TOTAL CARBON, BULK DENSITY AND SOIL STRENGTH AFFECTED BY CONSERVATION SYSTEMS

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Abstract

Soil compaction often limits crop yields in the Southeastern U.S., particularly during periods of drought which have been prevalent the last two growing seasons. However, conservation technologies including cover crops and in-row subsoiling reduce the negative effects of soil compaction. The relative benefit of these technologies on large fields where terrain varies has not been studied. A 22.5-acre field with varied soil landscapes in the Coastal Plain was used to evaluate how soil strength changes after conservation technologies were used. This field was severely degraded from annual conventional tillage for more than 30 years, but has shown great improvements in soil quality and productivity on every landscape position after conservation technologies were used. Soil bulk density, soil moisture, and cone index measurements were taken in different landscape positions and in conventional and conservation tillage systems to evaluate how these treatments had changed soil strength. Results showed that the most important factor in predicting soil compaction was still row position, with the highest soil strength found underneath the trafficked row middle. Landscape position also greatly affected measurements of soil compaction. Treatment effects were not as large as the two previous factors, complicating the finding of easy solutions to soil compaction problems.

Introduction

Soil compaction limits crop yields throughout much of the Coastal Plains region of the Southern United States. Root-impeding layers near the soil surface cause shallow rooting, which can lead to little drought resistance. This is especially problematic because Coastal Plain soils are inherently sandy with small amounts of organic matter and little water-holding capacity. Roots must extend deeper in our sandy soils to sustain row crops through the frequent short-term droughts we often experience.

The causes of soil compaction that have been identified are vehicle traffic, cropping systems, and natural variability (Raper, 2005). However, severe erosion caused by conventional cropping systems, intense rainfalls, and rolling terrain have also caused much soil movement throughout the region. It is hypothesized that landscape position may also be a factor in soil compaction with little topsoil being found on higher elevations of a field. Therefore, an experiment on a Coastal Plain soil was conducted to determine the impacts of landscape zone on soil compaction.

Methods and Materials

In the fall of 2000, a field-scale experiment was initiated at the E.V. Smith Research Station in Shorter, AL (85°:53’50” W, 32°:25’22” N). The site consists of a 22.5-acre field that has a long history of row cropping, mostly cotton under conventional tillage. Soils are mostly fine and fine-loamy, kaolinitic, thermic Typic and Aquic Paleudults. A corn-cotton rotation was established at the site. Corn was planted in 30 in rows while cotton was planted in 36 in rows.

Four treatments were imposed on the site: (1) conventional tillage (CT), (2) conventional tillage + manure (CT+M), (3) conservation system (CS), and (4) conservation system + manure (CS+M). Conventional tillage consisted of fall tillage (chisel plowing/disking) and spring tillage (field cultivation and in-row subsoiling). The conventional tillage plots were left fallow. The conservation system used no surface tillage but did include an in-row subsoiling treatment to alleviate soil compaction problems prevalent in the region. The conservation system included a cover crop system which was crimson clover (*Trifolium incarnatum* L.) prior to corn and rye (*Secale cereale* L.) prior to cotton.

All in-row subsoiling operations were conducted prior to planting with a KMC (Kelly Manufacturing Company, Tifton, GA) ripper bedder to an approximate depth of 16 in. Subsoiling and planting operations were conducted with a Trimble AgGPS Autopilot® automatic steering system (Trimble, Sunnvale, CA) which was capable of inch-level precision.

Dairy bedding manure was applied in the CT+M and CS+M treatments during fall of each year prior to establishment of the cover crops.

Treatments were established in 20-ft wide and ~ 800-ft long strips crossing the landscape in a randomized block design (RCB) with six replications. An 8-ft alley separated strips. Each strip was divided into cells of 20 ft x 60 ft which resulted in 496 cells for the entire field with half of these cells being in corn and the other half being in cotton for a particular year.

Three landscape zones were computed using Fuzzy k-means unsupervised classification methods from four input layers (16.4 ft resolution). These four inputs were: (1) seasonal high water table estimated from an Order 1 (1:5000) soil survey, (2) elevation, (3) complex topographic index (CTI), and (4) percent maximum downhill slope. The three landscape zones which were identified were summit, sideslope, and drainageway. Landscape zones differed in several aspects. The summit is at a relatively higher elevation, has a moderate slope (typically < 2%), and low CTI. The summit possesses well drained soils with sandy loam textured surface horizons ~12 in thick, that overly relatively clayier (heavy sandy clay loam) argillic horizons. The sideslope has relatively steeper slopes (4 to 6%), and intermediate elevation and CTI. Sideslope soils are moderately well to well drained, and have relatively clayier (sandy clay loam) and thinner surface horizons (~8 in) due to historical erosion. The drainageway resides at the lowest elevation, has intermediate slopes (2-4%), and the highest CTI values. Soils within the drainageway generally have mantles of varying thickness of more recently deposited materials (from upslope eroded materials) overlying buried soils. These soils are somewhat poorly to moderately well drained, are more variable, but generally have sandy loam to loam textured surface horizons of varying thickness.

A selection procedure was used to reduce the number of cells that could be intensively sampled and give an overall assessment of the 4 treatments and 3 management zones. Thirty six (36) study cells were identified to have the appropriate classifications and were used for intensive sampling following corn harvest in 2006.

Soil strength measurements were obtained with the multiple-probe soil cone penetrometer system (Raper et al., 1999). This machine acquired three sets of soil strength measurements across the row from which cone index values were calculated (ASAE Standards, 2004a; ASAE Standards, 2004b). This tractor-mounted machine was also used to acquire three cores in each of three row positions (in-row, trafficked row middle, non-trafficked row middle) from each plot. The cores were subdivided into 2 in increments for assessment of bulk density and soil moisture.

Statistical analyses were performed for each depth using the four different treatments and the three landscape positions with the appropriate ANOVA model using SAS. A predetermined significance level of $P \leq 0.10$ was selected and Fisher's least-significant-difference test (LSD) was used for means separation.

Results and Discussion

Due to space limitations, discussion will be limited to significant main effects of the cone index measurements.

Previous publications from this long-term research effort have identified that the use of conservation systems (CS) has resulted in increased crop yields for both corn and cotton. No significant improvements in yield resulted from the use of manure treatments. During dry years of the study, the drainageway was found to have the greatest yields while no significant differences in landscape position were found during wet years.

Analysis of cone index measurements showed that one of the most significant factors was row position (fig. 1). Greatest values of cone index (which were greater than 2 MPa and were root-limiting (Taylor and Gardner, 1963)) were found in the trafficked row middle and mid-way between the trafficked row middle and the row. These excessive values of cone index were found beginning at the soil surface and extending all the way down through the profile.

Secondary to row position was landscape zone (fig. 2). On the summit and sideslopes, we found excessive values of cone index only near the surface and extending down no more than 8 in. Shallow in-row subsoiling should be capable of removing this compacted layer in these two landscape zones. However, in the drainageway zone, excessive values of cone index were found down to approximately 14 in. Much larger expenditures of energy would be required to ameliorate this compacted layer.

Lastly, treatment effects were also noted (fig. 3), although they tended to not be as significant as row position or as landscape zone. Conservation systems treatments had reduced cone index values as compared to conventional tillage systems. Also, some benefits of manure were also found for both conventional and conservation systems, although these differences were restricted to within 6 in of the soil surface.

Conclusions

1. The greatest differences in cone index strength occurred across the row with the most compacted layers being found near the trafficked row middle.
2. The drainageway landscape zone had excessive values of cone index as compared to the summit and sideslope landscape zones. It is hypothesized that this results as a function of sand deposition from higher elevations.
3. Conservation systems had reduced soil strength compared to conventional systems.
4. Manure had positive effects on soil strength, but only near the soil surface.

Disclaimer

The use of trade names or company names does not imply endorsement by USDA-ARS.

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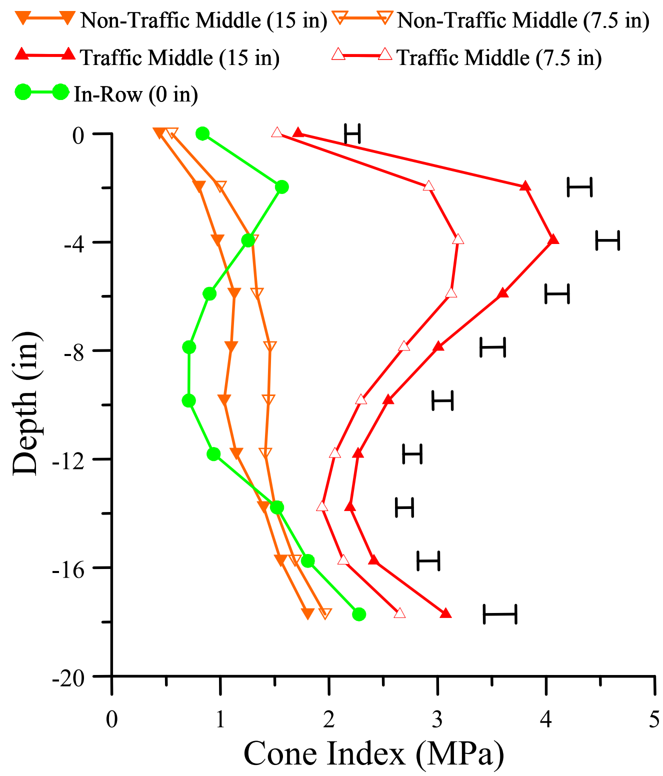

Figure 1. Cone index (MPa) values for different row positions. Bars indicate statistical significance ($LSD_{0.10}$).

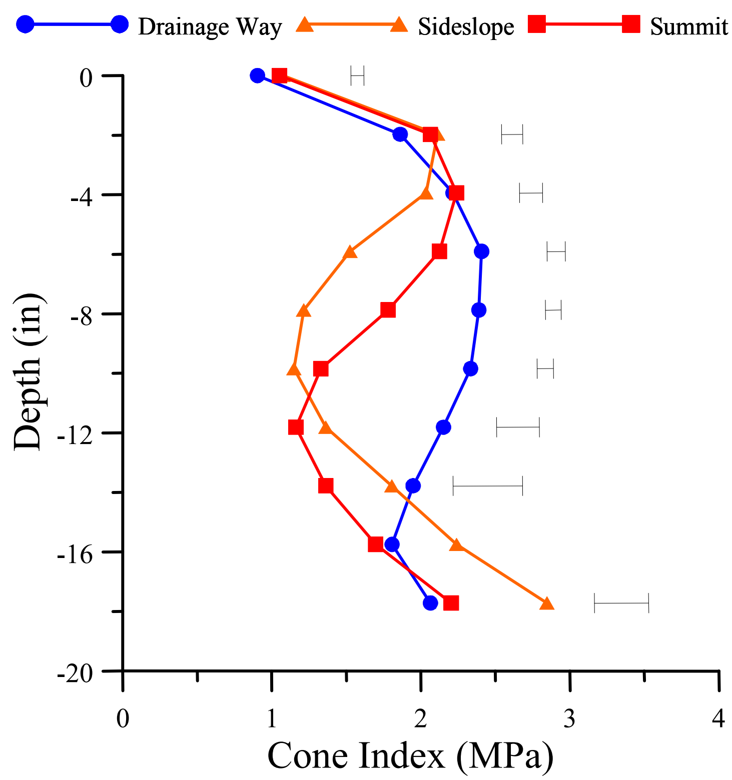

Figure 2. Cone index (MPa) values for different landscape zones. Bars indicate statistical significance ($LSD_{0.10}$).

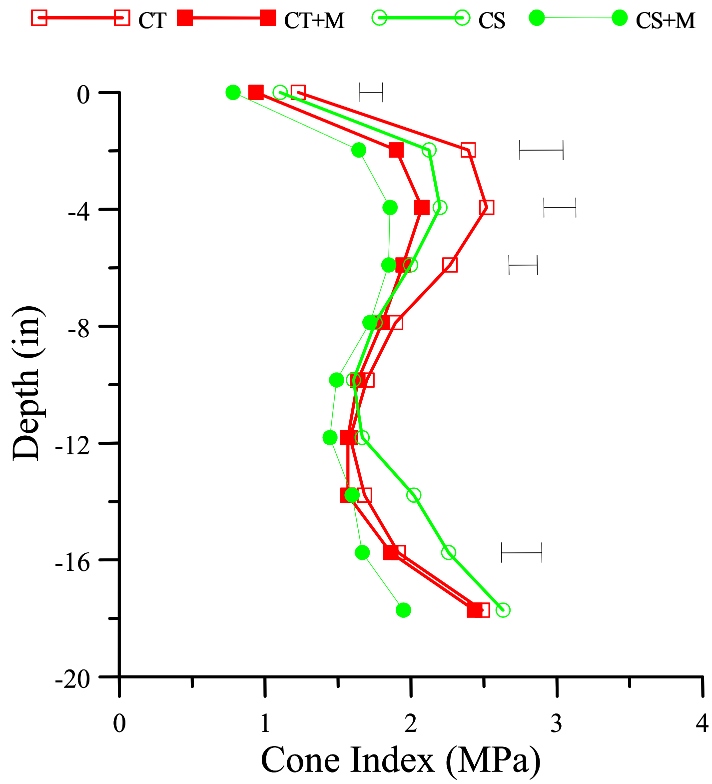

Figure 3. Cone index (MPa) values for different tillage and manure treatments. Bars indicate statistical significance ($LSD_{0.10}$).