Effects of Conservation Tillage on Runoff-Water Quality in the Arkansas Delta

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RESEARCH PROBLEM

Recent evaluations of surface-water quality in eastern Arkansas have identified a number of lakes and streams in the area that are impaired for one or more of their designated uses because of high turbidity (ADEQ, 2002). State agencies have determined the cause of the problem to be excessive soil erosion from agricultural fields. Traditional agricultural production practices leave the soil surface bare of vegetative cover most of the spring during which time the most intense rainstorms of the year occur (USGS, 2003). These conditions have proven to be a dangerous combination for producing surface-water runoff and erosion.

BACKGROUND INFORMATION

A number of methods, known as best management practices (BMPs), have been established to decrease damaging runoff from agricultural sources into lakes and streams. One of these BMPs, conservation tillage (CT), has been adopted throughout the United States and has been shown to be very effective in controlling these water quality problems. Conservation tillage provides a number of benefits including increased water infiltration and decreased soil erosion (CTIC, 2003b). Despite the effectiveness of CT, adoption rates in Arkansas are extremely low (CTIC, 2003a) and extensive studies under Arkansas conditions are limited. The objective of this study was to determine the effects of two tillage practices, no-till (NT) and conventional till (CN), on sediment load, turbidity, runoff volume, and runoff concentrations of dissolved P (DP), bio-available P (BAP), and total P (TP).

PROCEDURES

A single study was conducted in May of 2003 on a Stuttgart silt loam (fine, smectitic, thermic Albaquultic Hapludalfs) at the Rice Research and Extension Center (RREC), located near Stuttgart, Ark. Treatments consisted of two tillage methods (CN and NT) in three crop rotations including continuous rice (*Oryza sativa* L.), rice-soybean (*Glycine max* L.), and rice-corn (Zea mays L.). In 2003, rice was seeded in all three crop-rotation systems and in mid-April, prior to seeding, phosphorous was broadcast at a rate of 130 lb P_2O_5/acre. The P was lightly incorporated in the CN system, but in the NT system P remained on the soil surface. Normal weather patterns occurred between planting and when the rainfall simulations were conducted with a 1.5-in. storm occurring on 7 May.

The experimental design was a modified split block with four replications for a total of 24 plots. Within each of these plots, 2- by 1.5-m microplots were established and used for rainfall simulation. Prior to rainfall simulation, residue cover was measured on all 24 plots using the string method (Hartwig and Laflen, 1978). Volumetric water content was also determined on the plots using dielectric voltage readings converted to volumetric water content using a soil-specific calibration (http://www.soil.ncsu.edu/sera17). Rice was at the 5-leaf stage (May 28-29, 42 days after seeding) when rainfall simulations were conducted.

Rainfall simulations were conducted according to National Phosphorous Project Protocol (Sharpley and Daniel, 2004) for simulated rainfall-surface runoff studies (http://www.soil.ncsu.edu/sera17/). One rainfall simulator (Humphry et al., 2002) was used to simulate a 7.0 cm/h (2.8 in/h) rainfall, which is equivalent to a storm with a 5- to 10-yr return period in eastern Arkansas (USDC, 1963). Water used for rainfall simulations came from uncontaminated sources and, prior to application, was sent through a series of filters to simulate the chemistry of natural rainfall. The duration of the simulations varied from plot to plot depending on time until runoff, but they were conducted to provide 30-min runoff events. Runoff volume was collected, recorded, and a 1-L composite sample was taken for analyses. Samples were analyzed for sediment load (concentration x runoff volume), turbidity, DP, BAP, and TP.

The effects of tillage, rotation, and their interactions were determined by analysis of variance procedures conducted with the PROC GLM procedure in SAS. A significance level of 0.10 was chosen and means were separated using Fisher's protected least significant difference (LSD).

RESULTS AND DISCUSSION

Statistical analyses of the effect of tillage, rotation, and interactions on dependent variables are listed in Table 1 and 2. Percent residue cover was the only variable significantly affected by the tillage by rotation interaction (Table 1). Residue cover in NT and CN treatments averaged 88% and 5%, respectively, with trends different among crops within each tillage system. Residue cover was always greatest for NT (99% for continuous rice, 92% for soybean-rice, and 73% for corn-rice) with residue cover in CN treatments ranging from 3 (soybean) to 7 (corn) %.

Significant differences between the NT and CN systems were obtained for volumetric water content, time until runoff, sediment load, turbidity, DP load, and TP load (Table 2). No-tillage treatments had twice the volumetric water content of CN (i.e., 28.8% and 14.6% for NT and CN, respectively). It also took twice as long for runoff to occur (time until runoff) for NT (12.1 min) as compared to CN (5.9 min), meaning more water entered the soil profile for NT than CN. Sediment load was 8 times lower for NT than CN (Table 2 and Fig. 1), resulting in nearly twice as much turbidity for CN when compared to NT (Fig. 2). However, loads for DP were significantly higher for the NT treatment than the CN treatment, possibly due to P leaching from the crop residue and P release from the surface-applied P fertilizer. Total P load was significantly higher from CN than NT (Fig. 3).

PRACTICAL APPLICATIONS

Reduced tillage, especially NT, shows promise for significantly reducing turbidity, sediment load, and TP load in agricultural runoff; however, increased loads of DP from NT require further investigation and possible innovative management practices to minimize runoff losses.

ACKNOWLEDGMENTS

Support for this research was provided by Fertilizer Tonnage Fees administered by the Soil Test Review Board.

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Table 1. Analysis of variance for dependant variables as affected by no-till and conventional tillage on continuous rice, rice-soybean, and rice-corn rotations at the Rice Research and Extension Center (RREC) near Stuttgart, Ark.

	P value		
	Tillage	Rotation	Tillage x rotation
Residue cover, %	< 0.0001[z]	0.0008[z]	0.0070[z]
Runoff volume, L	0.6164[y]	0.04144[y]	0.1804[y]
Runoff percentage, %	0.6163[y]	0.4152[y]	0.1818[y]
Time to runoff, min	0.0401[z]	0.8519[y]	0.5715[y]
Volumetric water content, %	0.0009[z]	0.1320[y]	0.2821[y]
Sediment load, g	0.0242[z]	0.1452[y]	0.1392[y]
Turbidity, NTUs	0.0435[z]	0.1684[y]	0.2454[y]
Dissolved P load, mg	0.0062[z]	0.7148[y]	0.8797[y]
Total P load, mg	0.0988[z]	0.2255[y]	0.2444[y]

[z] Significanct at the 0.1 probability level.
[y] Non significant.

Table 2. Mean values for significant dependant variables as affected by no-till and conventional tillage on continuous rice, rice-soybean, and rice-corn rotations at the Rice Research and Extension Center (RREC) near Stuttgart, AR.

	Tillage		
	No-till	Conventional till	LSD
Residue cover, %	88.0 a	5.3 b	5.3
Volumetric water content, %	28.8a	14.6 b	2.5
Time to runoff, min	12.1 a	5.9 b	4.2
Sediment load, g	36.9 a	299.1 b	145.9
Turbidity, NTUs	70.3 a	1345.0 b	942.4
Dissolved P load, mg	44.7 a	2.1 b	14.5
Total P load, mg	72.9 a	93.8 b	20.7

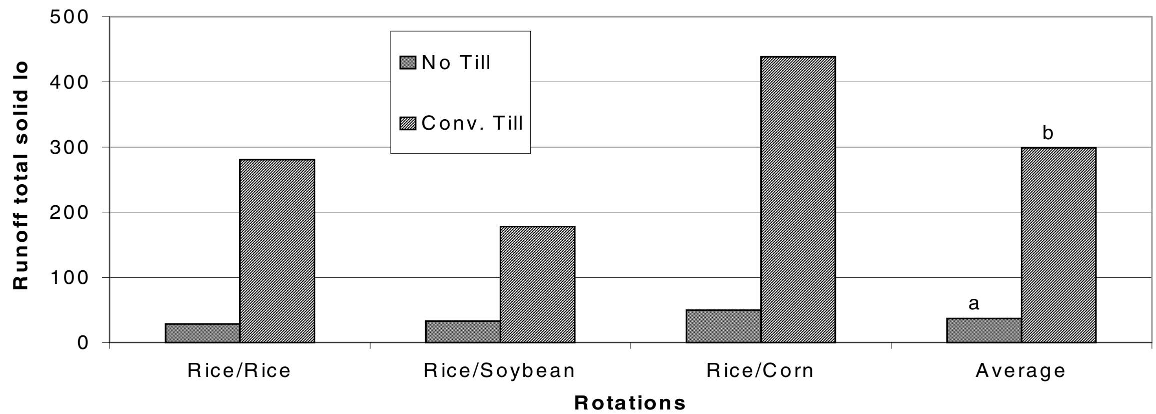

Fig. 1. Effect of tillage and rotation on total solids in runoff water.

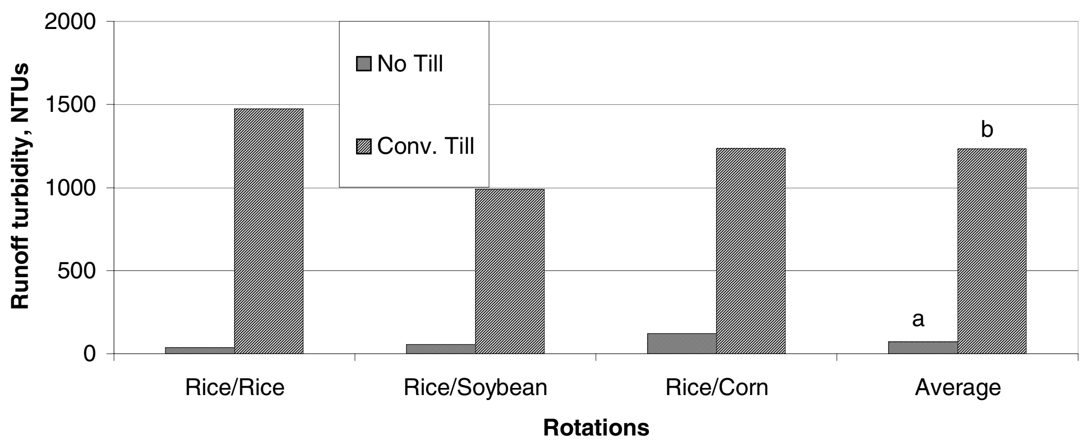

Fig. 2. Effect of tillage and rotation on runoff turbidity in Nephelometric Turbity Units (NTUs).

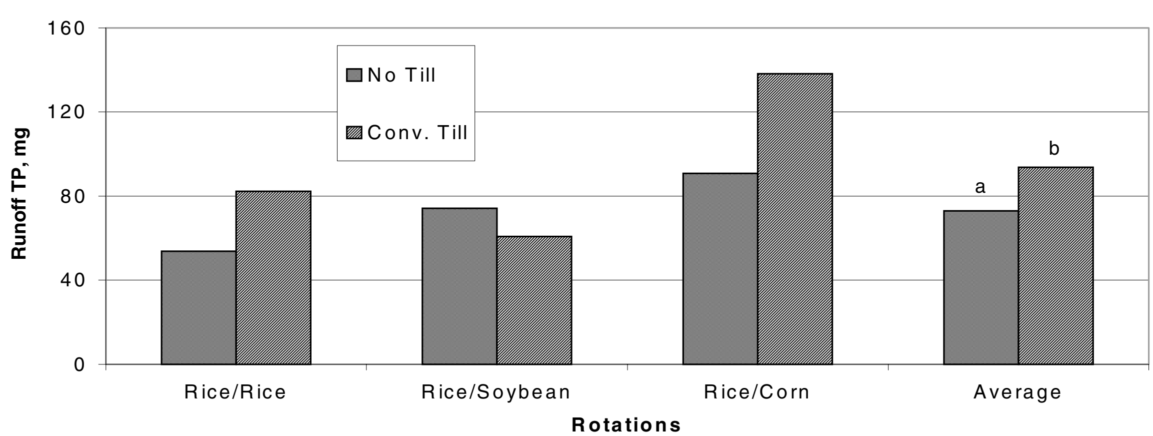

Fig. 3. Effect of tillage and rotation on runoff total phosphorous (TP) loads.