# SHORT AND LONG TERM EFFECTS OF CONSERVATION TILLAGE ON SOIL RESISTANCE AND AGGREGATE STABILITY IN RICE PRODUCTION SYSTEMS.

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## ABSTRACT

Rice production is traditionally tillage intensive and has seen little adoption of conservation tillage practices. This situation has occurred during a time when soil organic matter and structure were declining in quantity and quality. Water management, tradition, land tenure, crop subsidies, and soils that are not responsive to conservation tillage are some of the reasons given for low adoption of conservation tillage in rice production areas. In order to determine if soil aggregate stability and resistance were affected by conservation tillage a series of measurements were taken from on-station tillage studies and a on-farm site where conservation tillage has been practiced on specific fields from 2 to 41 years. Data indicate that the percentage of water stable aggregates increases with the adoption of conservation tillage and values continued to increase up to the 41 year measurement. Changes in soil resistance were dependent on soil type, crops grown, and length of time conservation tillage was practiced. Soybeans were effective in reducing soil resistance in no-till plots while corn was the opposite. Continuous rice reduced soil resistance in fields no-tilled up to 41 years (when measurements stopped). Aggregate stability and soil resistance were sensitive to tillage and were found to be good indicators of soil health.

## INTRODUCTION

Rice production, as practiced in eastern Arkansas, is tillage intensive. Rice producers generally level fields to a slope between 0 and 0.15% so that, during flooding, water can flow evenly across the field. Leveling involves disking and harrowing fields several times as well as smoothing it with a land plane before planting. Rice is harvested at 18 to 20% moisture, which is shortly after the field is drained. Depending on the weather conditions after drainage, moist soil can lead to rutting during harvest and the need for additional tillage (Anders et al., 2002).

The percentage of conservation tillage used in the United States increased from 5.1% in 1989 to 16.3% in 1998 (Conservation Technology Information Center, 1999). In rice production, conservation tillage is not readily accepted. In the Delta, which covers most of eastern Arkansas, conservation tillage adoption increased from 2.4% in 1989 to 10.7% in 1998 (Parsch et al., 2001). Much of this increase is attributed to soybean production and not rice production. This low percentage could be partially due to the fact that the clay soils in this area are difficult to manage and rice production has specific water management needs.

Benefits of conservation tillage have been well documented for many crops. Some benefits include: reductions in soil erosion, increased soil aggregate stability, increased soil carbon, reduced soil resistance, increased diversity and activity of soil microbes, and increased water infiltration. Unlike many of the row crops where extensive studies have documented these benefits, data available from rice production systems are limited. In a long-term study located at the University of Arkansas Rice Research and Extension Center, data comparing conventional- and no-till rotations containing rice have shown a 10-fold reduction in runoff from no-till rotations compared to conventional-till rotations (Harper et al., 2003; Anders, 2004). These results suggest that many of the soil processes documented in non-flooded row crop production systems are present in rice (flooded) production systems.

Increased soil aggregation is one beneficial aspect of conservation tillage. Soil aggregation is the process whereby smaller soil particles bind together to form larger, more stable particles. Amezketa, (1999) reported that newly formed soil aggregates are bound by organic and inorganic compounds. Without intensive tillage, soil particles become more stable. Formation of more stable soil units creates space between them allowing movement of air and water in to the soil (Soil Quality Indicators, 1996). Stable soil aggregates, resulting from conservation tillage, improve the ability of air and water to mix, allowing beneficial plant growth in a shallow root zone. Shallow root development also enables the plant to utilize nutrients and elements such as nitrogen and carbon that are near the surface (Fawcett and Caruana, 2001). The impact of conservation tillage on soil aggregation and aggregate stability in rice production systems has not been documented.

Soil strength or resistance is the ability of the soil to resist penetration or displacement by outside forces such as erosion. Soil strength increases as soils become drier and is strongly dependent on moisture (Kay, 1990). This increase could result in poor infiltration and depending on moisture content; soil strength can influence plant root development. In intensively tilled rice soils there is little attention given to soil strength because rice has a fibrous root system that is concentrated at the soil surface. However, much of the rice production in Arkansas is found in rice-soybean rotations where soybeans are a crop that is characterized by deep rooting. In these systems soybeans may require frequent irrigation because of restricted rooting. Soil strength is often measured with a penetrometer, a device that measures the force required to force a rod with a pointed tip straight down through the soil (Schuler and Wood, 1992). Soil resistance data indicate that soils under no-till management have decreased resistance (Anders 2004). Soil strength relationships between tillage, rotation, and aggregate stability have not been documented in rice production systems.

The objectives of the data presented in this paper are to: 1) Determine the effect of conservation tillage, rotation and soil type on soil aggregation, 2) Determine the effect of conservation tillage, rotation, and soil type on soil resistance, and 3) Determine possible relationships between soil aggregate stability and resistance.

## MATERIALS AND METHODS

On-station data were collected from a long-term rotation initiated in 1999 at the University of Arkansas Rice Research and Extension Center, Stuttgart, Arkansas. Soil at the study site is a silty clay loam (fine, montmorillonitic, thermal, Typic Albaqualf of the Dewitt soil series). Four replications planted into 10 main plots; each representing 7 rotations. Main plots were divided into tillage sub-plots (no-till vs. conventional-till). Sub-plots were further divided into fertility (standard vs. enhanced) and variety (2) sub-plots. Rotations reported on in this paper are: 1) continuous rice, 2) rice-soybean, and 3) rice-corn. The field was graded to a 0.10% slope in 1999 with rotation and no-till comparisons beginning in 2000. All crops are similarly managed with the exception of treatment differences. Levees are constructed around all main plots during the winter to collect winter rainfall and aid in residue decomposition. Data presented for tillage and rotation comparisons are made from contrasting 3m x 9m plots where variety and fertility were the same.

On-farm data were collected from the Isbell Farms located near Humnoke, Arkansas. Soil at all field locations is described as heavy (buckshot) clay. All fields have been planted into continuous rice for between 2 and 41 years. All fields are flooded during the winter and shallow tilled when weeds become a problem (5-10 years). Additional samples were collected from a prairie reserve area with the same soil as the station and where no tillage has taken place.

Aggregate stability samples were collected using a 7.62 cm diameter core to a depth of 20 cm in March of 2003. All samples were forced through a 8 mm screen and allowed to air-dry. Sub-samples of 200 g dried soil were processed using a “wet sieve” method (Yoder, 1936). Five screen sizes were used (0.25, 0.50, 1.00, 2.00, and 4.00 mm) with samples cycled for 5 minutes at 130 cycles per minute. Separated sizes were oven dried and weighed.

Soil resistance measurements were collected in March of 2003 using a Spectrum® Field Scout SC-900 penetrometer. Four samples to a depth of 40 cm were collected from each plot at the same time a moisture samples was collected to the same depth. Moisture samples were divided into 5 cm segments and dried to determine moisture percent.

Data analysis was completed using standard error bars calculated using Systat (SPSS Inc.) at a 0.68 difference level.

## RESULTS AND DISCUSSION

Aggregate stability: Total weight of water stable aggregates increased in the no-till when compared to the conventional-till for the continuous rice and rice-soybean rotations after 4 years of no-till (Table 1). Percentage of increase was 4% higher for the continuous rice rotation when compared to the rice-soybean rotation. For the rice-soybean rotation there were increases in four of the five size classes with a decrease in the largest (4.00mm) class from 0.67% to 0.52%. The largest increase was with the smallest aggregate size where weights increased from 5.18% to 7.10%. There were increases in the three smallest class sizes in the continuous rice rotation. However these increases were of a larger magnitude than were observed in the rice-soybean rotation data. Total values were significantly lower than the 55% reported from samples collected in an undisturbed prairie (data not presented).

Aggregate stability values from continuous rice fields that were managed as no-till for 2 to 41 years showed a trend of increasing total water stable aggregate percents with increased time in conservation tillage (Fig. 1). Total percent water stable aggregates increased from 65% at 2 years to over 73% at 41 years. Biggest changes came in the percentage of large water stable aggregates. Overall values for these measurements were much higher than those presented in the station study and this reflects differences in soil type. These values suggest that if the approach of using water stable aggregates as a means of measuring soil health is used; these soils have improved in quality. They would also support the type of management used in these fields as a valid approach for improving soil quality in rice production areas.

Soil resistance: Soil resistance values in the continuous rice rotation ranged from 200 Kpa near the surface in the conventional-till to nearly 4000 Kpa in the same treatment (Fig. 2). Values greater than 2000 Kpa are restrictive to root growth. Resistance in the continuous rice rotation decreased significantly in the 10 to 25 cm depth range in the no-till treatment when compared to conventional-till in the same rotation (Fig. 2). Lower resistance values in the 0-5 cm depth in the conventional-till plots is attributed to tillage. Higher values in the no-till treatment are the result of a plow layer. Soil moisture values were greater in the no-till plots through the top 35 cm of the soil profile. Reductions in the plow layer resistance did not result in increased irrigation requirements in the no-till plots (data not shown).

Reductions in soil resistance were dependent on tillage and rotation phase in the rice-soybean rotation (Figures 3 & 4). Values recorded following soybeans showed significant reductions in soil resistance in the no-till plots compared to the conventional-till plots for all depths between 10 and 35 cm (Fig. 3). The same comparison following the rice phase of the same rotation showed reductions in soil resistance through a smaller profile range. Increasing reductions in soil resistance in plots previously planted into soybeans when compared to those previously planted into rice suggests soybeans have a more extensive and vigorous root system. Soil moisture values were higher at all depths in the no-till plots when compared to the conventional-till plots at all depths (Figures 3 & 4). These differences were significant in only a few cases and there were no distinct patterns.

Of the rotations compared in this paper the only comparison where there was not a significant reduction in soil resistance was following corn in the corn-rice rotation (Figures 5 & 6). Soil resistance values were higher for the no-till treatment in the 16 to 35 cm depth range when compared to the conventional-till treatment. These results suggest that corn is not effective in reducing soil resistance. These results are bore out by the fact that corn yields have been consistently low (data not shown) and corn oftentimes requires irrigation on a more regular basis than soybeans. These observations suggest corn roots are often restricted to the surface soil layers and may not penetrate the soil. There were some reductions in soil resistance following the rice phase of the rice-corn rotation (Fig. 5). There was a small increase in soil moisture when comparing no-till to conventional-till in both rotation phases. These results indicate corn is possibly not well suited for no-till in rice rotations if farmers are hoping to reduce plow layer resistance and improve plant root densities.

Soil resistance values in no-till fields where continuous rice has been grown from 2 to 41 years show a general decrease in soil resistance with increasing years of production (Fig. 7). None of the values shown in these comparisons are sufficient to reduce root growth. In total these results indicate that there is no detrimental effect on soil resistance when continuous no-till rice is grown on a heavy clay (buckshot) soil.

## CONCLUSIONS

Aggregate stability measurements were sufficiently sensitive to measure trends of increasing percentages of water stable aggregates in plots that were no-till for four years compared to those who were conventional till for the same time period. No-till resulted in a greater percent of larger aggregates in all rotations. There was an increase in total water stable aggregates and a shift to larger aggregates in a heavy clay soil that had been no-till farmed from 2 to 41 years.

Changes in soil resistance were dependent on tillage and crop species. Soil resistance was reduced in no-till plots where rice and soybeans were rotation components. When corn was included in the rotation there was an increase in soil resistance through much of the profile. There was an increase in soil water content in no-till plots compared to conventional-till plots regardless of crop species and rotation sequence. No-till rice production in a heavy clay soil resulted in a steady decrease in soil resistance from 2 to 41 years of continuous rice. Changes in soil resistance that can be attributed to tillage were evident earlier than detected changes in soil aggregate stability. Trends of increased percent water stable aggregates and decreased soil resistance were noted and need to be further investigated.

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Table 1: Percent water stable aggregates collected in 0.25, 0.50, 1.00, 2.00, and 4.00 mm sieve sizes for conventional-and no-till continuous rice and rice-soybean rotations in March 2003 at the University of Arkansas Rice Research and Extension Center.

| Rotation | Tillage | Sieve diameter | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0.25mm | 0.50mm | 1.00mm | 2.00mm | 4.00mm | Total |
| Rice-soybean | Conventional | 5.18 | 1.68 | 1.06 | 0.68 | 0.67 | 9.27 |
| Rice-soybean | No-till | **7.10*** | **1.95** | **1.15** | **0.75** | 0.52 | **11.46** |
| Rice-rice | Conventional | 4.44 | 1.64 | 0.96 | 0.79 | 0.60 | 8.44 |
| Rice-rice | No-till | **6.19** | **2.26** | **1.16** | 0.65 | 0.58 | **10.84** |

- Bold designates an increase in percent water stable aggregates.

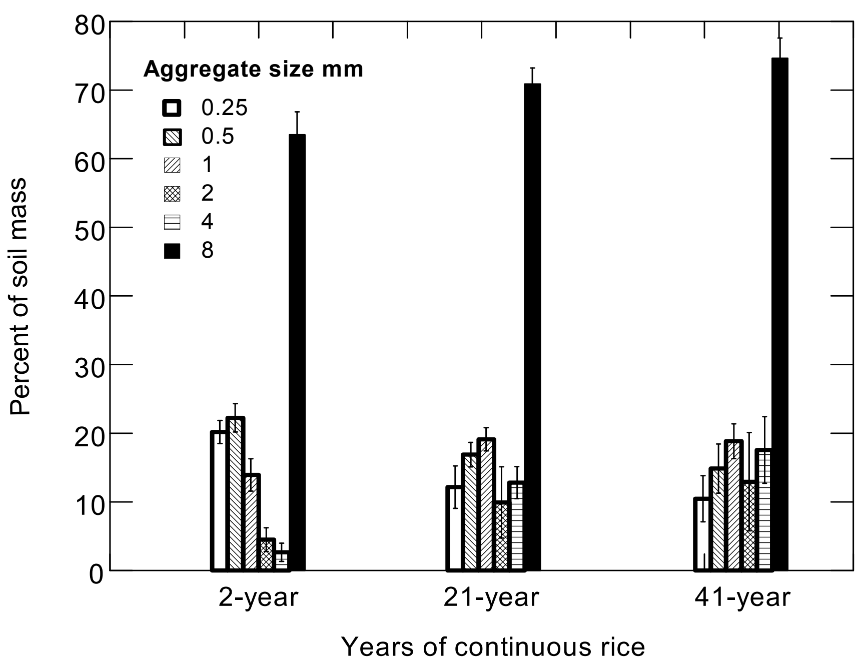



Figure 1: Percent of soil mass for five aggregate sizes from samples collected at the Chris Isbell farm on fields that were no-till continuous rice for 2, 21, and 41 years.

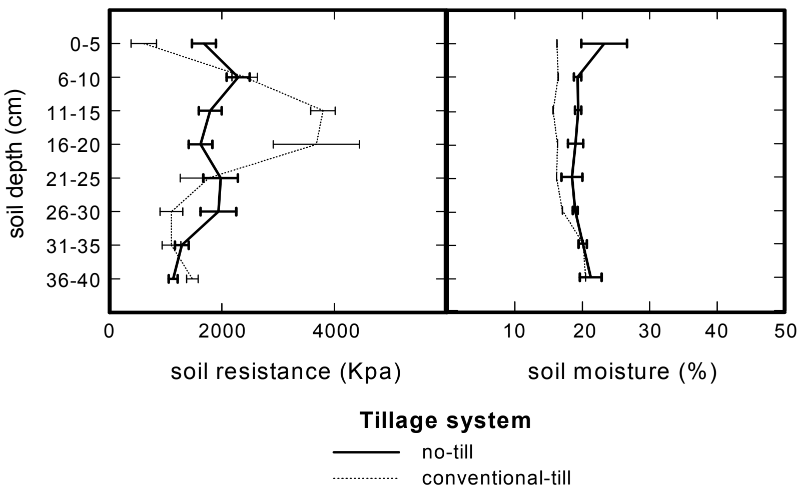
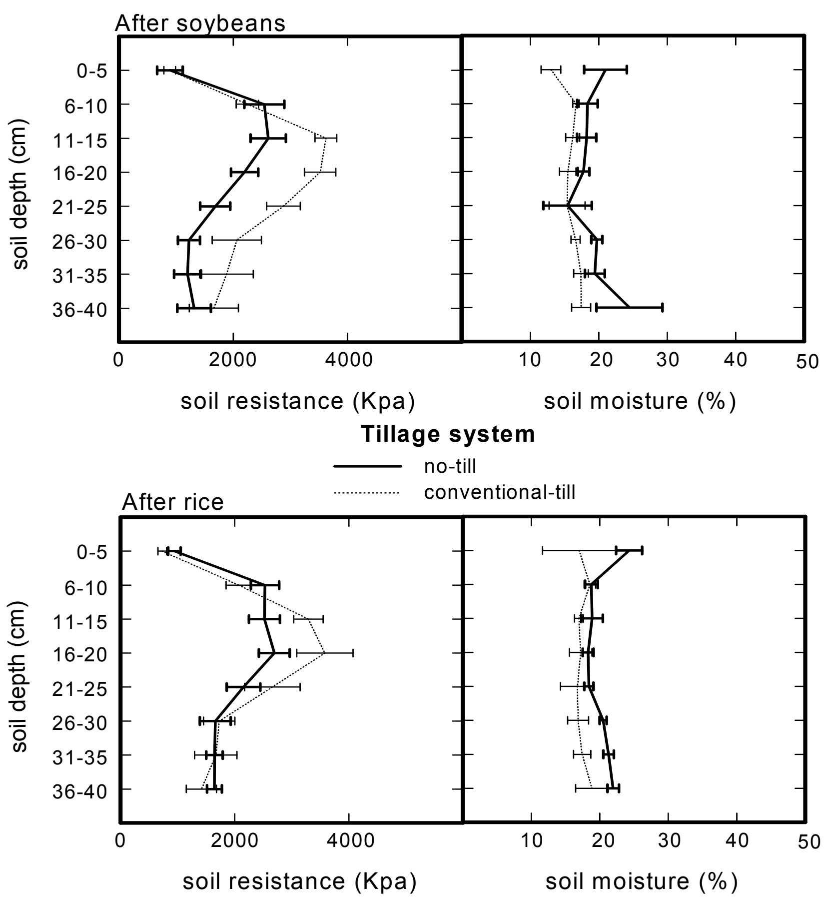
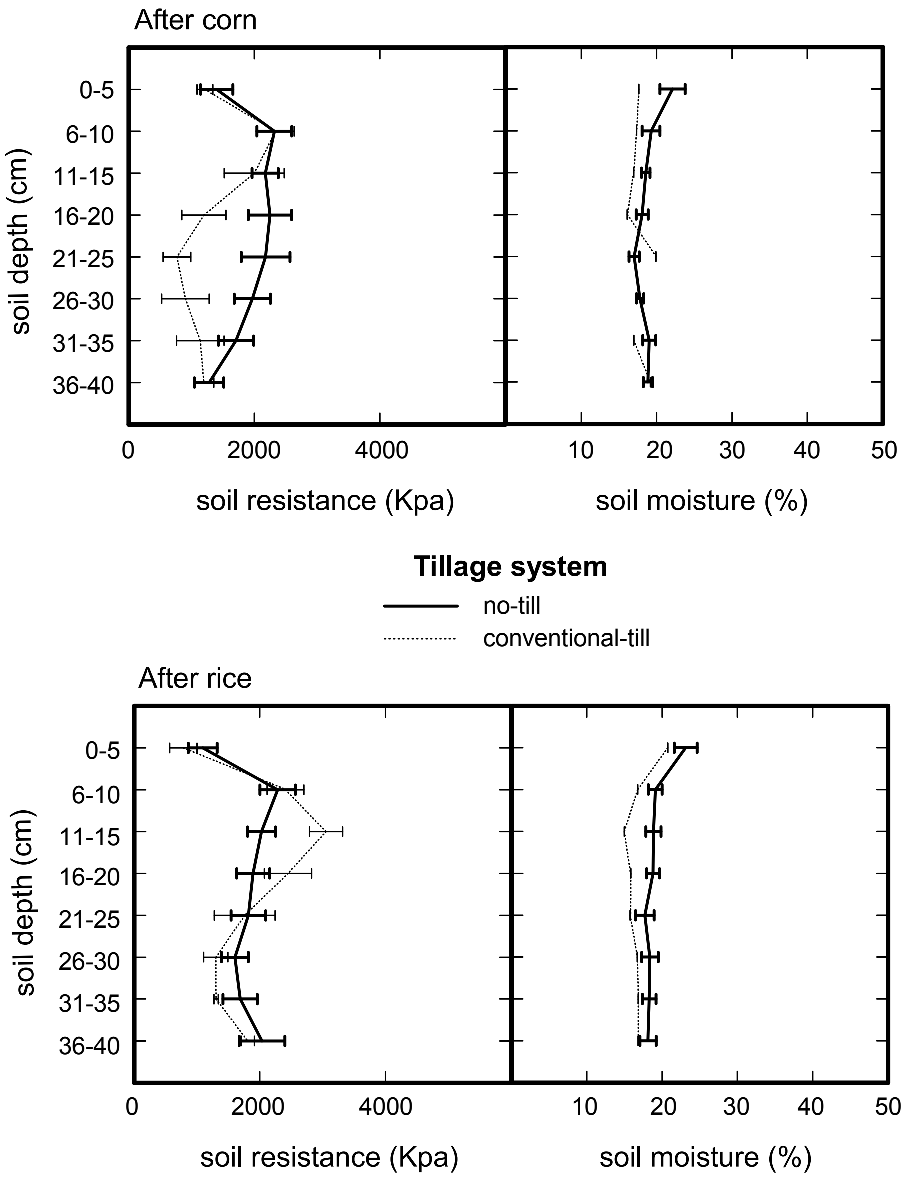



Figure 2: Soil resistance (Kpa) measured in no-till and conventional-till continuous rice plots at the University of Arkansas Rice Research and Extension Center in 2003.




Figures 3 & 4: Soil resistance (Kpa) and water content (%) measured in no-till and conventional-till plots in 2003 that were planted into a rice-soybean rotation at the University of Arkansas Rice Research and Extension Center.




Figures 5 & 6: Soil resistance (Kpa) and water content (%) measured in no-till and conventional-till plots in 2003 that were planted into a corn-soybean rotation at the University of Arkansas Rice Research and Extension Center.

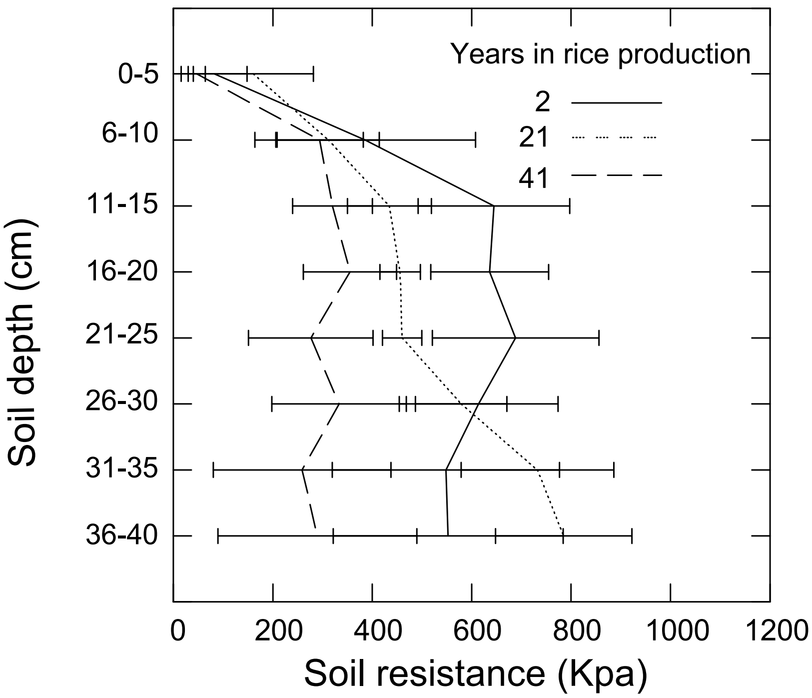



Figure 7: Soil resistance (Kpa) values for continuous rice fields that were no-till managed for 2, 21 and 41 years.