DETERMINISTIC ASSESSMENT OF AGRICULTURAL NONPOINT SOURCE POLLUTION IN MISSISSIPPI DELTA MANAGEMENT SYSTEMS EVALUATION AREAS (MSEAs)

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INTRODUCTION

Agricultural activities are considered a major source of nonpoint source pollution in the nation. Surface and subsurface waters draining agricultural fields transport nutrients, pesticides, and suspended sediments to receiving streams and aquifers causing them to become contaminated for designated uses. Examples of nonpoint source pollution due to agricultural activities can be seen in studies from around the nation such as one by Goolsby and others (1991) where one or more herbicides were detected in 146 water samples collected from the Mississippi River and its major tributaries; also, from the same study, nitrate concentrations were elevated because of the influx of nitrogen derived from fertilizer in Iowa, Illinois, and possibly Minnesota and Wisconsin. Similarly, Pereira and Hostettler (1993) labeled the Mississippi River, a "drainage canal" for pesticide-contaminated surface and ground water from the midwestern United States. Parsons and Witt (1988) reported 74 pesticides were detected in ground water in 38 states. Duda and Johnson (1985) estimated that agricultural lands contribute about 74 percent of the phosphorus and 64 percent of the suspended sediment discharged to the nation's surface waters. In the Beaver Creek Watershed Study in West Tennessee, Roman-Mas and others (1994) reported that excessive sediment transport was the major water-quality problem in that particular watershed.

The Clean Water Act reauthorization in 1977 recognized best management practices (BMPs) as methods to control agricultural nonpoint source pollution (Council for Agricultural Science and Technology 1992). Subsequent reauthorizations required each state to prepare a nonpoint source pollution assessment report and a management program. Also, Federal assistance was authorized to support demonstration projects and actual pollution control activities, such as farmers participating in voluntary BMP programs (Lee 1993; Moreau 1994). Future reauthorizations may include agricultural policies and practices, as related to stream-habitat destruction, soil erosion, and agrichemical transport, that are more regulatory in nature (Brezonik and Cooper 1994; Wise 1994).

The Problem

Water-quality research in agricultural regions is necessary to assess the effects of agricultural activities on water quality and to evaluate the effectiveness of BMPs. Because agricultural regions may vary within a particular state due to differences in soils, cropping history, agrichemical use and so forth, most state nonpoint source pollution monitoring programs are limited in scope and resources. Such monitoring activities are typically based on an occurrence and distribution approach, as opposed to a deterministic approach. Occurrence- and distribution-type studies are important in that they identify areas in a state where excessive levels of nonpoint source pollution occur. However, data collected from such studies are generally broad-based and are of limited value to assess the farm-level effects of agricultural activities on water quality. For example, organo-chlorine pesticides such as DDT have been banned from use since the early 1970s. Since that time, producers began using pesticides that are less toxic, more water soluble, and that break down easier in the

environment. Very little field-level research has been conducted to assess the effects of these newer chemicals and their metabolites on water quality (Pereira and Hostettler 1993). Deterministic water-quality research at the field level is necessary to provide a more comprehensive data base for planning purposes with regard to the fate and transport of pesticides, as well as nutrients and sediment, in agricultural regions (Pereira and Hostettler 1993).

Although BMPs have been recognized as alternatives for reducing the transport of chemicals and sediment from agricultural fields, the overall effects of BMPs, both individually and collectively, and their effectiveness from one agricultural region to another have yet to be fully assessed. Research activities designed to identify the benefits of BMPs on operational farms or at the farm level are difficult and expensive. Thus, most of the research and monitoring activities used to design and evaluate the performance of BMPs are conducted on small watersheds and experimental plot studies. For example, research by Webster (1993) on experimental plots showed that grassed filter strips aided tillage practices in reducing pesticide transport in runoff from soybean fields. However, some BMPs that work well for one agricultural region may not for another. For example, reduced tillage practices intended to decrease sediment and agrichemical transport in surface-water runoff may increase chemical transport into shallow ground water depending on soil type and other factors. Also, a particular BMP or set of BMPs that may reduce all forms of agricultural nonpoint source pollution very effectively may be too expensive for a producer to implement in a farming system. Deterministic research that includes socio-economic, as well as environmental, evaluations of BMPs at the farm level is necessary before regulatory policies are implemented.

The Mississippi Delta MSEA Project

One of the most intensively farmed agricultural areas of the United States is the southern part of the Mississippi River Alluvial Plain in Mississippi, a 7,000-square-mile area locally referred to as "the Delta." Agricultural activities in the Delta differ significantly from those in other regions such as the midwestern United States. The humid sub-tropical climate in the Delta increases dependence on pesticides, and the crops and cultural practices dictate a different array of pesticides than those used in other areas of the nation. For example, one of the primary crops produced in the Mississippi Delta is cotton. Little cover remains after cotton harvest in the late fall, and the soil is left unprotected during the rainy season of the early winter months, thus increasing runoff potential. These factors, in combination with high regional rainfall, increase the chances for greater chemical movement and soil erosion within the environment. Many of the lakes and streams in the Delta have been severely affected by past agricultural practices. The following paragraphs list documented cases regarding nonpoint source pollution problems associated with high levels of pesticide, nutrient, and sediment concentrations transported from the Delta's agricultural fields.

McDowell (1989) reported that about 8,000 tons of pesticides were applied in 1983 to 2 million acres of crops (primarily soybeans, cotton, and rice) in the Delta. Fish kills and diminished fish production in Delta lakes in the 1960s and 1970s were attributed to pesticides, specifically toxaphene and DDT, transported by runoff from agricultural fields (McDowell 1989). In a report by Rinella and others (1993), the highest average concentrations of DDT in fish tissue in the nation were collected in 1984 by the U.S. Fish and Wildlife Service from the Yazoo River in Mississippi. Subsequent studies 10 years after the ban of DDT indicated that DDT accumulation in fish tissue, as well as DDT detection in soils, wetlands, and sediments, were still occurring in intensively farmed communities in the Delta (Cooper 1989). Pereira and Hostettler (1993) report that the Yazoo River is a major contributor of cotton and rice herbicides and cyanazine to the Mississippi River.

In the Lake Washington drainage basin in Washington County, Mississippi, studies are being coordinated by the Mississippi Department of Environmental Quality, Office of Pollution Control (MDEQ-OPC), in an effort to improve the water quality of the lake (Mississippi Department of Environmental Quality 1992). During the summer of 1990, a toxic blue-green algae bloom occurred in Lake Washington causing recreational activities to be prohibited at the lake for several months. Movement of nutrients (as well as pesticides) into the subsurface soils and potentially into ground water have been attributed to leaching into permeable sandy and silty soils and movement through large, drought-induced cracks in low-permeability clays (McDowell 1989).

In a study by Murphree and others (1984), significant erosion and soil loss were shown to occur in the Delta, and suspended clay and fine silt were shown to be transported great distances despite low slopes and low transport capacities existing in the area. Intensive tillage practices and lack of cover or residue contributed to the erosion problems. Agrichemicals adsorbed onto sediment particles can be transported as well. In a study by Willis and others (1976) at a small watershed in northwestern Mississippi, high levels of pesticide and sediment yields were produced during the spring tillage periods when the soil was left unprotected and vulnerable to erosion. In a subsequent report by McDowell and others (1981) for a study in that

same watershed, about 93 percent of toxaphene yield was associated with sediment transported by storm runoff.

The National MSEA Concept. The U.S. Department of Agriculture (USDA) and the U.S. Environmental Protection Agency (EPA) established the Model Implementation Program in 1977 and the Rural Clean Water Program in the early 1980s. The overall thrust of these programs was to research, demonstrate, and stimulate the adoption of BMPs (Swader and Adams 1994). In the late 1980s, there was increased concern regarding the presence of agrichemicals in water resources and, in particular, ground water. The Presidential Water Quality Initiative soon followed in which the USDA Water Quality Program was initiated in 1990 (Swader and Adams 1994). As part of the Water Quality Program, USDA, in cooperation with the U.S. Geological Survey (USGS) and other federal, state, and local agencies, established Management Systems Evaluation Areas (MSEAs) in five Midwestern States.

The overall purpose of a MSEA is to research the economic viability of alternative farming methods to reduce over-dependency on agricultural chemicals and to accelerate the transfer and adoption of such methods (Council for Agricultural Science and Technology 1992). Scientists assess landscapes and farming systems for their vulnerability to water contamination from farm chemicals, provide information about the behavior and effects of agrichemicals on watershed ecology, and identify economically/environmentally-sound BMPs as components of farming systems to reduce agrichemical contamination of soil, water, air, and biological resources.

Purpose, Scope, and Objectives of the Mississippi Delta MSEA. The experimental design and direction of the National MSEA program is a suitable framework to evaluate agricultural nonpoint source pollution in the Mississippi Delta. The purpose of the Mississippi Delta MSEA project is to assess how agricultural activities affect water quality in the Mississippi Delta and to increase the knowledge needed to design and evaluate BMPs as components to Delta farming systems. Cotton production will be the primary crop-of-interest; however, other crops such as soybean, rice, and catfish production may be evaluated as well because such crops are integrated with cotton production in typical Delta farming operations. A deterministic, holistic approach will be used to assess water quality and aquatic resources of three Delta oxbow lake watersheds over a 5-year period.

The data base that is generated from this project will be useful to management agencies in making sound decisions regarding agricultural nonpoint source pollution and implementation of BMPs. The BMPs will be evaluated for their economic, management, and environmental value at the farm and watershed scale. In addition, educational and public awareness programs will be developed to communicate those ideas that help to reduce potential agricultural effects on ground and surface water. Seven major objectives exist within the framework of the Mississippi Delta MSEA project:

- Assessment - Conventional and alternative farming systems will be assessed as to their effect on hydrologic processes, sedimentation and erosion control, and agrichemical movement in surface runoff, crop root zones, and unsaturated zones. Conventional and alternative farming systems will also be assessed as to their effect on water quality, ecological processes, and fisheries resources in oxbow lakes.
- Component - Specific components of each watershed will be monitored and evaluated as to their role in pollutant fate and transport, such as: the effects of soil and plant processes on pesticide movement; the effect of soil processes on macropore development; the effects of riparian zones on agrichemical movement; and the hydrologic interaction between oxbow lakes, ground water, and river systems in close proximity to the study watersheds.
- Sampling Protocol - Intensive monitoring strategies will be implemented (and may, in some cases, be developed and tested) to assess the effects of agricultural activities on water quality and aquatic resources. Also, sensitivity analyses will be used to compare and contrast traditional and non-traditional field techniques to determine optimal sampling strategies for the MSEA project.
- Farming System - Innovative BMPs will be implemented and evaluated for potential use in the Mississippi Delta, such as: reduced tillage practices for cotton or other high intensity crops; ultra-low volume application techniques as a way of pesticide application; application of winter cover crops to reduce erosion; improved communication of weather forecasts to producers; and drainage network improvements.
- Modeling - Field and watershed-scale models will be used to assess the differences in measured responses between conventional and BMP watersheds and to identify the causes of those differences. If necessary, new components or algorithms may be developed to improve the accuracy of model predictions.
- Socio-economic - The potential effects of watershed-wide adoption of alternative farming systems and practices on production, farm income, water quality, and aquatic resources will be assessed. The effects of the MSEA project

on the attitudes and behaviors of producers regarding the use of alternative farming systems will be assessed. Information sources to producers regarding current and alternative farming systems will be evaluated as to their effectiveness to communicate environmental issues.

- Extension - The MSEA project team will attempt to increase awareness and adoption among producers of farming systems and practices that protect and enhance surface- and ground-water quality and associated aquatic resources.

Participating Agencies and Organizational Structure. The Mississippi Delta MSEA Project will be cooperatively administered by a consortium of several local, state, and federal agencies, as well as local universities and organizations. These agencies and organizations include, but are not limited to: USDA-Agricultural Research Service (ARS); USGS; Mississippi State University (MSU); MDEQ; USDA-National Resources Conservation Service (NRCS); USDA-Consolidated Farm Service Agency (CFSA); Mississippi Agricultural and Forestry Experiment Stations; Yazoo-Mississippi Delta Joint Water Management District; Mississippi Soil and Water Conservation Commission; Delta Council; and the Mississippi Farm Bureau Federation.

Several committees have been organized to ensure the successful completion of project objectives. Technical development of the project will be guided by co-chairmen from ARS, USGS, and MSU within the framework of a Technical Steering Committee composed of scientists-representatives from the participating agencies. In addition, a much larger Advisory Committee has been organized to work with the scientists with respect to project goals and design, as well as to communicate project milestones and ongoing results. Both committees have organized smaller sub-committees to carry out specific tasks when appropriate.

STUDY AREA DESCRIPTION

During March and May 1994, a Site Selection Committee composed of scientists and agency field-representatives was formed to locate three study watersheds for the MSEA project. One watershed will be a "control" with no (or very few) management practices; the second watershed will contain BMPs common to the Delta region; and the third watershed will contain BMPs that may be considered more innovative or that require more research. Comparisons will be made with respect to surface runoff, ground water, soils, and lake ecology between the control watershed and the BMP watersheds.

The Committee recommended that the Mississippi Delta MSEA project should focus on Delta oxbow lake watersheds, which offer the advantage of coupling field sampling with receiving-water (oxbow lake) sampling to determine the downstream effects of agricultural activities and BMPs. It was recommended that these watersheds be small enough to facilitate improvements to a significant part of the watershed so that changes in water quality can be measured. The Committee then compiled a list of "ideal" requirements or criteria to be considered for the study watersheds. Some of those criteria are as follows:

- The oxbow lake should be about 20 acres in size in order to be adequately managed;
- The predominant crop in the watershed should be cotton;
- Accessibility must be adequate during storms in order to allow service of sampling equipment;
- The watersheds should be in close proximity to each other to minimize travel time;
- The watersheds should be relatively isolated to control vandalism and fishing-access problems; and,
- The land owners and operators must be willing to cooperate with the scientists and commit to the MSEA project for a 5-year period.

The Committee then gave these criteria to field representatives of the NRCS and CFSA to identify potential oxbow-lake watersheds in their particular jurisdictions that met these criteria. After subsequent meetings and field trips, the committee recommended the following three oxbow-lake watersheds in Sunflower and LeFlore Counties in northwestern Mississippi (Figure 1):

A. Beasley Lake watershed (Sunflower County) - The total drainage area of this watershed is about 800 to 1,000 acres, and the surface area of the lake is about 40 acres. Soils are generally a loam-type that support cotton as the predominant crop. The watershed has a large riparian zone area on the western side of the lake.

B. Thighman Lake watershed (Sunflower County) - The total drainage area of this watershed is about 1,800 to 2,000 acres, which makes this watershed the largest of the three. The surface area of the lake is about 20 acres. Soils in the watershed vary from a loam-type to a very heavy clay-type. The predominant crop in this watershed is cotton, especially to the north of the lake. However, because of the variability in soil types, other crops exist in the watershed as well, such as soybean, rice, and catfish production.

C. Deep Hollow Lake watershed (LeFlore County) - The total drainage area of this watershed is about 400 acres, which makes this watershed the smallest of the three. The surface area of the lake is about 20 acres. Most of the watershed has the loam-type soils that support cotton production (about two-thirds of the watershed), but heavier, clay-type soils are also present where soybeans are produced. The western side of the watershed is defined by the east levee of the Yazoo River, and a large riparian area lies between this levee and the lake.

Another committee has been recently formed with the purpose of recommending which BMPs will be used for the MSEA project. This committee is composed of scientists, agency field-representatives, and producers. The committee is in the process of evaluating current and proposed "farm plans" developed by local NRCS staff for the study watersheds. These farm plans are developed in cooperation with a particular producer detailing which crops and farming practices will be used on his/her property. The committee will then make recommendations in cooperation with the study area producers as to additional BMPs to be used in the study watersheds.

LEADING RESEARCH ACTIVITIES

The data collection and research activities associated with the Mississippi Delta MSEA project are comprehensive and detailed in design. The leading research organizations for the MSEA project are the USGS, ARS, and MSU. The following paragraphs summarize the research activities of these organizations.

U.S. Geological Survey

The USGS will assess the effects of agricultural activities with respect to surface-water quality and will evaluate selected BMPs based on their ability to reduce peak surface-water concentrations of sediment, pesticides, and nutrients during storms. Water-quality and stream-monitoring stations will be established in each of three study watersheds. The sampling strategy followed by the USGS is patterned after the sampling strategy used by Roman-Mas and others (1994) in the Beaver Creek watershed study in which runoff samples were collected frequently during storms to define pollutant-concentration distributions. Sensitivity analyses will be used to optimize the sampling strategy. A paired-basin approach will be used to compare data collected from the two BMP watersheds to data from the control watershed, thus determining how effective the BMPs improve surface-water quality. In addition, the data base will help in the evaluation of existing models to assess agricultural nonpoint pollution and implement BMPs. The USGS research activities are funded through a cooperative agreement with the MDEQ.

USDA Agricultural Research Service

The National Sedimentation Laboratory at Oxford, Mississippi, proposes research in the ecological health of Delta oxbow lakes, vertical crack development in heavy clay Delta soils, and the quality of shallow ground water. The Southern Weed Science Laboratory at Stoneville, Mississippi, will focus on chemical application technology and the influence of tillage systems on pesticide sorption and microbial populations. Research proposed by the Soil and Water Research Unit at Baton Rouge, Louisiana, is concerned with the effect of BMPs on insecticide loadings to surface runoff and the use of weather forecasts to optimize timing of pesticide applications. These research activities are federally funded through the National MSEA program of the USDA-ARS.

Mississippi State University

Research activities proposed by MSU cross a wide range of disciplines. This research will monitor the off-site movement of agrichemicals in runoff and will aid in the evaluation of BMPs. Related research will evaluate the effectiveness of site-specific herbicide and fertilizer management as a BMP. Other research will assess the biological response and impact of agrichemicals on Delta oxbow lake fisheries. Socio-economic research will measure the potential effects of watershed-wide adoption of alternative farming systems. Finally, extension activities will increase the awareness and adaptation among land owners of practical and profitable farming systems. The MSU research activities are funded through research grants as approved by the USDA Cooperative States Research Service.

SUMMARY

The overall purpose of a Management Systems Evaluation Area (MSEA) assessment is to research the economic viability of alternative farming methods to reduce over-dependency on agricultural chemicals and to accelerate the adoption of such methods. The purpose of the Mississippi Delta MSEA project is to assess how agricultural activities affect the water in the Mississippi Delta and to increase the knowledge needed to design and evaluate BMPs as components to farming systems. The three study watersheds for the Mississippi Delta MSEA project are located in Sunflower and LeFlore Counties in northwestern Mississippi in agricultural areas that are primarily in cotton production.

The data-collection and research activities that will be conducted in association with the Mississippi Delta MSEA project are very comprehensive. The resultant data base will be useful to management agencies in making sound environmental decisions concerning agricultural nonpoint source pollution in the Mississippi Delta. Other anticipated benefits associated with the MSEA project at its conclusion are as follows:

1. Data will be collected to understand the behavior of farm chemicals in the environment and their effect on surface and subsurface water quality and the resultant influence on aquatic resources in Delta oxbow lakes;
2. Environmentally sound and economically profitable BMPs and farming systems that are socially acceptable to local producers will be identified as well as the knowledge required to implement those systems;
3. The ability of riparian zones to assimilate and transform agrichemicals will be evaluated; and,
4. An understanding of producer behaviors and perceptions of economic and natural resources benefits of farming systems will be evaluated.

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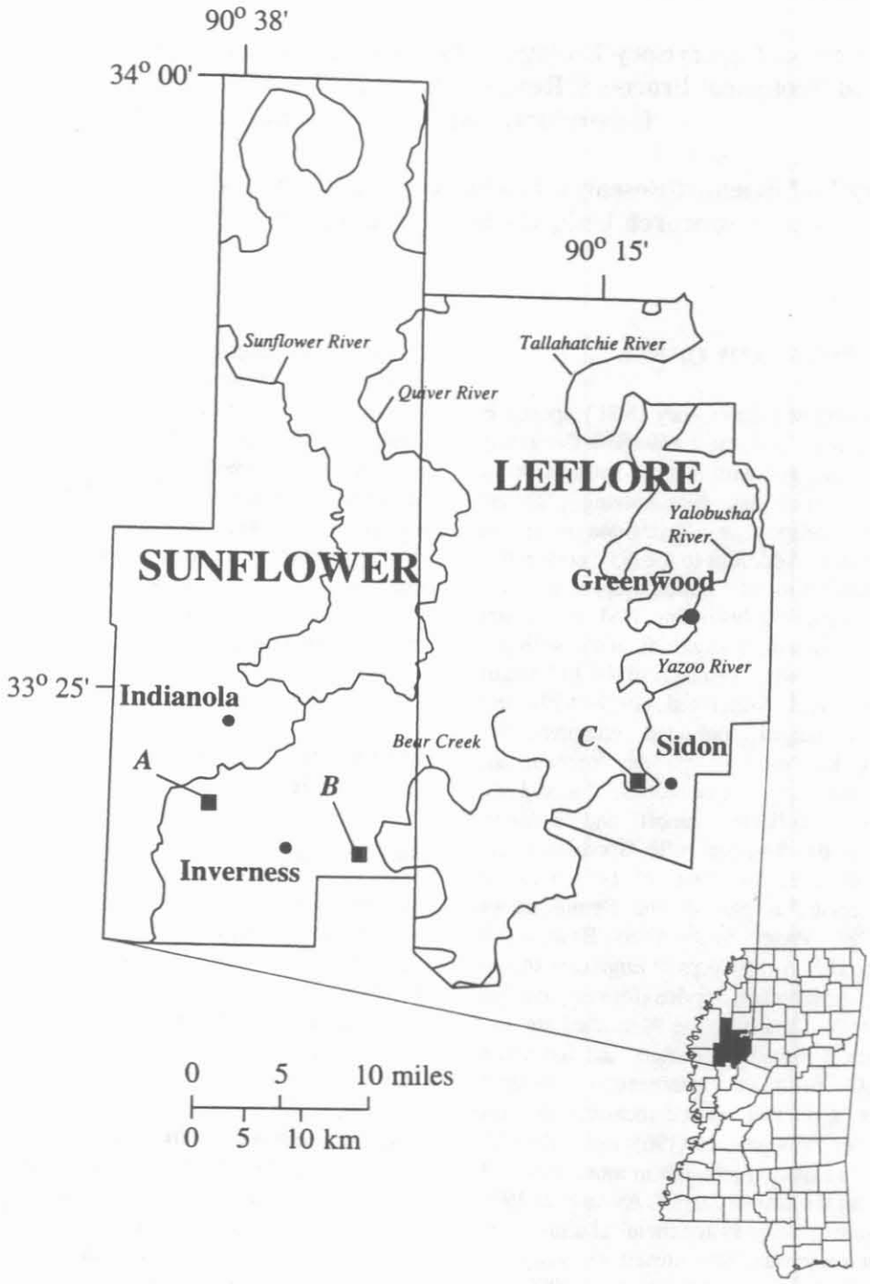

Figure 1. Mississippi Delta MSEA study watershed locations: A) Beasley Lake watershed; B) Thighman Lake watershed; C) Deep Hollow Lake watershed.