the Southwest and West are the primary hotspots for animal manure problems, in part because of soil and climate factors and in part because those areas lack adequate cropland on which to apply manure properly. The link between feed production and livestock concentrations in the Midwest does allow, in many instances, for land application of animal manure and recycling of the nutrients in the crop production system, but that does not mean that all manure is now being handled adequately (USDA, Dec. 1996. p.40-41).

Nutrients, mainly nitrogen, phosphorous and potassium, are applied to promote plant growth. If they are applied inappropriately or in excessive amounts, these beneficial materials can threaten associated water resources adequately (USDA, Dec. 1996. p.41). Another important pollution source is pesticides. Since 1979, the agricultural sector has accounted for about 80 percent of all pesticide use each year. Some crops, such as cotton, are pesticide-intensive. Others, such as wheat, are not. Pesticides may contaminate water by leaching through the soil profile or by running off the field surface into nearby water bodies. Many of the same factors affecting leaching and runoff potential, and some areas have high potential for both pathways. But distinctions are also apparent. For example, pesticide runoff potential is greater in the Midwest, while leaching potential is greater in the humid Southeast (USGS, 1999).

Developments such as integrated pest management, biotechnology, improved pesticide and nutrient management planning, and livestock manure management systems all work to reduce the potential for agriculture to impair the nation's water resources. Agriculture also contributes to water quality improvements through such conservation measures as buffer strips, grassed waterways and wetland and riparian area restoration, among others that will be discussed in the upcoming sections (USDA, Dec. 1996. p.45).

Cropland Nonpoint Source Pollution

More specifically, in agricultural streams seasonal patterns in water quality tend to emerge. The patterns reflect many factors, but primarily the timing and amount of chemical use, the frequency and magnitude from rainstorms or snowmelt and specific land management practices, such as irrigation and tile drainage. Concentrations of nutrients and pesticides in these agricultural streams are greatest during runoff following chemical applications. The seasonal nature of these factors dictate the timing of elevated concentrations in drinking-water sources and aquatic habitats (USGS, 1999, p.7).

- *Nitrogen and Phosphorous*: Some of the highest levels of nitrogen occur in streams and ground water in agricultural areas. Application of fertilizers, manure and pesticides have degraded the quality of steams and shallow ground water in agricultural areas, and have resulted in some of the highest concentrations of nitrogen measured in National Water-Quality Assessment program. Compared to nitrogen, a smaller proportion of phosphorous (originating mostly from livestock wastes or fertilizers) tends to be lost from watershed to streams. NAWQA studies found that the annual amounts of total phosphorous and total nitrogen measured in agricultural streams were equivalent to less than 20 percent of the phosphorous and less than 50 percent of the nitrogen that was applied annually to the land. This is consistent with the general tendency of phosphorous to attach to soil particles and move with runoff to surface water. Even with the lower losses from land for phosphorous than nitrogen, however, phosphorous is more likely to reach concentrations that can cause excessive aquatic plant growth. Nitrogen concentrations are rarely low enough to limit aquatic growth in freshwater, whereas phosphorous concentrations can be low enough to limit such growth. Hence, excessive aquatic plant growth and eutrpophication in freshwater generally results from elevated phosphorous concentrations (typically the limiting nutrient for aquatic plant growth in saltwater and coastal waters) (USGS, 1999, p.8) .

- *Pesticides*: Pesticides, primarily herbicides, are frequently found in agricultural streams and shallow ground water. Extensive herbicide use in agricultural areas (accounting for about 70 percent of the total national use of pesticides) has resulted in the widespread occurrence of herbicides in agricultural streams and shallow ground water. The highest rate of detection for the most heavily used herbicides – atrazine, metolachlor, alachlor and cyanazine – were found in streams and shallow ground water in agricultural areas (USGS, 1999, p.8).

- *Insecticides*: Insecticides were frequently detected in some streams draining watersheds with high insecticide use but were less frequently detected in shallow ground water because most insecticides are applied at lower levels than herbicides and tend to sorb into soil or degrade quickly after application (USGS, 1999, p.8).

Rangeland Nonpoint Source Pollution

Nonpoint source pollution from rangelands may be caused by grazing, roads, construction activities, mining, recreational activities and natural processes. Concentration of livestock, heavy grazing and hoof action are potential causes of excessive sedimentation, heat, nutrients and pathogens (University of California Cooperative Extension).

While erosion on most rangeland in California is well below the traditionally accepted tolerance level, the vast area of rangeland and its critical position in the state's water supply system offers an opportunity to improve water quality throughout the state. Soil erosion and sedimentation are primary contributors to lower water quality from rangeland. Pasture and rangeland generally become a source of nonpoint pollution when grazing removes a high percentage of the vegetative cover, exposing the soil surface to erosive action of water and wind. Eroded soil subsequently becomes sediment, creating the potential for water degradation that may lead to impaired uses. Roads and other areas of disturbed ground can be major contributors of sediment to stream and lakes. Many roads are located along streams where the muddy runoff from the road is discharged directly into the stream. Streambanks and associated riparian zones are subjected to heavy livestock use. Trampling and grazing of vegetation are frequently associated with streamside instability and accelerated erosion (University of California Cooperative Extension).

Thermal pollution has two basic sources related to grazing and livestock production. Heavy grazing can result in loss of streamside vegetation that shades streams and helps to maintain cool water temperatures required by many cold waters fishes, especially trout, salmon and steelhead. Drainage of irrigation water that has warmed as it crosses a hay field, pasture or meadow can also raise the temperature of cold water streams (University of California Cooperative Extension).

Nutrients from manure and decaying vegetation can become pollutants near streams and lakes during the rainy season or periods of runoff. In these locations runoff can carry nutrients into water bodies quickly. Nutrient problems are usually most critical where animals congregate for water, feed, salt and shade. Nitrate and phosphate are usually the nutrients of concern. Pasture fertilization can be a source of these and other nutrients (University of California Cooperative Extension).

Localized contamination of surface water, ground water and soil itself can result from animals in pastures and rangelands. Research reports show that livestock operations may cause increased coliform bacterial pollution in rangeland streams. Although fecal coliforms themselves are not pathogenic, they indicate that pathogens could exist and possibly flourish. Fecal streptococci may also be a reliable and definitive measure of human or animal pollution. The extent of pathogens depends largely on livestock density, timing of grazing, frequency of grazing and access to the stream. Fecal coliform levels tend to increase as the intensity of livestock use increases. Maintaining the health of livestock is critical and proper management of the herd, its byproducts and exposed land is essential. Grazing strategies that maintain adequate vegetative cover are the best approaches to reducing grazing caused erosion and sedimentation. Dispersal away from streams rather than concentration of livestock appears to be the best means of reducing nutrient and pathogen loading (University of California Cooperative Extension).

Livestock activities that may lead to impair beneficial uses fall into three categories: heavy grazing, hoof impacts and livestock waste concentration. Heavy grazing removes vegetation that covers the soil. Vegetation protects soil from the erosive energy of raindrops. Vegetation acts as a sediment trap. Vegetation increases infiltration rate, getting water into the ground where it can do some good rather than running off as overland flow that can erode soil. Hoof impacts can destroy streambank vegetative cover and physically breakdown streambanks. Livestock waste concentration can be a source of pathogen and nutrients pollution, especially if they concentrate in or near streams (University of California Cooperative Extension).

Best Management Practices

Because too much of an agricultural input in the wrong place can cause water quality degradation or other environmental problems, management practices and systems have been developed that can sustain yields and protect the natural resources that produce them. The key is to reduce pollutant loading by interrupting the process at the point of availability, detachment or transport. Farmers and ranchers are reducing potential pollutants by decreasing the availability of soil to become sediment, primarily through the use of agronomic practices such as cover crops, residue management and rotations that include close-grown crops. They are reducing nutrients for transport by accounting for all nutrients available, regardless of source, method of incorporation and application rate and timing. Pesticides are being reduced through integrated pest management, crop rotations, cultivation, biological pest control, scouting and selecting pesticides that are more environmentally friendly, as well as through reducing the use of pesticides in their operations. Salt is controlled through irrigation water management, which takes into consideration application, timing and amount. Heavy metals are controlled by soil acidity, monitoring and limiting quantities and locations for sludge application. Finally, pathogens can be controlled by: minimizing surface runoff, detachment and transport; excluding livestock from surface waters; using buffer strips in riparian areas; and properly disposing of dead animals (USDA, March 1996).

Among these possibilities there are a core four BMPs that when applied are a common sense approach to improving farm profitability while addressing environmental concerns. These BMPs are easily adaptable to virtually any farming situation and can be fine-tuned to meet unique needs. The net results tend to be better soil, cleaner water and greater on-farm profits. Sustainable soils which increase long-term productivity result from increased organic matter, improved soil moisture, reduced compaction, sequestered carbon and reduced erosion from water and wind. This leads to improved water quality in addition to food, fiber, energy and other renewable resources produced by agriculture. Sharpening management skills and utilizing the latest appropriate technologies results in higher levels of economic efficiency and cropland productivity. These four core practices are conservation tillage, crop nutrient management, weed and pest management, and conservation buffers (Core4).

Conservation tillage is a system of crop production with little, if any, tillage. It increases the residue from the crop that remains in the field after harvest through planting. The result is increased natural recycling of crop residue. Conservation tillage is currently used on 38 percent (109 million acres) of all U.S. cropland (293 million planted acres). By leaving crop residue undisturbed for as long as possible, microbial and other biological activity in the soil feeds on the stalks, leaves and other crop residues. This increases organic matter, improves soil tilth and ultimately increases soil productivity. Soil erosion can also be reduced by 90 percent compared to intensive tillage. Reducing soil erosion also reduces phosphorous and pesticide movement. Reductions in phosphorous result in reductions in algae and increased oxygen supply for fish. There is also reduced risk of nutrients escaping the soil by increasing nutrient availability and uptake by plant roots (Core4).

The more risk is reduced, the better the opportunity in increased profitability. The conservation tillage system reduces labor, equipment costs and fuel use, particularly when no-till is used. No-till soybean production normally increases profit per acre. No-till wheat improves rotation diversity providing more crop flexibility and greater profits over the entire rotation period. No-till cotton also increases profit per acre. This will become apparent as ginners improve their ability to gin strippers harvested cotton (Core4).

The second practice is crop nutrient management, which looks to match nutrient availability with the plant's needs. Crop producers do this by increasing the efficiency of nutrient use. Thus producers fine-tune application rates, timing and placement to match plant growth. Increased use efficiency results in reduced nutrient loss. Efficient crop nutrient management addresses all nutrients including manure, fertilizer and natural mineralization. It provides plants the right combination of nutrients near the roots when the plants require the nutrients for growth. It assures nutrients are in a form that the plant can use. This relies on research to improve our understanding of the plant's needs, and requires utilization of new technologies that will enable producers to use nutrients more efficiently (Core4).

These processes reduce the risk of nutrients making their way to streams, groundwater and surface water. The reduction of nutrients reaching surface waters reduces algae growth which can result in increased oxygen supplies and improved habitat for fish, increased recreational activities including boating and swimming, better aesthetics and reduces water treatment costs. This type of management practice can also increase profit per acre by increasing the efficiency of crop inputs and the resulting yields (Core4).

Weed and pest management is a comprehensive approach to fine tuning on-farm management of harmful weeds and pests. These types of management strategies allow for better control, with minimum risk to the environment. These include resistant plants, cultural controls, soil amendments, beneficial insects, natural enemies, barriers, physical treatments, behavioral disputants, biological and conventional pesticides. Inputs such as mechanical cultivation, pesticides, fertilizers and tillage trips cost money. By using best management practices to apply these inputs when they are actually needed, growers can reduce costs. Weed and pest management can help match the best method of control with the optimum time to maximize benefits of the control. Thus, weeds and pest management can improve the bottom line for growers. By using mechanical cultivation, pesticides, fertilizers and tillage only when necessary, growers protect the environment, by reducing sediment and polluted runoff from entering our lakes, streams and rivers. Utilizing scouting and selecting the appropriate control for the weed or pest identified supports the biological integrity of all life on earth (Core4).

Conservation buffers are small areas or strips of land in vegetation designed to slow water runoff, provide shelter and stabilize riparian areas. Strategically placed in the agricultural landscape, buffers can effectively mitigate the movement of sediment, nutrients and pesticides within farm fields. Buffers include counter buffer strips, field borders, filter strips, windbreakers and wetlands. A small amount of land in buffers can assist producers in meeting both economic and environmental goals. When located in environmentally sensitive areas, buffers provide another line of defense to filter both surface and shallow ground water before it enters streams and lakes. Buffers can reduce sediment by 80 percent, phosphorous by 40 percent, pathogens up to 60 percent and a significant amount of nitrogen, thereby improving fish habitats. Other benefits include reduced wind erosion, reduced downstream flooding, slower water runoff and stabilized streambanks among other things. Buffers can also reduce crop losses from flooding, protect soil in vulnerable areas and provide tax incentives (National Conservation Buffer Initiative-NRCS, p.3).

Other examples of commonly available BMPs include:

- Manure crediting – Commercial fertilizer applications are made after considering the amount of nutrients provided by manure applications.
- Legume crediting – Commercial fertilizer applications are made after considering the amount of nutrients provided by legume crops.

- Split application – Approximately half of the required amount of nitrogen for corn production is applied at or before planting. The remainder is applied after the crop begins to grow.
- Irrigation scheduling – A variety of practices and techniques are used to minimize the quantity of irrigation water applied while avoiding crop stress from too little moisture.
- Deep soil nitrate testing – The amount of residual nitrogen in the soil profile is measured to determine the level(s) of commercial fertilizer application needed.
- Soil moisture testing – Measure the amount of water available from topsoil and subsoil (Feather, 1995).

Using BMPs to Improve Water Quality

California: San Francisco Bay/Sacramento-San Joaquin Delta Estuary

Agriculture contributes more than half of the pollution entering the nation's rivers and lakes. California's San Francisco Bay/Sacramento-San Joaquin Delta Estuary (Bay-Delta) is one of many water bodies in the country suffering from impaired water quality due, in part, to agricultural activities in its watershed. The Bay-Delta, which is the largest estuary on the west coast and the hub of the state's water delivery system, is critical to California's environmental and economic health. Evidence of pollutant effects in the Bay-Delta is sufficient to designate much of the estuary as threatened or impaired due to combinations of different toxic pollutants found in its waters (Agricultural Solutions).

Water conservation and pesticide use reduction techniques have improved water quality in the Bay-Delta ecosystem. There have been a number of case studies of farms and projects that have put these techniques to use. When water from rainfall or irrigation reaches agricultural fields it mobilizes salts, trace elements such as selenium, and other contaminants, including pesticides, that may be present in the soil. Before the federal and state water projects were built in California, the low rainfall received by most farming regions in the state mobilized naturally occurring salts and trace elements very slowly. With irrigation water now catalyzing the process, these elements, along with fertilizer and pesticide residues, can mobilize more rapidly and concentrate in harmful amounts in water draining from fields into the Bay-Delta and its tributaries. Selenium and pesticides are among the most problematic constituents of these flows.

Selenium is a trace element found naturally in crude oil and in most soils, especially those that developed from Cretaceous shales, such as soils on the west side of California's San Joaquin Valley. While small amounts of selenium are necessary to life, higher concentrations are toxic. The issue of selenium in agricultural drainage water first received widespread public attention in the 1980s, when selenium-laden drainage from the Westlands Water District in California's San Joaquin Valley caused deaths and deformities in thousands of waterbirds at the Kesterson Reservoir. While selenium is only one of many pollutants in agricultural drainage, it is of primary concern in California both because of its wide natural distribution in the soils on the west side of the San Joaquin Valley, and because of its proven toxicity, as illustrated by the Kesterson tragedy and elsewhere (Agricultural Solutions).

Organochlorine pesticides such as DDT are also routinely detected in the Bay-Delta watershed. A highly persistent class of chemicals, organochlorines are only slightly soluble in water, but their residues persist in soil and aquatic sediments and can concentrate in the tissues of aquatic organisms for years after they are applied. While DDT has been banned, other organochlorine pesticides such as dicofol and endosulfan remain in use throughout California's Sacramento and San Joaquin Valleys (Agricultural Solutions).

Organophosphate pesticides are also found in the Bay-Delta watershed. While less persistent than the organochlorines, at high enough concentrations organophosphates can be acutely toxic to aquatic organisms. Water conservation and pesticide use reduction can help improve Bay-Delta water quality. Water conservation can improve water quality by: reducing the volume of surface runoff and subsurface drainage; potentially reducing the pollutant loads of the remaining subsurface drainage; allowing more efficient application of agricultural chemicals; and limiting irrigation-induced erosion and sediment loads (Agricultural Solutions).

In addition to improving water quality, water conservation can leave more water in rivers, streams and wetlands for fish and wildlife, as well as reduce the number of fish killed directly by water diversions. Conservation can also help farmers increase crop yields and quality, reduce production costs as a result of water and energy savings, and reduce pesticide and fertilizer applications. Alternative pest management techniques can minimize pesticide contamination of the Bay-Delta ecosystem. Many of these techniques, including cover crops, soil building and crop rotation, are designed to prevent conditions that encourage pest problems, thereby eliminating the need for chemical intervention. Other alternative techniques control pest populations by enhancing populations of natural predators, or by relying on natural or less toxic substances to reduce or eliminate pests (Agricultural Solutions).

The following examples illustrate on-the-ground situations where water conservation and pesticide reduction techniques are being used successfully, and where farmers have found that these techniques maintain or increase the economic viability of their farming operation(s) (Agricultural Solutions).

- West Stanislaus Hydrologic Unit Area (HUA) Program, Stanislaus County. The HUA program was developed to reduce runoff of pesticide-laden sediment into the San Joaquin River. Using a mix of information and education, cost-sharing, technical assistance, and monitoring and evaluation, the program has reduced water use by 18 percent, saving over 12,000 acre feet of water per year. Cumulatively, the program has prevented over 718,950 tons of sediment from entering the impaired San Joaquin River.

- John Texiera of Trecho Farms in Los Banos. Through his extensive soil building program and use of drip irrigation, John has reduced herbicide use by 30 percent, synthetic fertilizer use by 25 percent and water use by 50 percent.

- Jim and Deborah Durst in Esparto. Using crop rotations, building soil fertility and using other integrated pest management techniques, the Dursts have completely eliminated use of synthetic pesticides and fertilizers.

- Lundberg Family Farms in Richvale. Using creative irrigation and integrated pest management techniques, the Lundbergs have reduced synthetic pesticide use 100 percent on organic fields and 50 percent on Nutra-farmed fields and have also reduced water use by 25 percent.

- Panoche Drainage District in Fresno County. Panoche has been directly confronted with the necessity of reducing selenium loads into the San Joaquin River, and as a result has adopted a variety of policies that are geared toward encouraging farmers to reduce or eliminate their drainage. Many farmers in the district, including two who are mentioned in this report, have changed their irrigation practices as a result of these policies.

- Sherman Boone in Denair. Releasing beneficial insects into his orchards and growing a cover crop both to improve soil fertility and provide habitat for beneficial insects, Sherman has eliminated synthetic insecticide use and reduced synthetic herbicide use by 33 percent and synthetic nitrogen fertilizer use by 50 percent.

- Claude and Linda Sheppard in Chowchilla. Using beneficial insects, and other IPM techniques, the Sheppards have completely eliminated the use of synthetic pesticides. They have also adopted irrigation water management techniques that have kept their water use 25 percent below the regional average for cotton.

- Craig McNamara in Winters. Growing cover crops for weed and insect control and for soil building, and using insect mating disruption techniques for the codling moth, on half of his acreage Craig has reduced synthetic herbicide use by 35 percent and reduced synthetic nitrogen fertilizer use by 50 percent.

- Doug Hemley in Courtland. Using insect mating disruption techniques to address codling moth problems, Doug has reduced insecticide use by 50 percent.

- Steve Nishita in San Juan Bautista. Using a linear move irrigation system, Steve has reduced water use, improved irrigation efficiency, reduced labor costs and improved yields on his farm.

- Mark Gibson in Hollister. Relying on beneficial insects and a cover crop, Mark has completely eliminated use of synthetic pesticides and fertilizers in his walnut orchards, and eliminated use of synthetic insecticide, herbicide and fertilizer use in his apricot orchards.

The farmers profiled here illustrate with their practices the changes that are possible in resource management. These case studies clearly demonstrate that farmers can significantly reduce their water use, as well as their reliance on synthetic pesticides and fertilizers. At this time, however, the farmers who are choosing to use these techniques are in the minority. While there are many factors that affect the choice of farming techniques, there is much that can be done on a policy level, using a mix of incentive-based and regulatory programs, to encourage increased use of sustainable farming techniques.

Indiana and Ohio: Lake Erie/Maumee River Basin
The Maumee River watershed drains a total of 6,608 square miles (4.2 million acres) in Ohio, Indiana and Michigan. The LEASEQ water quality study collected samples at Waterville, Ohio, which accounts for 6,329 square miles (4.0 million acres). Agricultural land accounts for 88 percent of the land use in the watershed in the test area. The Maumee River Basin was designated one of 43 Areas of Concern in the Great Lakes Basin in 1985. Though it carries only 3 percent of Lake Erie's water, it contributes significant portions of the phosphorous and sediment entering the lake.

A wide variety of programs promoting best management practices such as conservation tillage and fertilizer management have been implemented in the Maumee River watershed. Agencies including the U.S. Environmental Protection Agency, Ohio EPA, Ohio Department of Natural Resources, USDA-NRCS, local soil and water conservation districts, and university advisors and their counterparts in Michigan and Indiana, played major roles in improving the water quality in the basin.

They did so by implementing demonstration projects, educational efforts promoting treatment facilities and a cost-share program to encourage area farmers to buy or build conservation tillage equipment. For instance, 1.6 million acres in the LEASEQ study area is in conservation tillage, which reduces runoff of sediment, nutrients and pesticides. In addition, thousands of farmers have reduced their application of phosphorous and nitrogen fertilizers. The result has been a marked improvement in water quality. Delivery of total phosphorous from the Maumee River watershed to Lake Erie dropped 20 percent to 25 percent and dissolved phosphorous fell 60 percent to 70 percent during the 1975-1995 cleanup efforts in the Lake Erie basin. Suspended sediment is substantially lower now than in 1975, and total Kjeldahl nitrogen is down (Core4).

North Carolina: Herring Marsh Run
A 5,000 acre, coastal watershed, Herring Marsh Run had the potential for tremendous water quality problems due to exploding hog and poultry industries, as well as cropland and growing human population. Producers in the watershed joined state and federal agencies in a project of voluntary well testing, surface water sampling and Best Management Practices. The watershed project introduced classic BMPs such as conservation tillage, field borders and strips of grass along the edge of cropped fields that capture sediment and nutrients running off the land. The project also introduced groundbreaking practices such as animal mortality composting and variable rate fertilization demonstrations.

Perhaps most important, growers discovered that hog manure and poultry litter could be a valuable resource providing nutrients for crops and replacing approximately 180,000 pounds of commercial nitrogen fertilizer per year. Applying animal waste at agronomic rates – matched to crop needs – put tons of waste to use, kept nutrients out of streams and kept thousands of dollars in grower’s pockets. The improvements to the watershed included nitrogen concentration significantly dropping. Nitrogen concentration at the watershed’s outlet has been cut in half since the project started in 1990, from an average reading of approximately 2.5mg/L nitrate-N in October, 1990 to less than 1 mg/L in July, 1997. Seasonal peaks are also lower now than they were early in the project (Core4).

Strategies
Historically, government programs have provided farmers an income safety net by compensating them for the commodities they produce or do not produce. Such policies face resistance in an era of free markets, oversupply and constrained federal resources. They also risk undermining America’s case for reducing agricultural subsidies by its European trading partners. This situation presents the policy challenge of how to increase farmers’ income and not oversupply while still protecting the environment, within the context of political and fiscal realities (Crabtree, North Dakota Consensus Council).

As producers, farmers must consider the relative merits of permanent practices that have high capital costs versus those that have lower capital costs but require careful continuous management. Problems that solve one water quality must not increase the potential for another (USDA, March 1996). It is important to encourage farmers to act as responsible stewards of the land. While agriculture commodities are in surplus, the farmers’ essential services of land stewardship are in deficit. The marketplace does not recognize and reward farmers for the sound management of agricultural land, yet such services are in great demand by the public and necessary to sustain the future prosperity and livability of many of our nation’s communities. As stated earlier, while there are many factors that affect the choice of farming techniques, there is much that can be done on a policy level, using a mix of incentive-based and regulatory programs, to encourage increased use of sustainable farming techniques (Crabtree, North Dakota Consensus Council).

A broadly conceived and flexible policy of compensating farmers for retaining and slowing water and restoring natural ecological function to agriculturally marginal lands can generate a host of positive and mutually reinforcing outcomes. Agricultural benefits include: providing financial incentives for comprehensive stewardship services; diversify, stabilize and increase farm income by allowing producers to concentrate production on prime agricultural soils, while receiving payments for retiring and restoring unprofitable land; and create opportunities for expanding irrigation and high-value crop production in conjunction with water retention and storage for flood mitigation. Disaster mitigation benefits include support measures that store, reduce or slow run-off that causes flooding, and that reduces the risk of mudslides, fire and drought. They may also reduce repetitive damage to crops, and the associated recurring federal cost, through: retirement of marginal, flood-prone land; decrease potential flood damages to urban areas by reducing peak flood events downstream; and reduce the amount of developed land, thus increasing absorption, and reducing runoff and flooding. Finally, environmental benefits would include conservation of natural ecosystems such as wetlands, woodlands, grasslands and riparian areas. Reduction in sprawl and hazard-prone development . It would provide incentives for habitat development that supports endangered species recovery, and increase the natural absorption of carbon dioxide and other greenhouse gases through conservation and restoration of woodlands, grasslands, wetlands and riparian areas (Crabtree, North Dakota Consensus Council).

Presented here are a few strategies that may be employed at different levels of society to assist farmers in switching to more environmentally beneficial practices while still protecting the farm and allowing the farmer to be profitable.

Locally Led Conservation

Locally led conservation offers an opportunity to bring together, under the leadership of local conservation districts, the people who care about their home place. Included will be the landowners, as well as all the others whose lives and futures might be affected by what happens on the land. Locally led conservation brings downstream neighbors affected by what happens into the process of developing effective, voluntary approaches to conservation. People working together as neighbors find solutions to common problems and agree on ways to implement those solutions (USDA, Dec. 1996, p64).

Those who participate in locally led conservation efforts often include people and groups who value the land for very different reasons and in very different ways. As they come together to understand the land in a particular area, they are often able to focus far more clearly on the shared visions they may have for their home place. Where natural resource conditions and needs can be assessed, goals defined, opportunities and constraints identified, and responsibilities clarified, plans of actions can emerge that have a good chance to succeed because the plan is rooted in a shared vision and responsibility (USDA, Dec. 1996, p64).

One example of a locally led conservation is a low-interest loan offered in Ohio. The Ohio Environmental Protection Agency has been offering such loans through its Water Pollution Control Linked Deposit Program. The loans may be approved for any practice, equipment or management change that will have a positive effect on water quality. The farmer's interest rate is about 3 percent below the going market rate (USDA, Dec. 1996, p65).

Local and state governments can also examine their land-use plans from a watershed perspective, paying attention to how permitted land uses affect aquatic ecosystems and quality and quantity of surface and groundwater. The impact may be direct, such as allowing for building over aquifer recharge zones, or indirect, such as allowing aerial application of pesticides over homes or waterbodies. Consideration must be given in the zoning of rural areas to the different types of uses (row crops, livestock, other farm enterprises, industry or second homes) that may be made of the land. Whatever development is allowed, it should be undertaken so as not to have a major effect on water resources quantity or quality or aquatic ecosystems (Water Quality 2000, 1992, p. 82).

Public policy initiatives
Public policy initiatives to influence polluted runoff can be divided into four categories: 1) Voluntary actions, 2) incentives, 3) removal of policy barriers and 4) regulations. Experience has shown that a balance of all four approaches is needed. There are a number of incentive-based approaches to alleviate farm runoff and reduce flooding impacts. Among them are:

- Improving tillage and farm management practices to control erosion;
- Demonstrating the benefits of grass-based farming, which is adaptable to seasonal flooding;
- Restoring wetlands and riparian areas; and
- Advocating state and federal funding to share the cost of conservation activities.

Removal of existing policy barriers can also be necessary, because as long as commodity programs continue to reward destructive farming practices, environmental programs alone can never succeed. Farm policy reform must emphasize changing the policies that work against environmental protection. Regulations are also a necessary component of public policy to provide the final nudge for reluctant landowners, and to culminate in enforcement for the few "bad actors" that refuse to respond. Landowners who are contributing to pollution in impaired watersheds should be required to develop an integrated, site-specific plan that gives them flexibility in determining their options to meet water quality goals (Kemp, 1994).

Economic Incentives
Some economic incentives would include the federal government phasing out irrigation subsidies, which encourage the wasteful use of water, as well as cultivation of marginal quality lands where irrigation especially contributes to water quality problems. Water deliveries should be measured to each farm, and farmers should be charged only for the water they use. Rate structures that charge farmers on a per-acre basis regardless of water use promotes waste, not conservation. States should renew and expand their revolving fund loans for irrigation system upgrades. Such assistance can help overcome the obstacles of high up-front capital costs, which may otherwise divide farmers from adopting cost-effective technologies. Another no water based incentive would be to tax pesticides according to their toxicity. Higher taxes should be placed on the more toxic chemicals, including those that are scheduled to be phased out, to give extra incentive for early replacement with less toxic alternatives (Agricultural Solutions).

Federal Policy
A federal policy option that would reward farmers and ranchers for employing conservation practices could be very efficient. An example would be establishing three classes of conservation practices for which farmers and ranchers would receive progressively higher incentive payments, perhaps based on a percentage of the county rental rate. Producers that would adopt all Class I practices, if applicable, would receive a 10 percent payment. This would include thing like nutrient management, conservation tillage, runoff and drainage control, and managed grazing. In order to receive a 20 percent payment, Class II practices would include comprehensive nutrient management, intensive/rotational grazing, wetland restoration, etc. To receive a 40 percent payment, farmers would have to adopt Class III practices on a whole farm under a total resource management plan that would addresses all aspects of air, land, water and wildlife.

Good water quality reflects what we do on the land as well as what we do in the water. Because agriculture is by far the most extensive land use in the United States, improved water quality depends in large part on the commitment of improving the quality of soil and other natural resources as well as the water. The improvements in water quality we have seen reflect commitment to action. Agriculture's contribution to water quality impairment will likely continue declining as whole-farm planning creates a more ecologically aware farming environment, thus enhancing the environment as a whole (USDA, March 1996).

Conclusion

Within all these strategies the most important thing we must do is begin to see this country's farmers as more than just the producers of traditional commodities. They need to be viewed as stewards of the land whose decisions have a direct impact on the health of the rest of the nation. In order to protect the land so that it may produce the non-traditional commodities of safe drinking water, clear-flowing streams and scenic landscapes, we must work with the less than 2 percent of the citizens that care for over 50 percent of the land. Good water quality reflects what we do on the land as well as what we do in the water. Because agriculture is by far the most extensive land use in the United States, improved water quality depends in large part on the commitment of improving the quality of soil and other natural resources as well as the water. The improvements in water quality we have seen reflect commitment to action. We need this serious commitment from landowners and policy leaders alike to make the proper decisions and offer the right incentives to those that do a good job. Best management practices are available to mitigate the potentially harmful impacts of agriculture, and huge benefits from proper mitigation are also possible though conservation techniques like buffer strips and grassed waterways among many others. Agriculture's contribution to water quality impairment will likely continue declining as whole-farm planning creates a more ecologically aware farming environment, thus enhancing the environment as a whole (USDA, March 1996).

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