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# Short-Term Effects of Cover Crops and Tillage Management on Soil Physical Properties on Silt Loam Soil

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**Abstract:** Silt loam soils in the mid-southern United States are prone to soil erosion, crusting, and general soil degradation. A field experiment was established at three field sites in northeast Arkansas to evaluate the effect of cover crop and tillage management on cash crop yield and the physical properties of soil health, specifically infiltration rate and aggregate stability. Cover crop management included cereal rye, wheat and crimson clover, and a winter fallow. Tillage management included tillage and no-tillage. During the two-year study, yield was not significantly influenced by different tillage treatments. The cover crop treatment had greater yield than the no-cover crop treatment (5091 vs. 4264 kg ha$^{-1}$) at one site in one of the years. Water infiltration was significantly improved with cover crops compared to with no-cover crops, with a 52% and 64% increase at Walcott and Magnolia, respectively. Soil aggregate stability was significantly improved with no-tillage as compared with tillage in both years at Walcott, with a 16% and 58% increase in 2015 and 2016, respectively. Both cover crop and tillage management can have significant impacts on soil physical properties in a short period of time.

**Keywords:** cover crops; no-tillage; aggregate stability; infiltration

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## 1. Introduction

The Mississippi Delta region of Arkansas is a very intensive agricultural region of the United States, with over 2.5 million hectares of field crops grown in Arkansas (USDA-NASS, 2014). The majority of the field crop agriculture in Arkansas takes place in the Mississippi Alluvial Plain (Delta Region). Soils in this region are predominantly Alfisols and Vertisols developed from alluvial and loessal materials. The soils are highly productive and respond well to intensive agricultural management for the production of high yields of corn (*Zea mays* L.), soybean (*Glycine max* (L.) Merr.), winter wheat (*Triticum aestivum* L.), cotton (*Gossypium hirsutum* L.), and rice (*Oryza sativa* L.). However, the moist, humid climate of this region causes rapid decomposition of organic matter, and these soils are highly weathered [1]. Thus, these soils are prone to erosion and tend to be low in soil organic matter and the biophysicochemical attributes that are associated with higher soil organic matter levels, including soil structure, infiltration, and general soil health. The conventional, intensive agricultural management of the Mississippi Delta region does not allow for the accumulation of soil organic matter, does not provide cover for the soil to reduce erosion potential, nor does it provide for the habitat of the soil biosphere in order for year-round soil biological functioning [2].

Research shows there are many benefits of cover crops, such as: (i) reduced erosion, (ii) reduced water and nutrient runoff, (iii) improved soil structure, (iv) increased soil organic matter, and (v) improved microbial activity [3]. Much of the historical cover crop and tillage management research in the mid-south region has taken place in cotton production, where cover crops are used to protect cotton seedlings from blowing sand [4].

Cover crop use for the improvement of soil health is primarily a new idea in this region, though there are a few farmers who have been using cover crops for many years.

The use of no-tillage management has also been slow to become standard in the region. However, many studies show great benefits of no-tillage management. A 35-year tillage study in Ohio showed a consistent increase in aggregate stability with no-tillage throughout the course of the study [5]. In the first year of the study, the aggregate ratio (macroaggregates/microaggregates) was 0.98; in the 6th year, the ratio was 1.50; in the 20th year, the ratio was 2.08; and by the 35th year, the ratio rose to 2.60. No-tillage also helps the soil hold moisture better than conventional tillage methods [6]. In an 8-year study in Oklahoma, infiltration rates increased with no-tillage over conventional tillage, but it took several years for the difference to be observed [7]. Long-term studies on the impact of tillage in the mid-south region show important findings, but research is still needed on the short-term impact of no-tillage on soil physical properties.

Cover crops can add to the benefits that no-tillage imparts to soil physical properties as well as provide benefits on their own. In a two-year study with a cereal rye (*Secale cereal*) cover crop, bulk density was decreased by 3.5% compared to the no-cover crop treatments [8]. Cereal rye cover crop can also quickly and significantly change the aggregate stability of the soil, as shown in a study by Steele et al. [9]. In the >2 mm sample, aggregate stability was increased by 20% and 37% in the first two years compared to no-cover crop. In the 2 to 6 mm sample aggregate stability, in just the first year, increased 35% and by the end of the two years it had increased 41% [9]. Wright et al. [10] showed that no-tillage and plant roots could have a synergistic effect on aggregate stabilization.

Cover crops have been shown to increase infiltration rate after just one season. At three locations in Maryland, USA, after just the first season, the mean infiltration rate of the control treatment was 1.05 mm $s^{-1}$, while a cover crop of cereal rye had a mean infiltration rate of 2.87 mm $s^{-1}$ [9]. Another study showed after irrigation, the soil under cover crop had infiltrated 161 mm, and the soil without cover crop had only infiltrated 120 mm of the total irrigation [11]. This study also showed that different tillage management may not have as great of an impact on infiltration rate as cover crop management, as no-tillage only increased infiltration by 4% compared to standard tillage practices.

There is a lack of tillage and cover crop research in the mid-south region of the U.S. in corn-soybean rotations where production hectares of corn has quadrupled in the past 20 years (USDA-NASS, 2021). Though the benefits of cover crops and no-tillage are well known from research from across the U.S., the practical implementation of these practices is still lacking in the Mississippi Delta Region of Arkansas. Applied research in this area is needed in order to demonstrate the practicability of using these conservation methods to improve soil health in this region.

The objective of this study was to determine the impact of tillage and winter cover crop use on water infiltration rate, aggregate stability, and grain yield in a corn-soybean rotation. We hypothesized that both reducing tillage and utilizing cover crops would increase water infiltration rates and increase aggregate stability, while not impacting cash crop yields.

## 2. Materials and Methods

Three field locations in northeast Arkansas were used in this study. They were located at the Arkansas State University Research Farm Complex (A-State), Magnolia in Jonesboro, and Walcott in Greene County (Table 1). Research at the A-State and Walcott sites were established in the fall of 2014, followed by the Magnolia site in the spring of 2015. The A-State site had been in row crop production for over 10 years and was precision leveled in the fall of 2011. The Magnolia site had been in hay grass for over 20 years before the start of the experiment. The Walcott site had been in row crop production agriculture for 35 years under conventional disk-tillage management. All three locations were set up in split block arrangements. The plots were set out in 4 blocks representing 4 replications with 4 treatments in each block for a total of 16 plots at each site. The treatments included no-tillage with cover crops (NTCC), no-tillage with no-cover crop (NTNC), tillage with cover crops (TCC), and tillage with no-cover crop (TNC). However, at the Magnolia site, only the tillage vs. no-tillage treatments were in place in 2015; cover crop treatments were added at this location in the 2nd year of the study. The A-State plots were 9 m wide and 27 m long; the Walcott plots were 18 m wide and 68 m long; the Magnolia plots were 14 m wide and 122 m long, all based on the farmer's equipment size.

**Table 1.** Soil characteristics of the study sites.

| Study Site | Coordinates | Soil Type | Soil Taxonomic Great Group | Slope | Sand | Clay |
|---|---|---|---|---|---|---|
| | | | | % | -----g g$^{-1}$----- | |
| A-State | 35°50′21″ N 90°39′56″ W | Collins silt loam | Aquic Udifluvents | 0–1 | 0.03 | 0.14 |
| Walcott | 36°02′05″ N 90°41′50″ W | Calloway silt loam | Aquic Fraglossudalfs | 0–1 | 0.04 | 0.21 |
| Magnolia | 35°52′24″ N 90°41′34″ W | Loring silt loam | Oxyaquic Fragiudalfs | 3–8 | 0.15 | 0.10 |

Both the A-State and Walcott sites were furrow irrigated with lay-flat polytubing with furrows 150 cm apart, and the Magnolia site was planted flat with no irrigation (rainfed). All three sites were set up in a corn–soybean rotation and cash crops were planted on 76 cm rows. In the cover crop plots, prior to soybeans, cereal rye was planted and before corn, a mix of winter wheat and crimson clover (*Trifolium incarnatum* L.) was planted. Cereal rye was planted at a rate of 112 kg ha$^{-1}$, wheat was planted at a rate of 56 kg ha$^{-1}$, and the crimson clover was planted at 7 kg ha$^{-1}$ (in mix with winter wheat). Each fall, immediately after harvest of the cash crop, the cover crops were planted with a Great Plains 605 NT grain drill (Great Plains Manufacturing, Inc., Salina, KS, USA) on 19 cm row spacing. The cover crops grew through the winter with no fertilizer applied for the cover crop and were chemically-terminated with 3.5 L ha$^{-1}$ Roundup Powermax II (glyphosate; 2.3 kg ha$^{-1}$ active ingredient) just prior to cash crop planting in the spring. The tillage plots were disked and cultipacked just prior to cash crop planting at Magnolia, and were disked and bedded with a hipper roller at A-State and Walcott.

Soil samples were taken to a 10 cm depth prior to initiation of the project. A soil particle size analysis was determined by the pipette method [12] (Table 1) and a soil nutrient analysis was determined by a commercial soil testing laboratory (Waypoint Analytical, Memphis, TN, USA; Table 2). The main crop (corn or soybean) was fertilized according to University of Arkansas's extension recommendations, made each spring just prior to planting (135 kg ha$^{-1}$ of N, 101 kg ha$^{-1}$ of P, and 135 kg ha$^{-1}$ of K for corn and 50 kg ha$^{-1}$ of P and 67 kg ha$^{-1}$ of K for soybeans), and again for corn at the V6 growth stage with an additional 112 kg ha$^{-1}$ of N for a total of 257 kg ha$^{-1}$ of N. The corn and soybeans were planted on 76 cm row spacing. Corn was planted at a rate of 86,000 seeds ha$^{-1}$ and soybeans were planted at 300,000 seeds ha$^{-1}$.

**Table 2.** Soil nutrient characteristics at project initiation.

| Study Site | P | K | Soil pH | CEC |
|---|---|---|---|---|
| | ----mg kg$^{-1}$---- | | | cmol$_c$ kg$^{-1}$ |
| A-State | 38 | 80 | 6.9 | 7.4 |
| Magnolia | 53 | 77 | 5.0 | 9.3 |
| Walcott | 35 | 78 | 7.0 | 7.4 |

Each fall just prior to or just after harvest, soil samples were taken at the 0 to 5 cm depth for the aggregate stability analysis. The soil samples were taken at 3 random locations in each plot and were mixed together to make one composite sample per plot. The samples were then air-dried, and large clods were gently broken apart to pass a 2.0 mm sieve. Once air-dried, the samples were sieved to obtain the 1.0 to 2.0 mm aggregate size fraction from which aggregate stability was determined. The aggregate stability of the 1 to 2 mm size fraction was determined by wet sieving for three minutes using sieve sizes 1.0 and 0.2 mm, according to an adaptation [13] of the Kemper and Roseneau [14] method, where only the 1 to 2 mm aggregate size class was used in the wet sieving procedure. During the wet sieving procedure, aggregates were introduced into the water in an air-dry state and aggregates remained submerged in water during the sieving procedure. The aggregate stability was calculated as the mean weight diameter (MWD) of the soil sample and was determined according to Van Bavel [15]. The mean weight diameter was calculated for each sample by Equation (1):

$$MWD = \sum_{i-1}^{n} x_i w_i \quad (1)$$

where $x_i$ is the mean diameter of the particle size range of aggregates separated by the wet sieving, and $w_i$ is the mass of the aggregates in that size range, expressed as a fraction of the total dry mass of soil and corrected for sand grains larger than the sieve size. To correct for sand grains, after wet sieving, drying, and weighing the sample, aggregates remaining on the sieve were dispersed in deionized water and gently pushed through the sieve, with only sand grains larger than the sieve openings remaining. The sand remaining on the sieve was then dried in an oven at 105 °C for 2 h and re-weighed.

The infiltration rate was measured with a double-ring infiltrometer (model IN7-W, Turf-Tec International, Tallahassee, FL USA) [16], with the inner ring having a 15 cm diameter and the outer ring having a 30 cm diameter. The double-ring infiltrometer was placed in the soil at two random locations within each plot and the metal rings were driven into the soil to a depth of 5 cm. The mean of the two iterations represented the plot infiltration rate value. Rings were filled with water and allowed to drain for 15 min to moisten the soil. Rings were then re-filled and the water level in the middle ring was measured after 15 min to determine the rate of fall of the water; the infiltration rate was calculated over the full 15 min time period.

The yield was determined by harvesting the middle rows (6 m for corn and 9 m for soybeans) of each plot with a commercial combine; then transferred to a weigh wagon to obtain the harvested mass; yield values were adjusted to the standard 15.5% moisture for corn and 13.0% moisture for soybeans.

The treatment main effects and interactions were analyzed using PROC ANOVA in SAS 9.4 (SAS Institute, Inc., Cary, NC USA) at $P < 0.10$. When appropriate, means were separated using Fisher's Least Significant Difference (LSD) test at the 0.10 level.

## 3. Results and Discussion

There were no significant cash crop yield differences ($p > 0.10$) among any of the treatments at any of the sites in the first year of the study, where mean corn yield was 12,810 kg ha$^{-1}$ at A-State, and mean soybean yields were 2897 kg ha$^{-1}$ at Walcott and 4650 kg ha$^{-1}$ at Magnolia (Table 3). The mean soybean yield in the various treatments for the A-State site in the second year ranged from 4196 to 5104 kg ha$^{-1}$. There was no significant interaction between cover crop and tillage, but the main effect of cover crop significantly impacted soybean yield ($p < 0.10$) where the cover crop treatments (5091 kg ha$^{-1}$) had significantly greater yield than the no-cover crop treatments (4264 kg ha$^{-1}$). In the second year, there were no significant yield differences at the Walcott site, where maize yields ranged from 10,746 kg ha$^{-1}$ to 11,374 kg ha$^{-1}$, nor at the Magnolia site, where soybean yields ranged from 5643 kg ha$^{-1}$ to 6622 kg ha$^{-1}$ (Table 3).

**Table 3.** Effect of soil management, Tillage (T) and Cover Crop (CC), on corn and soybean yield at A-State, Walcott, and Magnolia in 2015 and 2016.

| Soil Management | A-State (Corn) | Walcott (Soybeans) | Magnolia (Soybean) | A-State (Soybeans) | Walcott (Corn) | Magnolia (Corn) |
|---|---|---|---|---|---|---|
| | --------------2015------------- | | | --------------2016------------- | | |
| | | | ------------kg ha$^{-1}$------------ | | | |
| NT CC | 12,667.0 a † | 3160.8 a | - ‡ | 5104.3 a | 11,129.1 a | 5643.0 a |
| NT NC | 12,780.0 a | 2918.7 a | - | 4337.6 b | 11,373.9 a | 5900.4 a |
| T CC | 12,598.0 a | 2750.5 a | - | 5077.4 a | 11,311.2 a | 6603.4 a |
| T NC | 13,194.3 a | 2757.3 a | - | 4196.4 b | 10,746.2 a | 6622.2 a |
| T | | | 4727.8 a | | | |
| NT | | | 4573.0 a | | | |

NT = no-tillage, T = tillage, CC = cover crop, and NC = no cover crop. † Different lower-case letters within a column represent significant differences at $p < 0.10$ using Fisher's LSD. ‡ Only the tillage treatment factor was in place at Magnolia in 2015.

In both years of cover crop and tillage management, there were no significant interactions with yield for corn or soybeans. Other research data vary regarding the influence of tillage on yield over various time periods from two to twenty years. Wang [17] showed an increase in yield of up to 12% when conventional tillage was implemented compared to no-tillage. Nkongolo and Haruna [18] showed in silt loam soil, that yield was increased when no-tillage was used compared to conventional tillage. Indeed, Pedersen and Lauer [19] and Temperly and Borges [20] observed that soybean under no-tillage yielded more than soybean under conventional tillage. They also observed that corn yielded greater or similar under conventional tillage than no-tillage. Cordell et al. [21], NeSmith et al. [22], and Parsch et al. [23] showed no difference in soybean yield due to tillage in southeastern U.S. soils. A summary of research studies in Arkansas [24] showed more positive yield advantages for no-tillage in soybeans in Arkansas but not for corn. On a regional basis (Southern U.S.), however, DeFelice et al. [24] found a yield advantage to no-tillage management over conventional tillage (12% yield advantage in corn and 5% yield advantage in soybean). Clearly, there are many variables that can influence yield with regard to tillage, including weather, planting dates, soil type, soil organic matter, etc., with soil drainage being a major factor that was identified [24]. The fact that no differences were observed in the current study for yield in either soybean or corn due to differences in tillage is consistent with many of the aforementioned studies. Furthermore, the lack of yield differences in the majority of the site years of this study indicates that we may not need to be overly concerned about yield drag when moving into conservation management practices.

Both aggregate stability and water infiltration rate were affected by either tillage or cover crop in some site years during this study. No-tillage resulted in greater aggregate stability than disk tillage management, while the water infiltration rate was greater with cover crop than without.

After just one season of the cover crop and tillage management treatments, the Walcott site showed greater ($p < 0.10$) aggregate stability in no-tillage management (0.362 mm) compared to disk tillage management (0.311 mm MWD; Table 4). In the second year, the Walcott site maintained its significant aggregate stability difference and was even greater than in the first year with no-tillage (0.707 mm MWD) greater than disk tillage management (0.446 mm MWD). There were no other significant interactions or main effects on aggregate stability due to tillage or cover crop management in the two years of the study. A short-term study by Acuña and Villamil [25] showed no impact of cover crops on aggregate stability in a soybean production system in Illinois, similar to our study where cover crop did not affect aggregate stability. After two years of cover crops and tillage management, there was no trend in any cover crop treatment being better than the other for aggregate stability across any of the sites. These results do not compare with what Steele et al. [9] had shown with cover crops showing a 20% increase in aggregate stability with cover crops compared to no cover crop management. However, these observations were taken in the 12th and 13th year of cover crop management. Hermawan and Bomke [26] conducted cover crop research in British Columbia, Canada, with the winter cover crops barley (*Hordeum vulgare* L.), cereal rye, ryegrass (*Lolium perenne* L.), and a control. In their research, they observed that treatments with cereal rye and ryegrass had significantly higher soil aggregate stability than the control and barley in the spring. However, in the fall, there were no significant differences in soil aggregate stability among any of the cover crops. It could be that the cover crops on our sites did not have sufficient time to have an impact on the stability of the aggregates.

**Table 4.** Effect of cover crop and tillage management on the aggregate stability mean weight diameter (MWD) and water infiltration rate (IR). The interaction of tillage and cover crop were not significant and, therefore, only main effects are presented. Values are the mean of three replicates.

| Main Factor | MWD (2015) | MWD (2016) | IR (2016) |
|---|---|---|---|
| | --------------------mm-------------------- | | cm $h^{-1}$ |
| | A-State | | |
| Cover Crop | 0.44 a [†] | 0.47 a | 2.90 a |
| No-cover crop | 0.42 a | 0.48 a | 1.95 a |
| No-tillage | 0.43 a | 0.49 a | 1.99 a |
| Tillage | 0.43 a | 0.46 a | 2.86 a |
| | Walcott | | |
| Cover Crop | 0.34 a | 0.63 a | 6.51 a |
| No-cover crop | 0.33 a | 0.52 a | 4.29 b |
| No-tillage | 0.36 a | 0.71 a | 5.08 a |
| Tillage | 0.31 b | 0.45 b | 5.72 a |
| | Magnolia | | |
| Cover Crop | - | 0.77 a | 7.38 a |
| No-cover crop | - | 0.82 a | 4.49 b |
| No-tillage | 0.71 a | 0.79 a | 6.47 a |
| Tillage | 0.65 a | 0.81 a | 5.40 a |

[†] Within a site, year, and factor, means followed by the same lower-case letter on not significantly different at $p = 0.10$.

Islam [5] showed similar results in a 35-year study in Carrol, Ohio. After just one year, no-tillage was significantly greater than the tillage treatment for aggregate stability. No-tillage also increased the stability of the aggregates every year after for the length of the study. A 3-year research study conducted on a Maryland Mattapex silt loam soil (fine-silty, mixed, active, mesic Aquic Hapludults) showed aggregate stability increasing every year with no-tillage and being greater than plow-tillage every year. In the final year of the 3-year study, the no-tillage treatment aggregate stability was more than 20% greater than the tillage treatment aggregate stability [10]. Their research helps confirm what we observed: aggregate stability can be improved with no-tillage compared with tillage.

The fact that reducing tillage affected aggregate stability was not surprising, though we did not expect to observe this after just one no-tillage season. The silt loam soils, on which the Walcott study site is located, are prone to aggregate breakdown. The act of tillage artificially breaks down soil aggregates and reducing the tillage breakdown of soil can improve aggregation.

The water infiltration rate was only measured in the second year of the study. Two of the three sites showed an increased infiltration rate due to cover crop management (Table 4). At the Magnolia site, the mean infiltration rate of cover crop treatment was 7.4 cm $h^{-1}$, while the no-cover crop treatment mean was 4.5 cm $h^{-1}$. The results were similar at Walcott with a cover crop treatment mean of 6.5 cm $h^{-1}$ and a no-cover crop treatment mean of

4.3 cm $h^{-1}$. The effect of cover crops on infiltration rates at Walcott (51%) and Magnolia (64% increase) shows that cover crops can quickly increase infiltration rates with just a few years of cover crop management.

These findings are similar to what other researchers have reported [9,27]. Steele et al. [9], at three locations in the eastern US, showed anywhere from 1.4 to 2.6 mm $s^{-1}$ increase in infiltration after the first season of cereal rye cover crop compared to the winter fallow. Water infiltration rate has the potential for improvement in just one season of cover crop management.

Other researchers have shown that planting a winter cover crop can increase the infiltration rate by as much as 48%, while no-tillage only increased the infiltration rate by 4% compared to conventional tillage [11]. Dao [7] showed, in an 8-year study in Oklahoma, an increase in infiltration rate with no-tillage compared to conventional tillage, but did not show an increase in the first few years. At all of the sites used in this research, there was no clear trend for any of the tillage practices being greater than the other to affect infiltration rate in the short term. The cover crop was the factor that improved infiltration.

The utilization of winter cover crops and no-tillage have some economic impact. Though not part of this study, it is important to note that there is a cost to planting cover crops. However, this cost can potentially be offset by reduced inputs. This study shows the potential for increased infiltration, which potentially provides an opportunity for reduced irrigation inputs. Other potential input reductions could be realized over longer periods of time. Furthermore, a reduction in tillage can reduce fuel usage, thereby realizing another input savings. From an economic standpoint, consideration must be given to both to added and reduced input costs as well as revenue.

## 4. Conclusions

This research compared crop yield and soil physical properties as influenced by different cover crops and tillage management. Yield differences were observed within the first two years at one of the sites by having a cover crop planted, while tillage did not have a significant influence on yield.

Certain physical properties can be positively influenced by the addition of cover crops and reducing tillage in a short amount of time. Specifically, cover crops were shown to increase infiltration rate, while reducing tillage was shown to improve aggregate stability. Landowners and producers can effect positive change in their soil in a short amount of time by understanding their specific resource concerns and utilizing specific soil management practices. The soil physical property improvements should facilitate both on-site and off-site benefits, including reduced erosion and runoff, and enhanced soil–plant-water interactions.

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