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Water Quality Assessment of a Conservation Reserve Program near an Oxbow Lake in the Mississippi Delta: Case Study of Beasley Watershed

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Abstract. *A case study of Beasley Lake Watershed, located in the Mississippi Delta region of the U.S. was used to evaluate runoff from edge-of-field sites with row crop management practices and Conservation Reserve Program (CRP) sites with trees. Approximately one-third of the Beasley Lake watershed (ca. 280 ha) was converted from cropped land to CRP beginning in 2003, and the remainder of the cropland is managed for soybean, cotton, or corn production. Sub-drainage areas (1.2 to 6 ha) with similar topography and soil types were either cropped (three sites under reduced tillage crop) or placed in CRP (three CRP sites) and were instrumented in 2005 to collect water samples from field drainage slotted-inlet pipes during all surface runoff events. Runoff samples were analyzed for sediments and nutrients. This paper reports on runoff, soil loss, and nutrient loss for each site. Establishing trees within areas adjacent to the oxbow lake reduced the concentration of sediments and nutrients leaving the watershed as compared to reduced-till crop management techniques. The impact of converting the cropped area into trees has reduced the sediment load entering the lake by an order of magnitude, resulting in improved water quality in Beasley Lake.*

Keywords. *Runoff, Sediment Yield, Water Quality, Conservation Reserve Program (CRP)*

Introduction

Soil erosion has long been recognized as a threat to the productivity of U. S. farms and the quality of surface waters. Excessive amounts of sediment cause taste and odor problems for drinking water, block water supply intakes, foul treatment systems, and fill reservoirs. A high level of sediment adversely impacts aquatic life, reduces water clarity, and affects recreation. Even in relatively flat areas, such as the Mississippi Delta, considerable soil erosion can occur. Murphree and Mutchler (1981) reported a 5-year average sediment yield as high as 17.7 t/ha·y from a flat watershed in the Mississippi Delta. Cooper and Knight (1990) found that suspended sediment loads generally exceeded 80 to 100 mg/L (maximum for optimal fish growth) during and immediately following storm events in two upland streams in Mississippi. Ritchie *et al.* (1979) found that 2.5 to 7.5 cm of fine sediments accumulated per year in natural lakes along Bear Creek, a drainage system in the Mississippi Delta where 75% of the land is in cultivation. Accumulated sediment has covered the bottom of many lakes and stream sections with fine silt (Ritchie *et al.*, 1986).

Fertilizers are extensively used in the United States to increase crop production. The wide spread use of fertilizer continues to be a major public concern because of possible human health risks and the eutrophication of surface water (Novotny and Olem, 1994). Nitrate concentration is a parameter of particular concern because of its link to the “blue baby” syndrome and formation of carcinogenic compounds (NCSU, 2000).

Improvement of water resources has been an issue of significant societal and environmental concern for many years. Off-site transport of sediment and its associated pollutants from agricultural cropland has been classified as one of the major sources of water quality impairment, and water quality would directly benefit if the amount of soil loss was reduced (NRCS, 1997). Impairment to surface water quality due to sediment and nutrient transport from agricultural cropland has been estimated to be about $9 billion per year (Ribaudo, 1992). Although more than $500 billion has been spent on water pollution control since the implementation of the Clean Water Act in 1972, the quality of the nation’s water still remains largely unknown (Akobunbo and Riggs, 2000).

In reducing soil erosion and solving nonpoint source (NPS) water quality problems, regulatory agencies promote BMP adoption on areas most susceptible to NPS pollution. Under the Environment Quality Incentive Program (EQIP), cost sharing is available from government agencies to agricultural producers who voluntarily implement BMPs (NRCS, 2001). Depending on local priorities and fund availability, the cost-sharing rate is up to 50 percent and may be more. Therefore, a significant amount of research has been conducted to identify management options for minimizing sediment yield and NPS pollution from agricultural land areas. Examples of such management options include conservational tillage (Loehr *et al.*, 1979; Mueller *et al.*, 1984), grass filter strips (Dillaha *et al.*, 1989; Line, 1991; Cooper and Lipe, 1992; Robinson *et al.*, 1996), and impoundments that retard flow and allow suspended sediment transported in runoff sufficient time to drop out of suspension (Laflen *et al.*, 1978). However, the impact of a particular BMP on water quality is still a challenge to estimate before any actual implementation (Parker *et al.*, 1994; Walker, 1994) at a particular location since data from one location may not be applicable to other locations. It is even more difficult to predict integrated effects of implementation of several BMPs.

Various national initiatives and programs have focused on assessing the impact agricultural BMPs have on water conservation and quality over the past two decades. The 1989 Presidential Initiative on Water Quality established water quality objectives and a framework for a national research and assessment endeavor called the Management Systems Evaluation Areas (MSEA) as part of the United States Department of Agriculture Water Quality Program (USDA, 1994). The multi-agency National MSEA program initially focused on five Midwestern states and then expanded to other areas, including Mississippi (Locke, 2004). The Mississippi MSEA (MD-MSEA) project was located in the Mississippi Delta (Figure 1) and was comprised of three oxbow lake watersheds, one being Beasley Lake Watershed.

Changes in US farm policy redirected USDA conservation programs to address natural resource issues such as water quality and ecosystem protection as high priorities. This commitment to environmental stewardship extended to the 2002 Farm Bill, with significant increases in funding for conservation programs. The USDA-Agriculture Research Service (ARS) partnered with USDA-Natural Resources Conservation Service (NRCS) in a nationwide assessment regarding the effectiveness of USDA conservation programs that was termed the Conservation Effects Assessment Program (CEAP). Fourteen watersheds, which included Beasley Lake Watershed, with a history of long-term natural resource ARS research were selected as benchmark locations for participation in CEAP. A significant data base from Beasley Lake Watershed spanning from 1994 to 2003 (MD-MSEA research) and into the present (CEAP) serves as an important resource for supporting CEAP goals.

As part of the CEAP assessments, this paper reports on the water quality from runoff taken from drain outlets at edge-of-field where conservation-till row crop land was converted to CRP with trees. This paper compares the runoff and water quality from 2005 to 2008 from edge-of-field drainage sites with row crop management practices to drainage Conservation Reserve Program (CRP) sites.

Materials and Methods

A case study of Beasley Lake Watershed, typical of topography and cropping systems in the Mississippi Delta region, was used to evaluate water quality from various BMPs placed on the watershed. The Mississippi Delta region (Figure 1) comprises 11 million hectares of the southern portion of the Mississippi River Alluvial Plain. This alluvial plain region is a narrow band, widening in some places to approximately 160 kilometers, that extends over 1100 kilometers from southeastern Missouri to the Gulf of Mexico. Historically, cotton (*Gossypium hirsutum* L.) production dominated the rural and intensively agricultural region, but in recent decades, agriculture has diversified to soybeans [*Glycine max* (L.) Merr.], rice (*Oryza sativa*), catfish (*Ictalurus punctatus*), and corn (*Zea mays* L.). The climate is classified as humid subtropical with an annual rainfall ranging from 1140 to 1520 mm and temperatures averaging 18^{o}C. Although the Delta region topography averages less than 1% slope, significant quantities of sediment are lost in runoff from the high rainfall events common during winter and spring months.

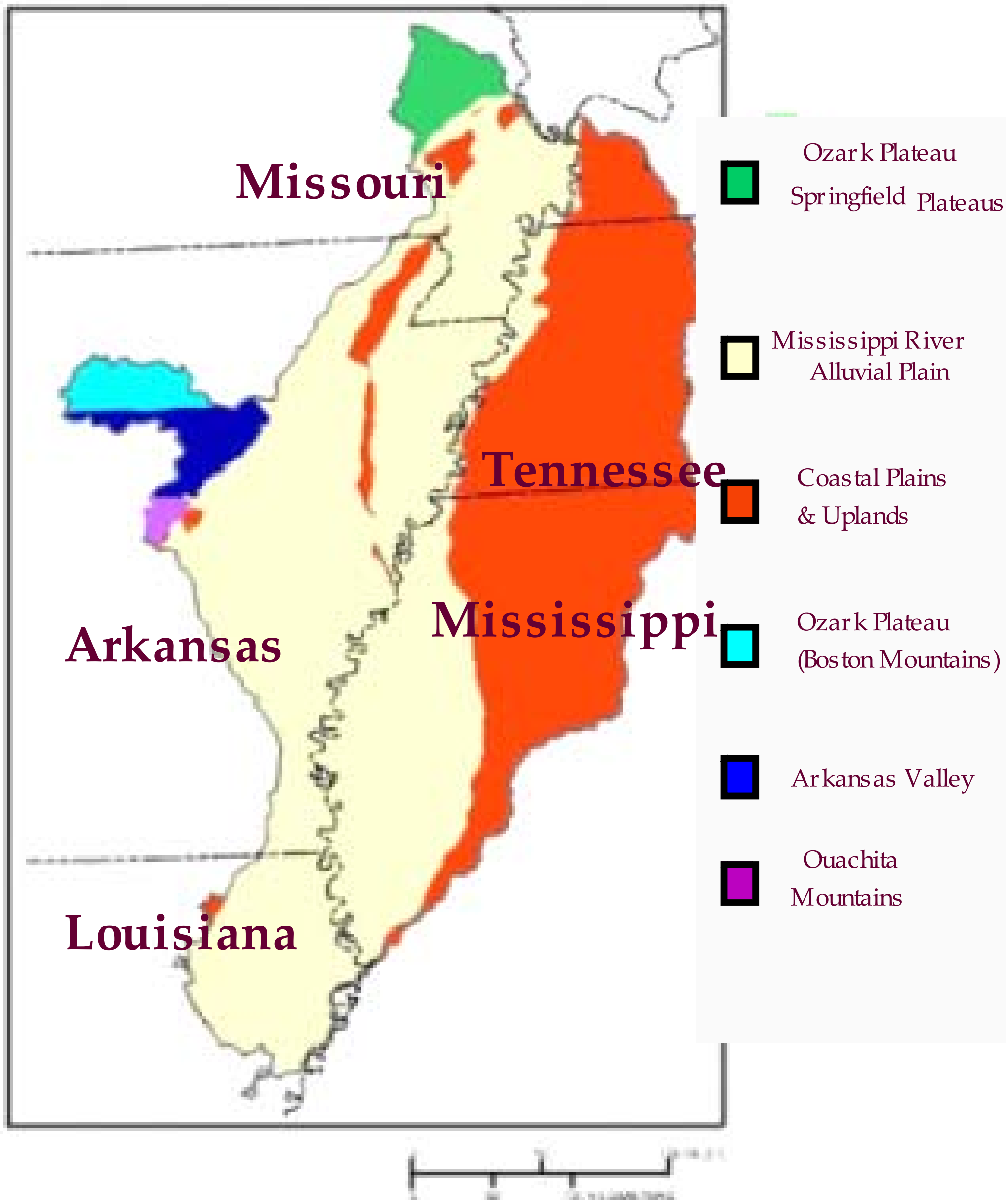

Figure 1. Map of area of United States that represents a sub region of the Lower Mississippi River Basin, an alluvial plain known as the Mississippi Delta.

Beasley Lake (Figure 2) is a 25-ha oxbow lake resulting from a course shift by the nearby Sunflower River. The total drainage area of this watershed is approximately 850 ha. The Sunflower River levee defines the northern part of the watershed boundary. Soils are generally loam to heavy clay, with part of the watershed being forested. Drainage of the watershed is dependent on man-made drainage ditches, which drain water into Beasley Lake itself. The predominant watershed crop is soybean, but corn and cotton are rotationally grown.

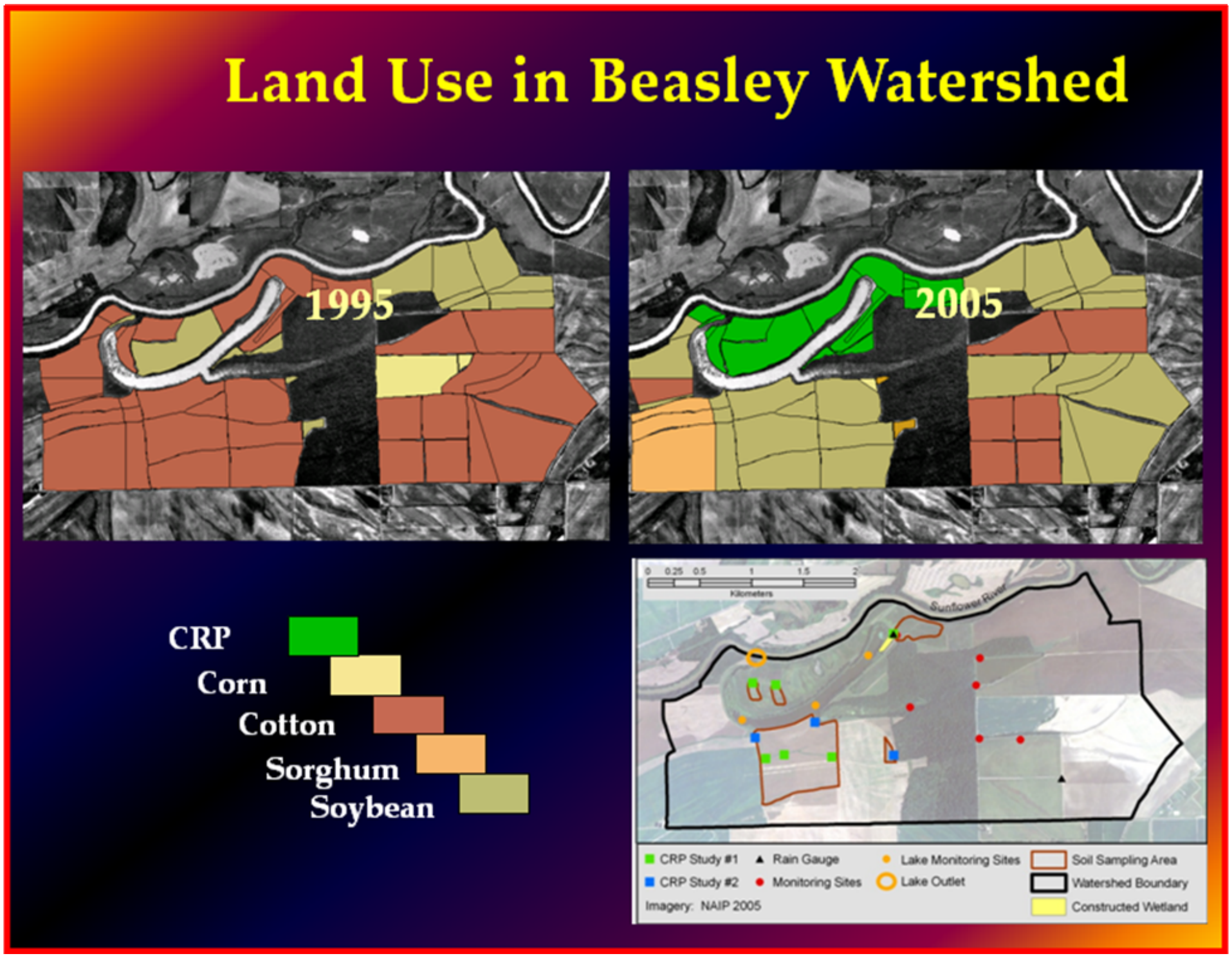

Figure 2. Map of Beasley Lake Watershed showing sampling locations and changes to watershed from 1995 through 2008.

Beasley Lake Watershed has evolved from row crop agriculture dominated by cotton production to a mixture of row crop and non-cropped areas from 1995 through 2008 (Figure 2). Approximately 12% (113 ha) of the Beasley Lake Watershed was converted from cropped land to CRP beginning in 2003, and the remainder of the cropland is still managed for soybean, cotton, or corn production. Research was initiated in 2005 monitoring runoff from edge of field slotted-inlet drainage pipe sites on both CRP and cropped land. Six sub-drainage areas (1.2 to 6 ha) (denoted by green squares in Figure 2) of similar topography and soil types were selected from either areas cropped in reduced tillage soybean (three sites) or areas planted in eastern cottonwood (*Populus deltoids)* trees and set aside as Conservation Reserve (CRP) (three sites). These trees, planted on a 2 m by 2 m grid, are one of the largest North American hardwood trees and are grown in riparian areas. Global positioning system (GPS) surveys were used to establish/delineate drainage acreages (4-6 ha) for each site. Also where needed, bermed borders were created to prevent surface runoff from entering into the measured sub-drainage area. Rain and runoff from rain events producing runoff were measured and sampled. Rain was measured using 1-mm tipping buckets connected to area-velocity flow logger/meter within the study area. Runoff was determined from flow measurements using area-velocity flow logger/meters and acoustic Doppler devices mounted in slotted-inlet pipes positioned at the outlets of the sub-drainage areas. Runoff from these rain events was collected starting in April 2005 from these sub-drainage areas instrumented with relatively simple and compact area-velocity flow logger/meters and automated composite water samplers. Instruments automatically collected runoff samples from field drainage slotted-inlet pipes on a flow proportional basis via acoustic Doppler devices during all surface runoff events. Within 24 h of rainfall events, runoff samples were collected, transported to the National Sedimentation Laboratory in Oxford, MS, and stored at 4°C (usually <24 h) for analysis. Runoff, sediment yield or soil loss, and nutrient loss were determined for each site. Analytical and chemical methods were based on procedures from APHA (1992). Calculation of means and statistical analysis were completed using SAS STAT software (SAS Institute, Inc., 1996).

The hypothesis being tested is that improvement in edge-of-field water quality can be demonstrated via land placed in conservation reserve program. Improvement in edge of field water quality was primarily based on the reduction of sediments, since many of the contaminants of interest entering streams are attached to these particles. Selected fields (three cropped or tillage sites and three CRP sites) in the Beasley watershed in a randomized complete block design were automated to collect surface water samples from field drainage slotted-inlet pipes during all surface runoff events. Runoff samples were analyzed for sediments and nutrients. Both soil and chemical loss and runoff data were analyzed on a quarterly, annual, and total basis. Statistical analysis was conducted by comparing CRP sites to tillage sites to determine effectiveness of CRP to improve water quality, chiefly by reducing sediments. Data were collected from April 2005 to July 2008.

Results and Discussion

Physical water quality data for the six drainage sites are shown in Table 1. Analysis of variance on the randomized complete block design showed significant differences in the means ($p=0.05$) between the total average runoff and total soil loss from crop areas as compared to CRP areas over the time of study. Differences in runoff and soil loss means among the four years were found within both the crop areas and CRP areas probably due to the annual rainfall quantity differences during this study. The analysis of variance tests also showed a significant difference in means of the quarterly data with the January through March period producing the most runoff (Figure 3) and soil loss (Figure 4) especially in the crop areas.

Flow of upwards to one half the rain producing runoff was found from row crop areas as compared to one fifth in CRP areas. These results are shown in Table 1 when comparing the total runoff of 1051 mm and 476 mm from crop and CRP, respectively to the 2047 mm of rain producing runoff over the testing period. Soil loss from the crop area was 2.1 t/ha·y as compared to the soil loss from the CRP area of 0.3 t/ha·y. Total runoff and total soil loss were 55% and 85% lower for the CRP areas than compared to the cropped areas. Both areas produced lower soil loss than the NRCS tolerance level of 3 t/ha·y; thus, these two best management practices would be considered appropriate for this agricultural watershed.

Table 1. Mean annual and total runoff and sediment yield from crop and CRP sites.

Year	Rain (mm)	Runoff (mm)		Sediment Yield (kg/ha)	
		Crop	CRP	Crop	CRP
2005	298	217	40	320	54
2006	632	311	170	2071	789
2007	631	365	119	1810	213
2008	487	158	146	4161	234
Total	**2047**	**1051**	**476**	**8362**	**1290**

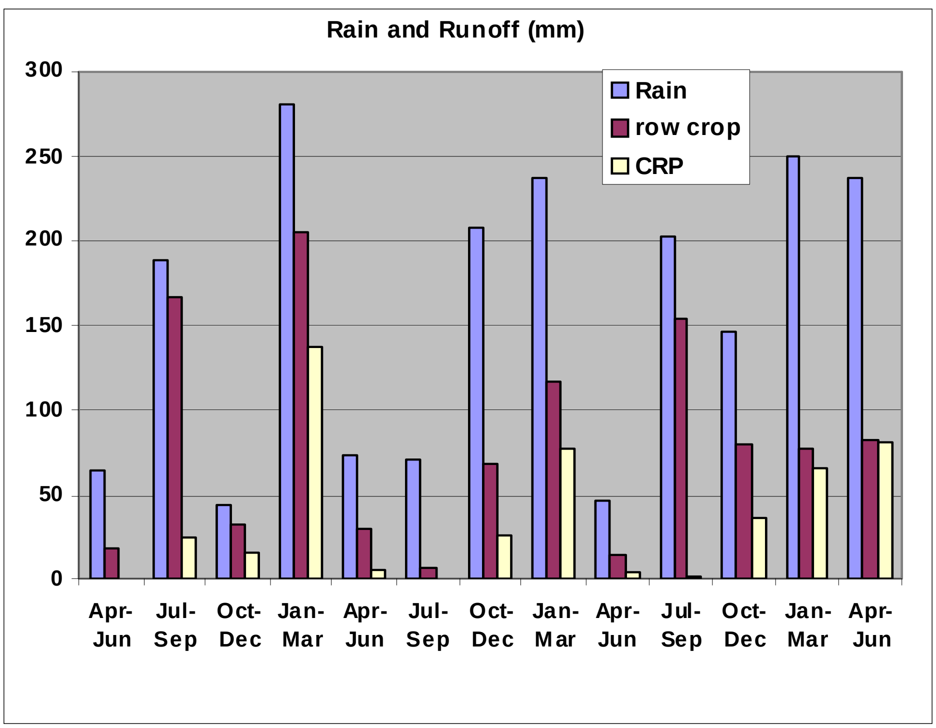

Figure 3. Quarterly rain and runoff from the three row crop sites and the three CRP sites.

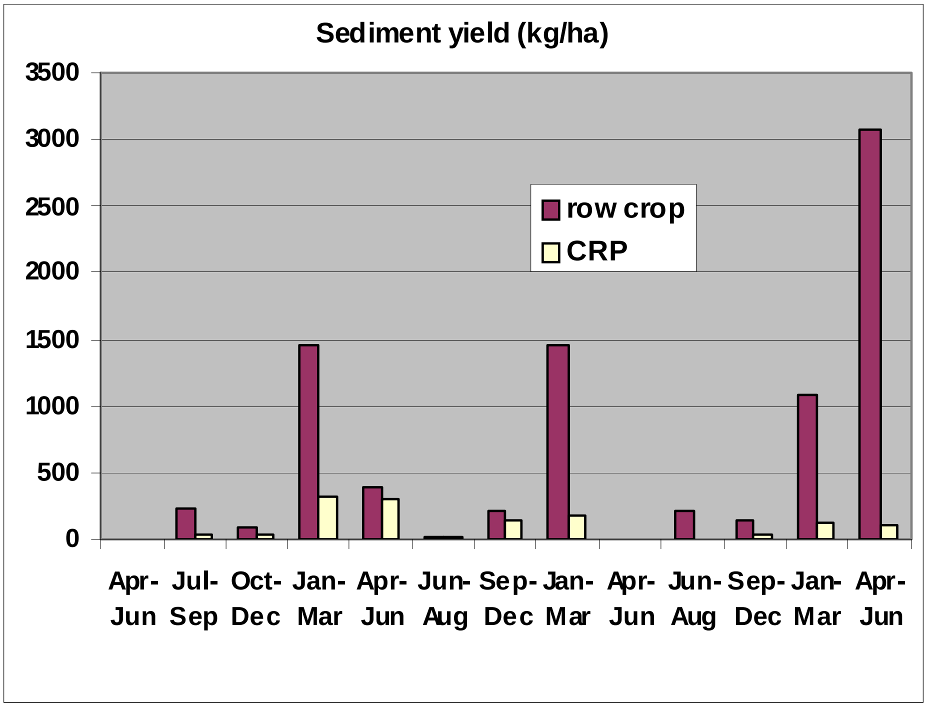

Figure 4. Quarterly sediment yield (kg/ha) from the three row crop sites and the three CRP sites.

The annual chemical water quality data from runoff collected from the six drainage sites are shown in Table 2. As found with the reduction of runoff and soil losses within the CRP areas as compared to the cropped areas, each of the chemicals analyzed showed favorable reductions toward the CRP areas. The total chemical losses for the study (Table 2) within the CRP areas as compared to the cropped areas were 83%, 71%, 35%, 36%, and 28% for NO_2-N, NO_3-N, NH_4-N, PO_4-P, and TOC, respectively. Also, almost all of the total Kjeldahl nitrogen (TKN) was in the water phase of the sample when comparing the TKN non-filtered (NF) data to the TKN filtered (F) data (Table 2). TKN losses within the water phase of the runoff were reduced by 45% for the study within the CRP areas as compared to that in the cropped areas. The total phosphorus (TP) losses for the study were 969 gm/ha and 628 gm/ha for the water phase of the runoff for cropped areas and CRP areas, respectively, and 712 gm/ha and 20 gm/ha for the sediment phase of the runoff for cropped areas and CRP areas, respectively. TP losses were reduced by 35% and 97% for the water and sediment phases of runoff, respectively, when comparing the CRP areas to the cropped areas.

Improvements in edge-of-field water quality were found when evaluating differences in sediments and nutrients in runoff resulting from converting cropped land to CRP. All physical and chemical water quality data from the runoff from these drainage ditches provide support for the hypothesis that improvement in edge-of-field water quality can be demonstrated via land placed in conservation reserve program. Reductions of soil loss and reduction of nutrients were found from each storm event, each quarterly, annual, and total data. The impact of converting one third of the cropped area into trees has reduced the sediments leaving the watershed and entering the lake by an order of magnitude resulting in improved water quality in Beasley Lake.

Table 2. Mean annual chemical loads from runoff of row crop and CRP sites.

Year	Drainage Type	NO_2-N (gm/ha)	NO_3-N (gm/ha)	NH_4-N (gm/ha)	PO_4-P (gm/ha)	TOC (gm/ha)	TKN (gm/ha) (NF)	TKN (gm/ha) (F)	TP (gm/ha) (NF)	TP (gm/ha) (F)
2005	row crop	154	3633	269	1251	54909	1947	1594	750	304
	CRP	6	46	52	694	4732	436	689	319	248
2006	row crop	56	5213	740	713	45879	3514	4044	1513	870
	CRP	27	3105	805	1053	60165	2363	3773	1199	1200
2007	row crop	75	3204	659	2575	46649	7155	7370	2451	988
	CRP	12	881	222	909	23699	1693	2556	656	542
2008	row crop	63	5342	272	2791	52348	3492	2963	2011	1716
	CRP	14	988	181	2000	55474	1591	1767	419	522

Summary & Conclusions

This study of Beasley Lake Watershed was used to evaluate runoff from edge-of-field sites with various row crop management practices, and quantifying effects of areas in the watershed that have shifted to forest (Conservation Reserve Program or CRP). Approximately one-third of the Beasley Lake watershed (ca. 280 ha) was converted from cropped land to CRP beginning in 2003, and the remainder of the cropland is still managed for soybean, cotton, or corn production. Sub-drainage areas (1.2 to 6 ha) with similar topography and soil types were either cropped (three sites under reduced tillage crop production) or CRP (three CRP sites) and were instrumented in 2005 to collect water samples from field drainage slotted-inlet pipes during all surface runoff events. These runoff samples were analyzed for sediments, nutrients, and pesticides. Reducing soil loss and nutrient loads in runoff from edge of field through the use of best management practices results in lower sediments and agrichemicals entering Beasley Lake. Establishing trees within CRP adjacent to oxbow lakes reduces the concentration of sediments and nutrients leaving the watershed as compared to reduced-till crop management techniques. The impact of converting one third of the cropped area into trees has reduced the sediments leaving the watershed by an order of magnitude resulting in improved water quality in Beasley Lake by July 2008.

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References

Akobundu, E. and D. W. Riggs. 2000. Pervasive permitting: The EPA's proposed TMDL rules. Water Resource Impact 2(3): 4-6.

American Public Health Association (APHA). 1992. Standard Methods for the Examination of Water and Waste Water. 18th ed. APHA. Washington

Cooper, C. M. and S. S. Knight. 1990. Water quality cycles in two hill-land streams subjected to natural, municipal, and nonpoint agricultural stresses in the Yazoo Basin of Mississippi, USA (1985-1987). Verh. Internat. Verein. Limnology 24: 1,654-1,663.

Cooper, C. M. and W. M. Lipe. 1992. Water quality and agriculture: Mississippi experience. J. Soil and Water Cons. 4(3): 220-223.

Dillaha, T. A., R. B. Reneau, S. Mostaghimi and D. Lee. 1989. Vegetative filter strips for agricultural nonpoint source pollution control. Transactions of the ASAE 32(2): 513-519.

Laflen, J. M., H. P. Johnson and R. O. Hartwig. 1978. Erosion modeling on impoundment terraces. Transaction of ASAE 21: 1131-1135.

Line, D. E. 1991. Sediment trapping effectiveness of grass strips. Proceedings of the Fifty Federal Interagency Sediment Conference. March 18-21, Las Vegas, NV, Volume 2: 53-56.

Locke, M.A. 2004. Mississippi Delta Management Systems Evaluation Areas: Overview of water quality issues on a watershed scale. In: Water quality assessments in the Mississippi Delta: Regional solutions, national scope. M.T. Nett, M.A. Locke, and D.A. Pennington, eds., ACS Symposium Ser. 877, pp. 1-15.

Loehr, J. M., D. A. Haith, M. F. Walter and C. S. Martin (Editors). 1979. Best Management Practices for Agriculture and Silviculture. Ann Arbor Science, Ann Arbor, Michigan, 740 pp.

Mueller, D. H., R. C. Wendt and T. C. Daniel. 1984. Phosphorous losses as affected by tillage and manure application. J. Soil Science Society of America. 48(4): 901-905.

Murphree, C. E. and C. K. Mutchler. 1981. Sediment yield from a flatland watershed. Transaction of ASAE 24(4): 966-969.

Natural Resource Conservation Service (NRCS). 1997. Water quality and agriculture: status, conditions and trends Online document, URL. http://www.nhq.nrcs.usda.gov/land/env/wq.html.

Natural Resource Conservation Service (NRCS). 2001. USDA Conservation Programs. http://www.nrcs.usda.gov/NRCSProg.html.

North Carolina State University. 2000. Nitrate-Nitrite. Available HTTP http://h2osparc.wq.ncsu.edu/info/no3.html. [2000, November 3].

Novotny, V. and H. Olem. 1994. Water Quality: Prevention, Identification, and Management of diffuse pollution. New York: Van Mostrand Reinhold.

Parker, S. W., S. Mostaghimi, R. A. Cooke and P. W. McClellan. 1994. BMP impacts on watershed runoff, sediment, and nutrient yields. Water Resour. Bull. 30(6):1011-1023.

Ribaudo, M.O. 1992. Options for agricultural nonpoint source pollution control. Journal of Soil and Water Conservation. 47: 42-46.

Ritchie, J. C., C. M. Cooper and J. R. McHenry. 1979. Recent sediment accumulation of sediments in lakes in the Bear Creek watershed in the Mississippi Delta. Southeastern Geol. 20: 173-180.

Ritchie, J. C., C. M. Cooper and J. R. McHenry. 1986. Sediment accumulation rates in lakes and reservoirs in the Mississippi River Valley. In S. Y. Wang, H. W. Shen, amd L. Z. Ding [eds.] Proc. Third Int. Symp. On River Sedimentation. Eng. Dept., Univ. Miss., Mississippi State. pp 357-365.

Robinson, C. A., M. Ghaffarzadah and R. M. Cruse. 1996. Vegetative filter strip effects on sediment concentration in cropland runoff. J. Soil and Water Cons. 50(3): 220-223.

SAS Institute, Inc. 1996. SAS STAT. www.sas.com/technologies/analytical/statistics/stat/index.html.

USDA. 1994. Water quality research plan for management systems evaluation areas (MSEA's): an ecosystems management program. Agricultural Research Service Bulletin, ARS-123, Washington, DC. 45 pp.

Walker, J. F. 1994. Statistical techniques for assessing water-quality effects of BMPs. J. Irrig. and Drainage Eng. 120(2): 334-347.