This paper was peer-reviewed for scientific content.
Pages 1094-1110. In: D.E. Stott, R.H. Mohtar and G.C. Steinhardt (eds). 2001. Sustaining the Global Farm. Selected papers from the 10th International Soil Conservation Organization Meeting held May 24-29, 1999 at Purdue University and the USDA-ARS National Soil Erosion Research Laboratory.

The Mississippi Delta MSEA Program

S.M. Dabney, R. A. Rebich and J.W. Pote*

ABSTRACT

The interagency Mississippi Delta Management Systems Evaluation Areas (MDMSEA) project began in 1994 with purposes of (1) determining how agricultural activities affect water quality in the agriculturally intensive Mississippi Delta and (2) increasing knowledge needed to design and evaluate best management practices (BMPs) as components of competitive Delta farming systems. Oxbow lake watersheds were chosen as study areas because they are "closed" systems where lake water quality and productivity are not affected by influences outside the watershed. BMPs were characterized as structural or agronomic. Structural improvements included berms with slotted-inlet pipes to control surface runoff or slotted-board risers that permitted holding water on fields during the winter. Agronomic components included reduced tillage, grassed field borders, cover crops, soil amendments, transgenic crops, and precision application of chemicals. One watershed received both structural and agronomic practices, one received only structural practices, and one was designated a farmer-managed control. Inputs for each field were recorded. Runoff was quantified and sampled at the edge of selected fields, along drainage pathways, and through riparian zones. Runoff, shallow ground water, and lake water samples were analyzed for biological, physical, and chemical constituents. The effects of management and spatial variability on productivity, profitability, soil quality factors, and weed populations were studied. Preliminary data indicated groundwater quality was good, with few pesticide detections and NO_3-N concentrations generally less than 1 mg/kg. The primary lake pollutant was found to be sediment, and agronomic practices had the greatest impact reducing sediment concentrations and improving fish growth rates.

INTRODUCTION

Mississippi River Alluvial Plain is one of the most intensively farmed agricultural areas of the United States. In Mississippi, a 7,000-square-mile area of this province is locally referred to as "the Delta". The warm humid climate in the Delta dictates a different array of crops and cultural practices than those used in Midwest of the USA. For example, one of the primary crops produced in the Delta is cotton (*Gossypium hirsutum* L.), a crop that frequently requires multiple pesticide applications. 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. Rainfall in the Delta generally varies between 1300 and 1500 mm annually. These factors increase the chances for chemical movement and soil erosion and have prompted some observers to suggest that agriculture's impact on water quality might be greater than in some other parts of the country. The Mississippi Delta Management Systems Evaluation Areas (MDMSEA) project began in 1994 with purposes of (1) determining how agricultural activities affect water quality in the Mississippi Delta and (2) to increase the knowledge needed to design and evaluate best management practices (BMPs) as components of competitive Delta farming systems (Rebich et al., 1996). Although cotton production was selected as the primary crop-of-interest for this 5-year project, other crops such as soybean and corn production have been evaluated as well because such crops are integrated with cotton production in typical Delta farming operations.

In contrast to most other MSEA projects, the MDMSEA project chose to focus on oxbow lake watersheds, which are old river channel meanders that have been cut-off over time. Oxbow lake watersheds are largely closed systems where lakes receiving runoff only from the study watershed; the lakes were therefore biological endpoints that reflected the impact of local management without confounding upstream influences. The MDMSEA quantified water quality impacts not only with analysis of surface runoff and groundwater samples, but by also by assessing biological health of the lakes as reflected by fish species diversity and growth rates. A socio-economic survey of BMP awareness and outreach through involving local middle-school science teachers and students helped increase local understanding and support for the project. A database of all farmer inputs as well as all research finds is under development and will be used with biophysical and economic models to generalize and extend results.

The project comprises at least 21 local, state, and federal agencies, organizations, and industries. A Technical Steering Committee (TSC) composed of 12 members represents these groups and directs the project through consensus development. The TSC includes representatives of the following agencies: USDA-Agricultural Research Service (ARS); U.S. Geological Survey (USGS); Mississippi State University (MSU); Mississippi Department of Environmental Quality (MDEQ); USDA-National Resources

---

*S.M. Dabney, USDA-ARS National Sedimentation Laboratory, P.O. Box 1157, Oxford, Mississippi, USA 38655; R. A. Rebich, U.S. Geological Survey, Pearl, MS, USA; J.W. Pote, Mississippi Water Resources Research Institute, Mississippi State University, Mississippi State, MS, USA. Corresponding author: dabney@sedlab.olemiss.edu

Conservation Service (NRCS); USDA-Farm Service Agency (FSA); Mississippi Agricultural and Forestry Experiment Stations (MAFES); Yazoo-Mississippi Delta Joint Water Management District (YMD); Mississippi Soil and Water Conservation Commission (MSWCC); Delta Council; and the Mississippi Farm Bureau Federation. Other agencies have contributed funding, material, technical expertise, or other services to the MDMSEA project (Rebich, et al., 1996). These include, but are not limited to: Mississippi Cooperative Extension Service; Delta Wildlife Federation; U.S. Environmental Protection Agency; U.S. Fish and Wildlife Service; Mississippi Department of Wildlife, Fisheries, and Parks; John Deere Corporation; and the Pyrethroid Working Group. Because the project is conducted exclusively on private property, the farmers and landowners are intimately involved in the selection and implementation of all BMP's. The purpose of this paper is to present an overview of the status and preliminary findings of the MDMSEA project.

STUDY AREA

Based on criteria including lake size, cropping dominated by cotton, accessibility, security, and landowner interest (Rebich et al., 1999), three oxbow lake watersheds located in Sunflower and Leflore Counties, Mississippi, were selected for the MDMSEA project (Fig.1):

A. Thighman Lake watershed (Sunflower County) - The total drainage area of this watershed is about 1600 ha, which makes this watershed the largest of the three. The surface area of the lake is about 9 ha. Soils in thewatershed vary from loam to heavy clay. The crops grown in this watershed are cotton, soybean (*Glycine max* Merrill), corn (*Zea mays* L.), rice (O*ryza sativa* L.). Catfish (*Ictalurus punctatus*) production in ponds is another significant land use in the watershed (Fig. 2).

B. Beasley Lake watershed (Sunflower County) - The total drainage area of this watershed is about 800 ha, and the surface area of the lake is about 25 ha. Soils are generally loamy and the primary crop is cotton with some soybean, corn, and rice. The watershed has a large riparian zone area on the eastern side of the lake (Fig. 3).

C. Deep Hollow Lake watershed (Leflore County) - The total drainage area of this watershed is about 160 ha, which makes this watershed the smallest of the three. The surface area of the lake is about 8 ha. High areas of the watershed have sandy loam soils that support cotton production. Closer to the lake, heavier silty clay soils are cropped with soybean. Much of the riparian area west of the lake has elevated terrain because of material dredged from the adjacent Yazoo River in the 1940's (Fig. 4).

FIRST PHASE DESIGN

Best management practices implemented in the first 5-year phase of the MDMSEA were characterized as structural or agronomic. Structural improvements included berms with slotted-inlet pipes to control surface runoff. Some pipes had slotted-board risers attached to their inlets to hold water on fields during the winter (Fig. 5). None of the watersheds contained any subsurface drainage tiles as this practice is uncommon in the Mississippi Delta. Agronomic components

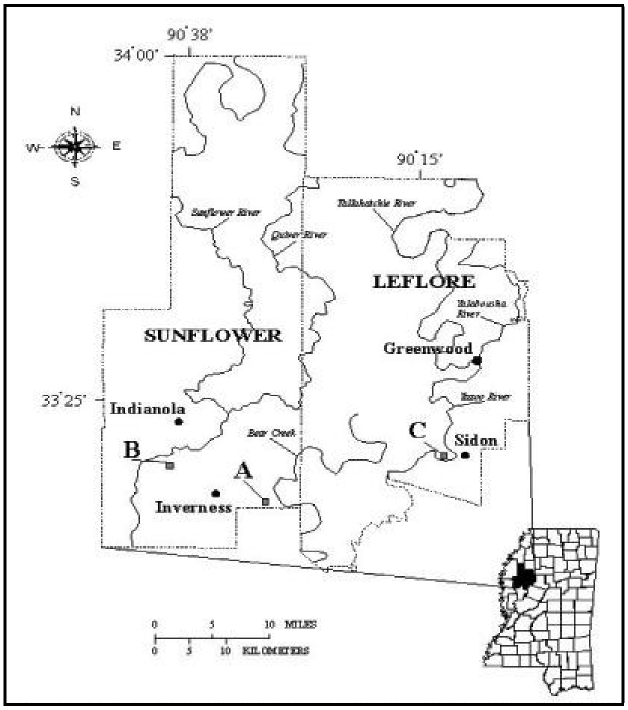

Figure 1. Mississippi Delta MSEA study watershed locations: A) Thighman Lake watershed; B) Beasley Lake watershed; C) Deep Hollow Lake watershed.

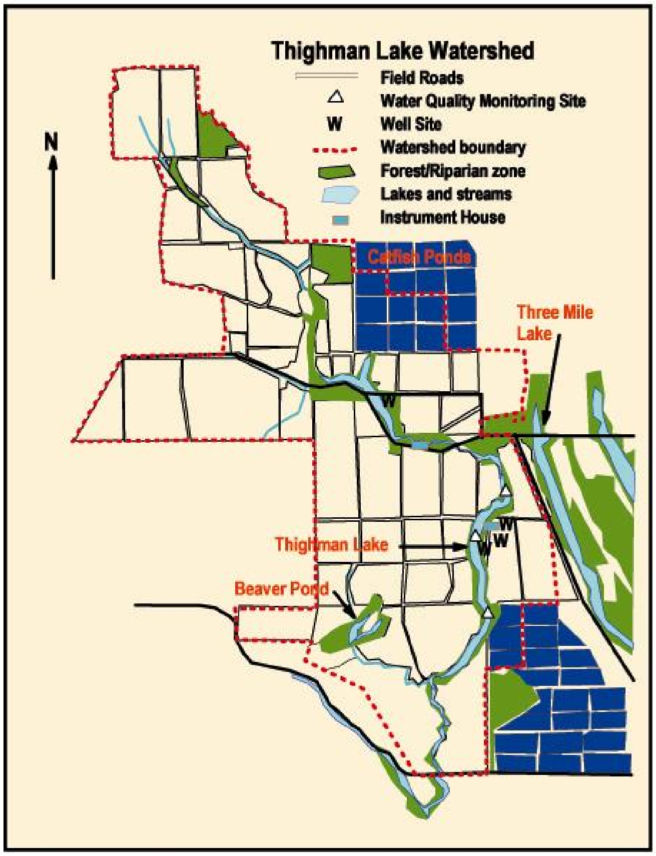

Figure 2. Thighman Lake watershed is the largest of the three MDMSEA watersheds comprising 1600 ha and including fields farmed by five farmers.

included reduced tillage, grassed field borders, cover crops, gypsum soil amendments, transgenic crops, and precision application of chemicals.

The BMPs were distributed among the three watersheds using a hierarchic approach. To minimize costs, the largest watershed, Thighman, was designated to serve as a control watershed where no BMPs would be installed during the first phase. Land owners were promised that at the end of the first phase of the project, they would receive the BMPs that were found to be most cost-effective at the other watersheds When the project started, the large Thighman watershed was largely farmed in cotton, but because of changes in farm legislation, market conditions, and attitudes in the Delta, producers in the Thighman Lake watershed began to use conservation tillage and crop rotation to improve production. This resulted in significant changes in land use so that in 1998, only one 18-ha field in Thighman watershed was planted to cotton. Thus, the Thighman watershed can be best described as farmer-directed control.

The Beasley Lake watershed was selected to have only edge-of-field BMP treatments that included grass strip field boarders and structural practices such as slotted-board risers and slotted-inlet pipes. Farmers in this watershed have largely retained conventional-tillage cotton culture. A special study included at the Beasley Lake watershed investigated surface runoff water quality from normal and transgenic Bt cotton, which was engineered to be resistant to some lepidopterous insects.

The Deep Hollow Lake watershed was selected to have both structural and agronomic BMPs. All cropland within the watershed received conservation tillage, winter cover crops, and precision herbicide application. Because these practices differed from the producers normal methods, the MDMSEA guaranteed the farmer would be compensated for any yield losses associated with these in-field conservation measures.

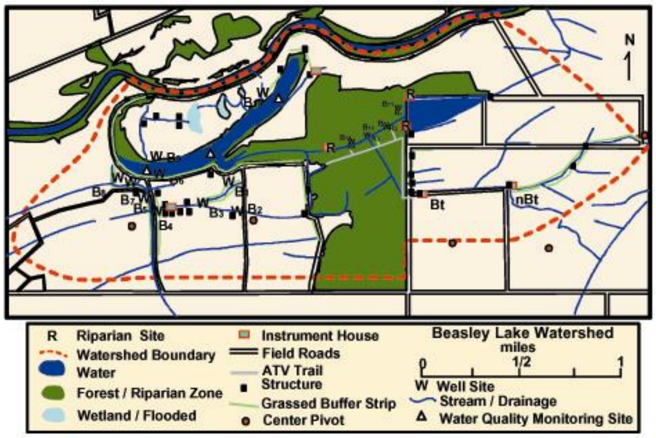

Figure 3. Beasley Lake is the largest surface area (25 ha) of the three MDMSEA watersheds and has an 800 ha watershed area. The primary crop is cotton. BMP treatments applied are all edge-of-field pipe structures and field borders. A large pre-existing riparian forest is intensively studied.

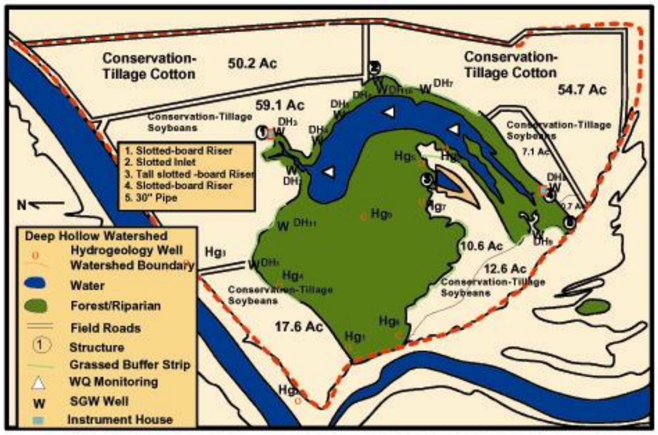

Figure 4. Deep Hollow Lake watershed in the smallest drainage area (about 160 ha) and has received the most intensive application of Best Management Practices. Cotton and soybean are grown with reduced tillage and winter cover crops are planted each fall, a grassed filter strip surrounds each field, and concentrated runoff flows are controlled with slotted-inlet and slotted-board riser pipes.

Figure 5. A slotted-board riser is a box welded to the inlet of a pipe that controls the surface runoff where it leaves a cropped field. Boards inserted into the control box hold water on the field during the winter, creating waterfowl habitat and allowing sediment to settle.

3-Year Season Avg.

Spray Savings, %

Cotton	Soybeans
73	49

Figure 6. Under-hood sensors detect chlorophyll so that nozzles are turned on only when weeds are present. This technology reduced post-emergence herbicide application by 63% compared to continuous spraying and provided excellent weed control in no-till fields (Hanks and Beck, 1998).

Table 1. Summary of responsibilities of primary organizations in the MDMSEA.

Agency	Activities
United States Department of Agriculture – Agricultural Research Service (USDA-ARS)	Ground water sampling, lake water quality and fish ecology, weed population assessment and control technology, spatial variability of soil quality factors, yield mapping, mechanics of crack development and water infiltration into clay soils, biophysical modeling
United States Geological Survey (USGS)	Surface water runoff gauging, sampling, and contaminant analysis
Mississippi State University, Mississippi Agriculture and Forestry Experiment Station, Mississippi Cooperative Extension Service (MSU/MAFES/MCES)	Filter strip effectiveness, socio-economic assessment and modeling, farmer liaison
Yazoo Joint Water Management District (YMD)	Data base development (farmer inputs, weather, research findings)
United States Department of Agriculture – Natural Resources Conservation Service (USDA-NRCS)	Practice planning and coordination
Mississippi Soil and Water Conservation Commission (MSWCC)	Cost-sharing for BMP and 319 grant development

Table 2. Selected properties and potential fluometuron adsorption (from Freundlich isotherm) of soil samples collected from a cropped field, an established filter strip, and riparian forested areas at the Beasley Lake watershed (Shankle et al., 1998).

Location	pH	CEC (cmol kg^{-1})	Organic Matter (%)	Clay (%)	Fluometuron adsorption (μg g^{-1})
Cropped area	4.7	11.7	0.7	13	49
Established filter strip, sampled 1m from edge	6.3	18.1	2.1	13	68
Riparian forest, sampled between 0 and 25m downstream of entrance	6.8	18.4	2.3	22	85
Riparian forest, sampled between 50 and 200 m downstream of entrance	6.4	23.3	3.1	26	110
Riparian forest, sampled between 400 and 800 m downstream of entrance	5.8	31.7	4.5	40	147

Responsibilities

The MDMSEA is an interagency and interdisciplinary effort. The leading research organizations for the MDMSEA project are the USDA-ARS, USGS, and Mississippi State University (MSU, including the Mississippi Agriculture and Forestry Experiment Station (MAFES) and the Mississippi Agricultural Extension Service (MAES)). Team efforts among these agencies are coordinated (Table 1) to help get the practices on the land and to ensure a comprehensive assessment of management impacts on key environmental quality parameters.

Current Status and Preliminary Findings

Soil quality

Best Management Practices and naturally occurring spatial variability affect soil quality and pesticide fate in soil. Herbicide binding and weed populations were both well correlated with organic carbon and clay content (Locke et al., 1998). This information will help target herbicide applications so that better weed control can be achieved while lowering herbicide costs and reducing the potential for off-site movement. Potential herbicide sorption and degradation, organic content, clay content, and cation exchange capacity all demonstrate an increasing gradient from soil adjacent to filter strips, to soil in filter strips, to soils in riparian areas (Table 2). Riparian zones support the greatest microbial activity (Shaw et al., 2001) and can be effective filters for nonpoint pollutants when runoff enters these zones as sheet flow.

Productivity

Yields under no-tillage and reduced tillage at Deep Hollow Lake were measured relative to those on surrounding conventionally-tilled fields. In the first year of no-till management, cotton yields were reduced and the farmer was compensated for lost income. In subsequent years, a reduced tillage management system consisting of fall in-row subsoiling, re-building of beds, and planting a winter cereal cover crop, followed by spring no-till planting and weed control produced only small yield differences from conventional tillage. Beginning in 1998, additional field tests were established at Deep Hollow and elsewhere to assess alternative no-till and reduced-tillage production system components including low-till subsoiling, gypsum application, reseeding cover crops, and later growth termination of cover crops to increase residue cover and water infiltration into soil. Intensive mapping of soil properties combined with yield monitors with geographical positioning systems (GPS) installed on the producers harvesting machines facilitate identification of the interacting influences of management practice and soil properties on yield variation.

Weed Control

MDMSEA researchers have teamed with counterparts in industry to develop a hooded herbicide sprayer with weed sensing technology that has effectively controlled weeds with significantly reduced amounts of herbicide. Three sensors mounted under each hood detect chlorophyll, causing the sprayer unit to turn on only when passing over weed vegetation in between crop rows. In the Deep Hollow watershed, the device has effectively controlled weeds using 57 to 82 percent less contact herbicide in cotton and 43 to 79 percent less herbicide in soybean (Hanks and Bryson, 1997). Results shown in Fig. 6 indicate an average savings of 63 percent using the sensor sprayer (Hanks and Beck, 1998). In related studies, researchers have used GPS technology to map the distribution and density of over 200 species of weeds and have identified shifts in weed populations over time that result from alternative management practices (Bryson and Hanks, 1997).

Groundwater Quality

In the area of shallow ground water research, nearly one hundred wells were installed throughout the MDMSEA watersheds. Wells were typically installed in sets of three, screened at depths of 1.5, 3 and 4.5 m. The sampling of shallow ground water was similar to that previously reported (Smith et al., 1991). Usually within 24h of a rainfall event, 500mL samples were collected from each well (using a battery-operated ISCO AccuWell model 150 portable pump fitted with a teflon-lined intake line) in two 0.5-L amber bottles with teflon-lined screw caps. Each well was pumped dry and the excess well water was discarded. Shallow ground water samples were placed on ice immediately, transported to the National Sedimentation Laboratory, stored at 4°C (<48 h). One bottle was prepared for pesticide analyses via gas chromatography (GC) using methods similar to the method of Smith et al. (1995), with modifications. Nutrient contents were determined from the second bottle. Nutrient sample preparation and analyses for PO4-P, NH4-N, and NO3-N was as previously reported by Schreiber (1992) using Dionex anion chromatography and Bran-Lubbe (Technicon) automated flow-through colorimetry. Total organic carbon (TOC) analyses were performed with a Rosemount Analytical Dohrmann DC-190 carbon analyzer with automatic liquid sampler. To date, about 700 samples have been collected from the wells. In all of these samples, only a few have had detections of pesticides (primarily herbicides), and these few detections were seasonal and at very low levels at or near the detection limits. While nitrate nitrogen has been frequently been found to occur in elevated concentration in midwestern MSEA projects, concentrations in the MDMSEA have rarely exceeded 1 ppm (Table 3). The low nitrate concentrations are likely the result of high rates of denitrification fueled by the high concentrations of dissolved organic carbon, mild winter temperatures, and the low aeration status of the soils with no subsurface tile drainage. In contrast, phosphorus concentrations are relatively high even though little or no fertilizer phosphorus is applied by the farmers, reflecting the naturally high phosphorus fertility levels in alluvial Delta soils.

Surface runoff gauging, sampling, and analysis

USGS has lead responsibility for surface runoff assessment in the MDMSEA. Operation of a streamflow and water-quality sampling network comprising nine sites began in the fall of 1995 as part of a cooperative agreement with MDEQ, Office of Pollution Control (Rebich, 1997). Additional gages for the Bt and non-Bt cotton watersheds were installed the next year. About 1,350 sediment samples, 460 pesticide samples, and 500 nutrient samples have been collected thus far. Figure 7 is a box plot of all of the discrete suspended-sediment concentration data to date indicating that only a slight difference between the Beasley sites and the Thighman sites; but lower sediment concentrations at Deep Hollow. Preliminary analyses of the nutrient and herbicide data indicate similar results. At all three locations, the highest levels of sediment, nutrients, and pesticides occur in runoff from the first few storms after tillage each growing season. Shifts in some of the trends of the data have recently been observed due to the changes in cropping patterns. For example, increased nitrogen and corn herbicide concentrations were observed in surface runoff at Thighman following planting of a large amount of corn during the 1998 growing season.

Table 3. Mean nutrient concentrations in shallow groundwater (averaged over all depths and sampling locations) in MDMSEA watersheds (J.D. Schreiber, personal communications, 1999).

Location	PO_4-P	NH_4-N	NO_3-N	TOC
	--------------------------mg/l-----------------------			
		1997		
Deep Hollow			0.22	41
Beasley			0.40	34
Thighman			0.30	40
		1998		
Beasley (entire watershed)	0.16	1.64	0.75	60
Beasley (riparian area)	0.02	0.27	0.20	145

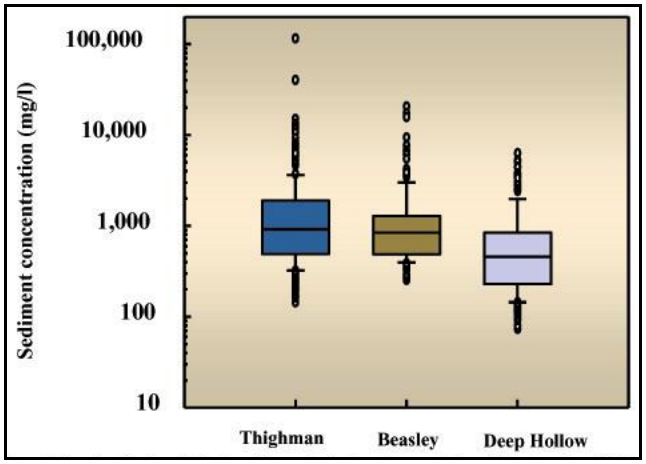

Figure 7. Box-plot showing distribution of suspended sediment concentrations of discrete edge-of-field samples collected in the MDMSEA watersheds. Conservation tillage at Deep Hollow reduced sediment more than the structural BMPs implemented at Beasley (Rebich et al., 1999).

Lake water quality and ecology

The lake ecology research has indicated that all three lakes were initially stressed due to high levels of sediment (Knight and others, 1998). Shortly after BMPs were installed in the Beasley and Deep Hollow watersheds, all three lakes were renovated by removing the resident fish species, and then restocked with sport species so that survival, growth rates, and spawning ability could be observed. Preliminary indications show that survival and growth rates of sport fish populations are best in Deep Hollow Lake followed by populations in Thighman Lake. Fish populations at Beasley Lake have not shown signs of any significant improvement over the original stressed conditions because the BMPs implemented did not reduce sediment enough to permit fish survival. In fact, very few of the re-stocked sport fish survived at Beasley Lake. Nutrient concentrations have been fairly consistent among the three lakes but occur at levels at about one order of magnitude lower than observed at the edge-of-field gages. Research in the area of microbial activity in the three lakes has identified certain beneficial algae that contribute to pesticide degradation (Zablotowicz et al., 1998).

Social understanding and acceptability of BMPs

Sociologists at MSU have lead responsibility for assessing the perception of BMPs within the Delta community. Results of a survey mailed to several hundred residents throughout the Delta indicated that farmers located close water-bodies were more concerned with water quality issues and BMPs than those not located near water-bodies. Also, those that use the water-bodies for sports activities such as hunting and fishing are much more concerned about water-quality and BMPs than those that do not. A follow-up survey is planned in the future.

Biophysical modeling and economic assessment of BMPs

In work that is just getting underway, MSU economists and ARS agricultural engineers are working together to determine the cost effectiveness of alternative BMP combinations. Data collected during the first phase of the MDMSEA will be generalized through application of the AGNPS98 water quality model to a wider range of climatic and soil scenarios. Biophysical model outputs will be input for the economic assessments.

Outreach activities

In 1998, educators at MSU received a three-year National Science Foundation (NSF) grant to fund STRIDE, which stands for Student Teacher Research Institute – the Delta Experience. In this activity, Delta middle school teachers and students work side-by-side with MDMSEA scientists on existing projects to expose students to the daily activities of field researchers thus promoting the science fields for future career choices. Over 32 teachers and students and 50 researchers from 14 different agencies participated in the first year of the program. Besides helping students learn the scientific method, this activity helps bring awareness of the conservation objectives of the MDMSEA into the homes and schools of the Delta community.

SUMMARY

The research findings of the first phase of the MDMSEA include:

- Sediment was the number one lake pollutant and lake restoration through restocking of sport fisheries was most successful where agronomic practices provided the greatest amount of erosion control and sediment reduction.
- Shallow ground water analysis has shown that most agrochemicals are processed at or near the surface and do not present a human or aquatic threat at these sites. Nitrate levels are an order of magnitude lower than values common in the Midwest.
- Herbicide applicators using weed-sensing technology provided excellent weed control using significantly less herbicide.
- Pesticide and nutrient concentrations are higher at edge of field locations but attenuate rapidly upon entering the lakes.
- Soil sorption and degradation characteristics associated with conservation tillage, filter strips, and riparian zones help to reduce pesticide and nutrient concentrations.
- Certain algae and bacteria were identified that are capable of herbicide biodegradation.
- Outreach by project scientists to local middle school science teachers and students through STRIDE has increased community involvement and interest in the project.

REFERENCES

Bryson, C.T. and J.E. Hanks. 1997. Weeds in reduced tillage cotton – Mississippi Delta management systems evaluation area, Abstract in: Proc. So. Weed Sci. Soc. Conf., 1997.

Hanks, J.E. and J.L. Beck. 1998. Sensor-controlled hooded sprayer for row crops. Weed Technology 12:308-314.

Hanks, J.E. and C.E. Bryson. 1997. Herbicide reduction in no-till crop production systems, Weed Sci. Soc. Am. Abst. 37:109.

Knight, S.S., C.M. Cooper and B. Cash. 1998. Preliminary analysis of MSEA lake water quality. In: Proc. Miss. Water Resour. Conf., Water Resources Research Institute, Mississippi State, MS, p. 39-44.

Locke, M.A., L.A. Gaston and R.M. Zablotowicz. 1998. Spatial effects on fluometuron sorption in soil from two Mississippi Delta oxbow lake watersheds, Weed Sci. Soc. Am. Abst. 38:15.12.3.

Rebich, R.A. 1997. Streamflow and water quality sampling network for the Mississippi Delta management systems evaluation areas (MSEA) project. In: Proc. Miss. Water Resour. Conf., Water Resources Research Institute, Mississippi State, MS, p. 19-28

Rebich, R.A., S.M. Dabney and J.W. Pote. 1999. The Mississippi delta management systems evaluation areas project - current status and preliminary findings. In: Proc. Miss. Water Resour. Conf., Water Resources Research Institute, Mississippi State, MS p.139-146.

Rebich, R.A., J.D. Schreiber and J.W Pote. 1996. Partnerships within the Mississippi Delta management systems evaluation area project. In: Proceedings of Delta: Connecting Points of View for Sustainable Natural Resources, conference sponsored by USDA-NRCS Wildlife Habitat Management Institute. p. 219-231.

Schreiber, J.D. 1992. Nutrients in ground and surface waters from a conventional and no-till watershed. In: Proc. Miss. Water Resour. Conf., Water Resources Research Institute, Mississippi State, MS, 46-53

Shankle, M.W., D.R. Shaw and W.L. Kingery. 1998. The effect of best management practices on fluometuron sorption. In: Proc. Miss. Water Resour. Conf., Water Resources Research Institute, Mississippi State, MS, p. 90-94.

Shaw, D.R., S.B. Blanche, M.W. Shankle, W.L. Kingery and J.H. Massey. 2001. Benefits of various best management practices in reducing herbicides in runoff water. Technical completion report of project 1434-HQ-96-GR-02679-22. Water Resources Research Institute, Mississippi State University, Mississippi State, MS. 18pp.

Smith, Jr., S., R.F. Cullum, J.D. Schreiber and C.E. Murphree, 1991. Herbicide concentrations in shallow ground water and surface runoff for land cropped to no-till soybeans. In: Proc. Miss. Water Resour. Conf., Water Resources Research Institute, Mississippi State, MS, 67-71.

Smith, S., Jr., J.D. Schreiber and R.F. Cullum, 1995. Upland soybean production: surface and shallow ground water quality as affected by tillage and herbicide use. Trans. ASAE 38:1061-1068.

Zablotowicz, R.M., K.K. Schrader and M.A. Locke. 1998. Algal transformation of fluometuron and atrazine by N-dealkylation. J. Env. Sci. Health (B):511-528.