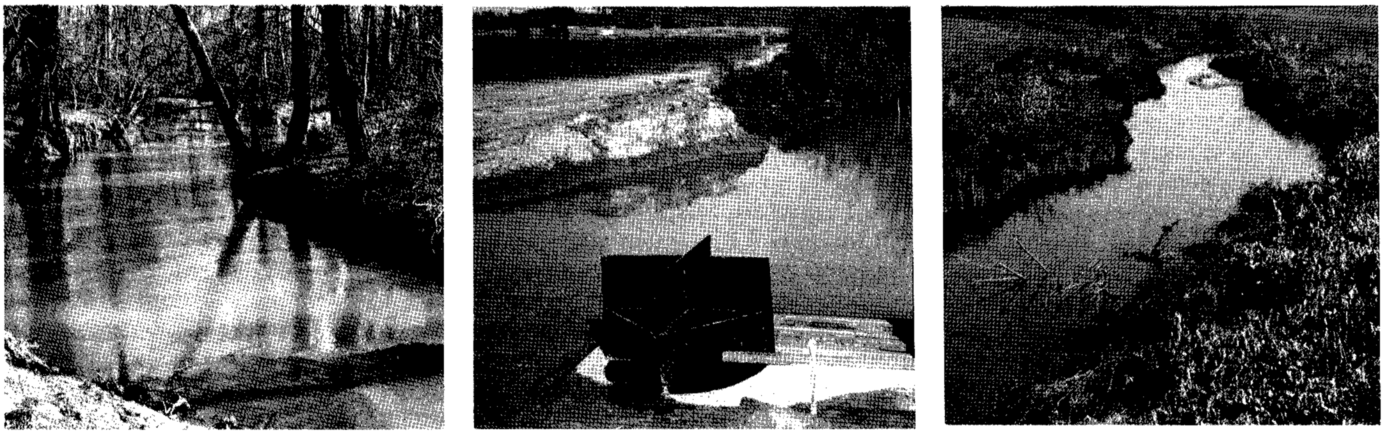

Water quality and agriculture: Mississippi experiences

By Charles M. Cooper and William M. Lipe

AGRICULTURE and water quality are linked inseparably because of agriculture's requirements for land and water. In the principal farming and livestock sectors of the United States, agricultural land is a major source of sediments, nutrients, pesticides, and coliform bacteria.

Although many problems are site- or region-specific, research conducted in the southern United States helps to focus on these basic water quality problems. Research shows that installation and maintenance of soil-conserving practices and animal waste treatment systems can curtail much of the pollution from agricultural activities now. Continuing research is needed to determine the best mix of agricultural practices and resource management and to develop new technology for managing agricultural pollution products and prevent their delivery to streams and lakes.

Water quality conditions result from past and present large-scale uses of land and water. In some states, 75 percent of the land area and 80 percent of the total water is used in agricultural production. Because farming demands a larger share of the landscape and more water than most other uses, society has burdened agriculture with a proportionately greater responsibility for water quality degradation. Thus, deterioration of water quality has become a major agricultural issue.

Conventional cultivation, without soil and water conservation practices in place, accelerates soil erosion and increases the potential for loss of sediments, nutrients, and agricultural pesticides. Erosion processes eventually result in lost soil productivity and off-site damages to streams and lakes (*6, 8, 10, 18*). Livestock production practices also add nutrients and coliforms to watershed runoff, creating additional problems (*19*).

In a recent assessment of lakes across the United States, the U.S. Environmental Protection Agency found that 25 percent of more than 12 million lakes surveyed in 34 states were impaired or partially impaired and 20 percent were threatened by pollution, mainly from nutrients and sediments (*32*). According to state reports, 76 percent of the pollution entering lakes originates from nonpoint or undescribed sources, 11 percent from point sources, and 12 percent from natural sources. Urban runoff, mining, and industry were major point sources in specific areas. But agricultural runoff was the most frequently cited source. States also reported that agricultural nonpoint sources caused 64 percent of river water quality degradation and that pesticides adversely affected almost 5,000 water bodies in 609 of the 3,137 counties surveyed (*32*).

Sediments

Instream suspended sediments and bedload are, by volume, the largest category of pollutants in the United States (*20*). The Mississippi River carries 331 million tons of topsoil to the Gulf of Mexico annually (*14*). Yearly discharge from agricultural land to waterways in the United States is estimated at 1,079 million tons of sediments and 477 million tons of total dissolved solids (*16*). This sediment load also represents the loss of topsoil that may only be replenished at a rate of less than one inch in 200 years. Sediments carried in runoff degrade downstream water quality and carry nutrients and pesticides that adversely influence aquatic life (*27*). Sediment accumulations fill drainageways, culverts, and stream and lake beds, resulting in restricted flow, habitat degradation, navigational difficulties, and reduced productive life of reservoirs (*30*).

In lakes, suspended sediments limit aquatic primary productivity, especially where suspension persists seasonally and limits light penetration. For example, in a multiyear study of Lake Chicot, Arkansas, algal biomass was significantly less in the turbid main south basin, which drained a channelized 360-square-mile agricultural watershed, than in the isolated, less-turbid north basin, with a watershed of less than 40 square miles. From 1980 to 1984, sediment concentrations each April averaged 69 parts per million in the north basin and 385 parts per million in the main body of the lake (*9*). A stormflow diversion completed in 1985 significantly decreased suspended sediments in the south basin. Mean suspended sediment concentrations for the five-year period after the diversion was completed were similar—39 parts per million in the south basin versus 30 parts per million in the north basin. As the suspended sediment load decreased, water quality in the south basin improved rapidly. Significant differences in algal density between the two basins disappeared as physical and chemical water quality parameters

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became more closely aligned.

Slow-flowing streams in the Mississippi River delta have many characteristics in common with natural oxbow lakes in the region. Suspended sediments are slow to deposit, and they degrade water quality conditions for longer periods than in upland streams. In two upland streams within the loess hills region of Mississippi, Cooper and Knight found that suspended sediment loads generally exceeded 80 to 100 parts per million—the maximum for optimal fish growth—only during and immediately following storm events (*14*).

Sediment accumulation in streams and lakes must be viewed as part of total water quality deterioration because it directly degrades fish habitat by burial. In natural lakes along Bear Creek, a drainage system in the flat alluvium of the Mississippi River, where 75 percent of the land is in cultivation, Ritchie and associates found that one to three inches of fine sediments accumulated per year (*28*). In similar watersheds, accumulated sediment has covered the bottoms of many lakes and stream sections with fine silt (*29*).

Bottom sediment accumulations also are sinks for persistent pesticide residues and metals. Sinks add to long-term contamination because they permit low-level re-entry of pollutants over long periods (*4, 34*). In a recent study of Moon Lake, situated in the delta region of Mississippi, DDT, arsenic, and mercury were detected in accumulated sediments of all 65 lake and wetland sediment cores examined (*7*).

Erodible cropland contributes the most sediment when soil tillage and minimum cover conditions coincide with seasonal heavy rainfalls. The most critical period on cultivated fields is during seedbed preparation and planting. An Alabama study showed that as much as 85 percent of total sediment loss may occur during the critical period from soil tillage until crop canopy and root development (*34*).

The first principle of sediment reduction from agricultural land centers on sound land use policy and management. Land should be used only within the capability to support crop production without excessive erosion. Highly erodible land should not be cultivated without protective soil and water conservation practices. The primary method of preventing sediment-related pollution involves such practices as conservation tillage, cover crops, grassed waterways, terraces, filter strips, water and sediment control basins, and contour farming. Comparing sediment and nutrient losses from conventional and no-till soybean systems in northern Mississippi, McDowell and McGregor found that no-till systems reduced annual soil loss to only 1 percent of that measured from conventional tillage (*21*). In an evaluation of winter cover crops for sediment and runoff reductions in northern Mississippi, Mutchler and McDowell found that when cover crops were established after cotton harvest in a conventional tillage system measured runoff fell from 48 percent to 26 percent of total rainfall and soil loss decreased from 33 tons to 9 tons per acre (*22*).

Farm ponds and water/sediment retention structures also are effective measures for removing sediments from runoff. In a five-year study, Dendy and Cooper (*6*) found that a 3.5-acre farm pond removed 77 percent of the annual sediment inflow from a mixed-pasture, row-crop watershed (*15*). The new concept of using slotted board outlets to pond runoff and trap sediment at the end of a field has an additional benefit in that sediment can be excavated periodically and easily returned to farm fields. Field outlet or overfall pipes also eliminate lateral stream headcuts, another source of sediment. By slowing and reducing runoff, soil and water conservation practices also reduce crest levels for large storms, which trigger major sediment contributions from stream banks and beds.

Continuing research is needed to select the best mix of agricultural and resource management practices and to develop technology for managing agricultural pollution

Nutrients

Eutrophication of surface waters and increasing concern over nitrates in surface water, groundwater, and near coastal waters are major water quality issues (*32*). In nutrient-deficient freshwater streams and lakes, phosphorus and nitrogen generally limit aquatic productivity (*33*). Conversely, excessive nutrient levels contribute to algal blooms and eutrophication. Although nutrients originate from other sources, such as residential lawns, turf areas, and septic systems, agriculture is the major contributor. American agriculture discharges 1.16 million tons of phosphorus and 4.65 million tons of nitrogen into waterways annually (*16*). Major agricultural nonpoint sources of nutrients include heavily fertilized cropland and livestock wastes. Enriched runoff from cropland remains the major seasonal nutrient source, but failing animal waste treatment systems are now being compared to urban point sources of nutrients.

Eutrophication, or enrichment, is a natural phenomenon, but accelerated cultural eutrophication prohibits functional water use and shortens lake life. Eutrophication eventually leads to a general deterioration in the quality of aquatic communities within streams and lakes (*23*). Oxygen depletion and fish kills are common events associated with cultural eutrophication. The 1972-1975 National Eutrophication Survey found 78 percent of 574 lakes across the United States were eutrophic (*25*). Mean water concentrations of phosphorus and nitrogen within predominantly agricultural drainage areas were nearly nine times higher than in forested basins.

Extensive algal blooms, documented in the Chowan River basin of North Carolina for the last 15 years, are a notable example. A study of the basin in 1979 found that 25 percent of the nitrogen and 20 percent of the phosphorus in water originated on cropland and that 23 percent of the nitrogen and 12 percent of the phosphorus originated from organic animal waste (*24*). Watershed characteristics, such as vegetation, topography, soil type, particle size, and organic matter, also influence nutrient contamination. In an ongoing study of the Coldwater River system in Mississippi in 1989 and 1990, channelized tributaries with little or no buffer zones had nitrate concentrations during storms of two to three parts per million compared to one part per million in natural stream reaches with wetland or riparian buffers.

Examples of enhancement of the designated use of lakes or streams from increased nutrients also exist. Although phosphorus loading in Lake Chicot, Arkansas, caused algal blooms in the isolated north basin, the resulting eutrophication yielded a superior sustainable fishery. Despite storm loading of nutrients in two creeks draining hill lands of northern Mississippi, no signs of nutrient eutrophication were noted in a three-year study (*14*).

As with sediments, the best corrective measures to reduce nutrient discharge begin on the land. Proper soil testing and efficient fertilizer application techniques, such as banding, can reduce potential nutrient discharge 35 to 94 percent (*24*). Slow-release nitrogen fertilizers and split applications also reduce nitrogen losses significantly compared to losses from conventional fertilizers and surface applications. Terraces, crop rotations, and other conservation tillage practices that reduce soil erosion result in more efficient nutrient uptake by crops, thus reducing nitrogen and phosphorus losses. Nutrient management practices that apply fertilizer according to soil needs within a field, as determined by grid soil sampling, have been shown to use nitrogen more effectively. In Mississippi, total losses of nitrogen and phosphorus in runoff were 91 and 86 percent less, respectively, in no-till soybeans compared to conventional tillage due to reduced sediment losses (*21*).

Impoundments have a positive effect on reducing downstream water quality problems arising from agricultural nutrients. Morris Pond, a 3.5-acre pond with a 36-acre watershed, trapped more than 74 percent of the phosphorus and nitrogen flushed from row crops and a confined cattle feeding operation in the watershed (*13*). As a result of this research, the Soil Conservation Service has developed interim standards for pollution retention ponds. Research on constructed wetlands shows a high potential for properly designed systems to remove nutrients, biological oxygen demand, and coliforms discharged from overloaded animal waste lagoons (*5*).

Pesticides

Producers applied about 400 million pounds of pesticides to the 10 major field crops in the United States in 1988 (*17*). Agricultural pesticides, primarily organochlorine insecticides, were identified as the leading cause of fish kills in the United States from 1961 to 1975 (*31*). Their persistence is well documented (*27, 35*). Ten years after the ban on DDT, residues continued to be detected in all watershed ecosystem components of Moon Lake in northwestern Mississippi (*7*). With more than 70 percent of the watershed in soybeans, cotton, and rice, residual insecticide concentrations were significantly higher in aqueous/sediment phases of surface waters during the winter/spring wet season than during the dry season. This period of maximum runoff corresponded to minimum ground cover and maximum soil disturbance on the cropland. Concentrations of DDT remained sufficiently high to accumulate in fish tissue 10 years after it was banned. Forty-five lake sediment cores, analyzed in 1982, contained a mean concentration of 235.4 parts per billion of all DDT compounds (DDT, DDD, and DDE). Sustained DDT concentrations, observed during periods of runoff, resulted from the magnitude of DDT remaining in watershed soils (mean=369 parts per billion) and emphasizes the importance of watershed management practices for long-term water quality improvement. During the same study (*7*), methyl parathion and two pyrethroid insecticides were detected less frequently and in lower concentrations in runoff and lake sediments, water, and fish. Methyl parathion was detected twice as often as the two synthetic pyrethroids in both water and fish, but it was detected in only 14 of 400 water samples (with a high concentration of 0.49 part per billion) and in 16% of 100 fish samples (with a high concentration of 15.96 parts per billion). When compared to the older organochlorines, these insecticides persist in the environment only for days or weeks, instead of years (*1*), but sublethal effects on aquatic life and water quality may be subtle and not well defined. Also, acute toxicity of newer compounds poses a serious potential for detrimental consequences to ecosystems if flushed into streams and lakes soon after application.

Constructed wetlands have shown potential for reducing the potential of agricultural pollutants entering surface water or groundwater.

Agriculture without pesticides currently is not an economic reality. But as caretakers of natural resources, farmers, chemical manufacturers, and private and commercial applicators must not allow chemical contamination to become the problem that it has been in the recent past. More efficient use and careful management using integrated pest management techniques can reduce substantially the amount of pesticides needed and offer less environmentally hazardous alternatives. Surveys estimate that 70 percent of cotton farmers are using integrated pest management techniques, such as commercial cotton insect scouting (*17*). This implies that 30 percent of applicators continue to select and use pesticides for cotton according to potentially unnecessary and wasteful routines. Education and recertification of both private and commercial applicators in all phases of pesticide management, including application, mixing, loading, transport, storage, handling, and container and waste disposal, is needed if increased federal regulation of pesticides is to be avoided.

Coliform bacteria

Coliform contamination of rural and urban surface waters has been a major environmental and public health concern for decades (*3*). Specific concerns in agriculture have centered on water supplies that receive direct runoff from pastures. Until recently, research has centered on major sources of coliform, such as feedlots, pastures, and land disposal areas (*19*).

Recent results show that sources of contamination are variable and complicated. Both soil and stream bottom sediments are reservoirs for coliforms. Wildlife and livestock contributions are difficult to quantify. In one study in Bear Creek, Mississippi, fecal coliform contamination in stream reaches serving as wildlife habitat were comparable to cattle crossings (*11*).

Water quality standards for fecal coliform concentrations in point-source discharges may be unrealistic for many natural streams (*13*). But management practices used for sediments, nutrients, and pesticides also help to control nonpoint coliform pollution. Constructed wetlands show promise for reducing fecal coliform concentrations in runoff from confined

Concentrations of DDT compounds (DDT, DDD, and DDE) and toxaphene residues in major watershed components in Moon Lake, Mississippi, and its watershed (7).

	ΣDDT		Toxaphene	
Component	Mean	Range and Standard Deviation	Mean	Range and Standard Deviation
		μg/kg		
Soil n=69	369.31	0 - 6,406.93 ± 981.19	734.01	0 - 7,377.72 ± 1099.22
Wetland n=20	212.84	0 - 568.14 ± 176.07	Not Detected	
Sediment n=45	235.45	0 - 650.80 ± 158.90	12.42	2.6 - 35.80 + 11.56
Water n=255	0.11	0 - 1.0 + 0.11	0.01	0 - 0.40 ± 0.06
Fish* n=28	243.96	80 - 463.0 ± 114.03	Not Determined	

*Mississippi Department of Wildlife, Fisheries and Parks.

livestock operations. Limiting livestock access to streams is a simple, effective way to lower coliform contamination.

Addressing the problem today

Sediment is the most prevalent water pollutant in the nation. Most agricultural nutrients and pesticides also travel with sediment in storm runoff. Research from study sites and watersheds in the southern United States focuses on the magnitude of four problem areas: sediments, nutrients, pesticides, and coliform bacteria. Several highly effective management practices work equally well in controlling pollution associated with these diverse problems. Current innovative technology is manifest in soil and water conservation practices that are based on the premises of retaining topsoil and nutrients on the land as valuable agricultural resources. When these practices are applied in accordance with Soil Conservation Service technical guides, they provide for erosion control, runoff detention, and treatment of nonpoint-source discharge before it leaves the land, thus preventing off-site damages, including water quality degradation.

Water detention is a key to reducing off-site damages, whether using grass waterways and filter strips or innovative pollution retention ponds, constructed wetlands, or slotted-board outlet pipes. Management of water quality also must include producing less contamination, such as is possible with nutrients targeted to specific field or crop needs, integrated pest management, and treating wastes on-site. To meet this nation's water quality goals, agriculture must practice a higher level of soil and water resource stewardship and acknowledge both the short- and long-term consequences of poor land and resource management. Innovative ideas are needed for the 21st century, but technology is available now to control many of today's agriculturally related water quality problems.

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