# Native Prairie and Agroecosystem Effects on Soil Physical Properties and Runoff Water Quality in the Arkansas Delta

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## BACKGROUND INFORMATION AND RESEARCH PROBLEM

Recent evaluations of surfacewater quality in eastern Arkansas have identified a number of lakes and streams 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 fragile combination for producing surfacewater runoff and erosion. In addition, runoff volumes from Delta soils have been shown to be extremely high, possibly due to changes in soil physical properties caused by agricultural production practices.

A number of methods, known as best management practices (BMPs), have been documented to decrease damaging runoff from agricultural lands 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 short- and long-term benefits. Short-term benefits, including increased water availability, reduced soil erosion, and improved water quality, are a direct result of residue cover present on the soil surface. Long-term benefits, including increased soil organic matter, improved soil tilth, and increased water infiltration, are a result of continuous long-term CT practices. Despite the effectiveness of CT, adoption rates in Arkansas are extremely low (CTIC, 2003) and extensive studies under Arkansas conditions are limited. The objectives of this study were to quantify differences in soil physical properties due to land use (including CT) and determine how these differences affect infiltration, runoff volume, sediment load, turbidity, and runoff concentrations of various forms of phosphorous.

## PROCEDURES

A single study was conducted in March 2004 on a Grenada silt loam (Fine-silty, mixed, active, thermic, Oxyaquic Fraglossudalfs) at the Roth Prairie and Harbecke Farms located near Stuttgart, Ark. Treatments consisted of three land uses: conventional till (CN), reduced till (RT), and native prairie (PR). The CN system had been tilled one month prior to rainfall simulation while the RT system had been under continuous CT management for eight years. The CT system was currently in wheat production and had been fallow the previous season. The RT system was previously planted in soybean and a typical soybean-corn rotation had been followed. Typical management practices associated with these two systems had been followed. The native prairie system had never been disturbed. All three systems experienced several rainstorms in the month prior to rainfall simulation.

Plots (2- by 1.5-m) were established and used for rainfall simulation. The experimental design was completely randomized with four replications for a total of 12 plots. Prior to rainfall simulation, residue cover was measured on all 12 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. Soil samples were taken and analyzed for aggregate stability, bulk density, total organic carbon, and Mehlich-3-extractable nutrient concentrations. Soil samples were taken from the area immediately surrounding the plots using a 2-inch diameter core sampler.

Soil samples were taken to a depth of 2 inches to characterize the zone of soil that interacts with runoff water. Mehlich-3-extractable P concentrations were obtained using an Inductively Coupled Argon Plasma Spectrometer (ICAP) and, along with pH and several other nutrients, are shown in Table 1. Post-simulation measurements included soil resistance.

Rainfall simulations were conducted on 26 and 27 March 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/hour (2.8 inches/hour) 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 exchange-resin filters to simulate the chemistry of natural rainfall. The duration of the simulations varied from plot to plot depending on time until runoff, but were conducted to provide 30-minute runoff events. Runoff volume was collected, recorded, and a 1 L composite sample was taken for analyses. Runoff water samples were analyzed for sediment load (concentration × runoff volume), turbidity, soluble-reactive phosphorus (SRP), and total phosphorus (TP).

The effect of land use was determined by analysis of variance procedures conducted with the PROC ANOVA procedure in SAS. A significance level of 0.05 was chosen and, when appropriate, means were separated using the Fisher's protected least significant difference (LSD) method.

## RESULTS AND DISCUSSION

Significant differences in residue cover existed among the three land uses with CN having the least (27.5%) and PR having the highest cover (98.5%, Table 2). The RT system also had a high amount of residue cover (80.8%), but was still significantly lower than that of the PR. Runoff volume was numerically the highest from the RT (91.9%) plots and statistically greater than runoff from the PR (65.7%). Runoff volume from the CN (79.8%) was not significantly different from the RT or PR plots. Soluble-phosphorus load was significantly higher from the RT (10.7 mg/plot) than from the CN (1.5 mg/plot) and PR (0.2 mg/plot) (Table 2). High phosphorus loads from RT systems are typically attributed to broadcast application of fertilizer and decomposition of residue on the surface of the soil. Phosphorus load is also influenced by the high volume of runoff from the RT system.

Total phosphorus load from CN (114.6 mg/plot) plots was twice that of RT (54.7 mg/plot) plots and nearly 10 times that of the PR (13.7 mg/plot) system (Table 2). This significant difference in TP load is most likely due to the increased amount of solids in the CN runoff. Total-solid load from the CN (89.2 g/plot) was more than 30 times greater than loads from the PR and RT systems which were nearly identical at 2.6 and 2.8 g/plot, respectively (Table 2). This difference in solid load is also reflected in the turbidity values of the three systems. Turbidity (measured in Nephelometric Turbidity Units, NTUs) of the CN (550 NTUs) runoff was significantly higher than that of the PR (22 NTUs) and RT (109 NTUs) systems (Table 2).

Bulk density of the PR (0.91 g/cm$^3$) system was significantly lower than that of the RT (1.19 g/cm$^3$) and CN (1.21 g/cm$^3$) systems (Table 3). Aggregate stability was significantly higher in the PR (49.6%) than in the RT (25.3%) and CN (19.8%) systems. Reduced tillage, although not statistically different, exhibited a trend of increased aggregate stability when compared with the CN plots. Total soil carbon of the PR (3.08%) plots was nearly twice as high as that of the RT (1.46%) and CN (1.59%) plots (Table 3). Significant soil resistance differences were apparent at the 10- to 30-cm depths of the soil profile (data not shown). Reduced tillage and CN also showed significantly higher soil resistance than the PR system at the 10- to 30-cm depth. The increased soil resistance is indicative of the presence of a plow pan.

## PRACTICAL APPLICATIONS

The short-term benefits of CT were evident. Reduced tillage practices were shown to be extremely effective at improving water quality, especially in terms of TP load, solid load, and turbidity, when compared to CN systems. In fact, when considering these parameters, RT exhibited very similar numbers to that of the undisturbed system, the native prairie.

The high soluble-phosphorus loads from the RT plots are of some concern. Even though SRP concentrations are typically higher from RT systems than from CN systems, loads are usually more similar because of the decreased runoff from RT plots. That was not the case in this experiment with the highest runoff volume coming from the RT plots. A typically accepted solution to controlling SRP loads is to make sure fertilizer is applied to RT systems several days prior to an expected rainfall, giving the fertilizer time to adsorb to the soil. In this case, fertilizer had not been applied to the RT system in several months, but the plots still showed very high SRP loads.

The long-term benefits of CT, even after eight years of continuous CT management, were not yet evident. Reduced tillage did not result in increased water infiltration compared to the CN systems. Nor did RT practices show significant differences in soil physical properties although the RT system was beginning to show signs of improved soil physical properties, especially in terms of aggregate stability. So, while RT is an effective BMP for improving overall water quality, it may not necessarily be the answer to other problems, including increased water infiltration and reduced SRP loads, especially in the Arkansas Delta.

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**Table 1. Soil pH and mean Mechlich-3-extractable nutrient concentrations for selected nutrients for conventional till (CN), native prairie (PR), and reduced till (RT) systems at the Roth Prairie and Harbecke Farms near Stuttgart, Ark.**

| | Soil | Mehlich-3-extractable nutrient concentrations | | | | | | |
|---|---|---|---|---|---|---|---|---|
| System | pH | P | K | Ca | Mg | S | Na | Zn |
| | | (mg/kg) | | | | | | |
| CN | 5.7 | 56 | 225 | 419 | 45 | 18 | 17 | 3.8 |
| PR | 5.0 | 23 | 142 | 207 | 46 | 27 | 17 | 1.3 |
| RT | 6.7 | 33 | 115 | 935 | 106 | 13 | 23 | 5.6 |

**Table 2. The influence of land-management system on residue cover, runoff volume, soluble reactive phosphorous, total phosphorous, sediment load, and turbidity for conventional till (CN), native prairie (PR), and reduced till (RT) systems at the Roth Prairie and Harbecke Farms near Stuttgart, Ark.**

| | System | | | |
|---|---|---|---|---|
| Measurement | CN | PR | RT | LSD0.05 |
| Residue cover (%) | 27.5 | 98.5 | 80.8 | 7.8 |
| Runoff volume (%) | 79.8 | 65.7 | 91.9 | 14.4 |
| Soluble reactive phosphorous (mg/plot) | 1.5 | 0.2 | 10.7 | 5.5 |
| Total phosphorous (mg/plot) | 114.6 | 13.7 | 54.7 | 20.5 |
| Sediment load (g/plot) | 89.2 | 2.6 | 2.8 | 17.5 |
| Turbidity (NTUs) | 550.0 | 22.2 | 109.5 | 68.1 |

**Table 3. The influence of land-management system on soil bulk density (BD), aggregate stability (AS), and total carbon (TC) of conventional till (CN), native prairie (PR), and reduced till (RT) systems at the Roth Prairie and Harbecke Farms near Stuttgart, Ark.**

| | Soil physical properties | | |
|---|---|---|---|
| System | BD | AS | TC |
| | ($g/cm^3$) | (%) | |
| CN | 1.21 a[z] | 19.8 a | 1.59 a |
| PR | 0.91 b | 49.6 b | 3.08 b |
| RT | 1.19 a | 25.3 a | 1.46 a |

[z]Means in a column followed by the same letter are not significantly different at the 0.05 level.