# Effect of Traffic and Tillage on Mechanical Impedance in a Layered Soil

**D. E. Radcliffe, G. Manor, G. W. Langdale, R. L. Clark, and R. R. Bruce[1]**

## Introduction

In several studies of the physical properties of southeastern soils under no-tillage systems, a compacted layer at a depth of about 6 to 10 inches below the surface has been identified (NeSmith et al., 1987, Radcliffe et al. 1988; Tollner et al., 1984). Fall tillage with a disk harrow can create a tillage pan (NeSmith et al., 1988), but the role that uninterrupted wheel traffic may play in creating these pans has not been shown. In-row chiseling with a coulter planter may be sufficient to disrupt these pans, but there is little information on the efficacy of this system (Radcliffe et al., 1985). The purpose of this study was to determine the effect of controlled wheel traffic and shallow in-row chiseling on mechanical impedance in a no-tillage cropping system.

## Materials and Methods

An experiment had been established in the fall of 1979 at the Southern Piedmont Conservation Research Center, Watkinsville, GA to test the effect of crop rotation in a double crop system under various tillage treatments. There were 10 cropping sequences consisting of various combinations of soybeans *(Glycine mwc* L. Merr., "Ransom") and grain sorghum *(Sorghum bicolor* L. Moench, DeKalb BR-64) following winter wheat *(Triticum aestivum* L. Thell, Coker 747). Only the continuous soybean and continuous grain sorghum sequences were examined in this study. Information on the other rotations is given elsewhere (Langdale and Wilson, 1987).

The tillage treatments were imposed in the spring of each year and consisted of coulter planting, coulter planting with in-row chisel to a depth of 9 inches, and conventional tillage with an offset disk harrow to a depth of 4 to 5 inches followed by coulter planting. These tillage treatments will be referred to as no-tillage (NT), minimum tillage (MT), and conventional tillage (CT), respectively. In the fall, before planting wheat, all plots were tilled with an offset disk harrow to a depth of 4 to 5 inches.

A randomized complete block split plot design was used with tillage treatments as main plots and crop sequences as subplots. Each plot consisted of four rows at 30-inch spacing with wheel traffic confined to the areas between the first and second rows and between the third and fourth rows (Figure 1). Small-plot combine traffic was not controlled. A 135-hp tractor was used for disking all plots in the fall and the CT plots in the spring. The same tractor was used to plant the MT treatment in the spring when the in-row chiseling was accomplished. A 75-hp tractor was used for all fall and CT and NT spring planting.

Cone index was measured in November 1987 at the end of the eighth year of the experiment. A hydraulically driven penetrometer, mounted on a transverse boom behind a tractor, was used to measure cone index (Clark et al., 1986). Three transects perpendicular to the rows were taken in each plot. Nine positions were measured along each transect starting in the wheeltrack between the first and second row and ending in the wheeltract between the third and fourth row (Figure 1). Positions 6 through 9 were mirror images of positions 1 through 4 in terms of location relative to wheel traffic.

After analysis revealed that these positions were statistically similar, they were combined into five positions relative to wheel traffic: (1) in the wheeltrack center, (2) 6 inches from the row toward the wheeltrack center, (3) in the row, (4) 6 inches from the row toward the nontraffic center, and (5) in the nontraffic center. Cone index was measured in one-inch increments to a depth of 24 inches. A rigid aluminum bar was laid along the transects and used to trip the switch that normally indicates the actual soil surface. As such, depths of all penetrometer measurements were relative to the same horizontal plane and not the actual soil surface, which was several inches lower in the wheeltrack positions.

Water content was measured gravimetrically on samples taken at the time cone index was measured. Samples were

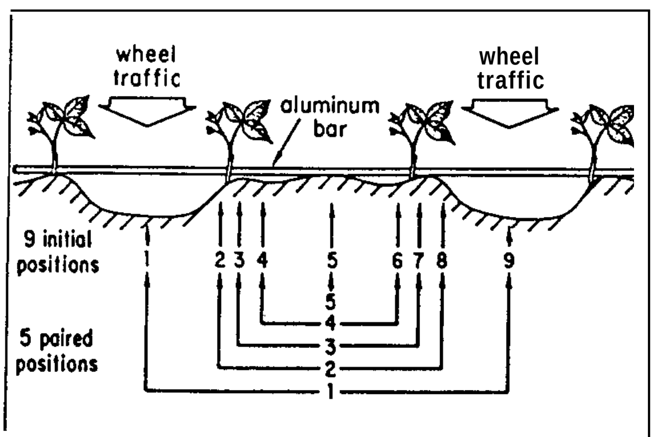


**Figure 1. Sampling scheme for penetrometer measurements.**

[1]Assistant Professor, Department of Agronomy, University of Georgia; Visiting Professor, Department of Agricultural Engineering, University of Georgia on leave from Agricultural Engineering Department, Technion, IIT, Haifa, Israel; Soil Scientist, USDA-ARS, Watkinsville, GA; Professor, Department of Agricultural Engineering, University of Georgia; and Soil Scientist, USDA-ARS, Watkinsville, GA.

Table 1. Profile characteristicsof Cecil soil from plot 3. (Bruce et al. 1983).

| Horizon | Depth (in) | Clay (%) | Silt (%) | Sand (%) | Bulk density ($g/cm^3$) |
|---|---|---|---|---|---|
| Ap | 0-8 | 6 | 20 | 74 | 1.43 |
| BA | 8-12 | 23 | 23 | 54 | 1.68 |
| Bt1 | 12-33 | 49 | 19 | 32 | I.46 |
| Bt2 | 3349 | 43 | 25 | 32 | 1.62 |

taken in the wheeltrack, row, and non-traffic positions in 3-inch increments to a depth of 18 inches.

The soil in this experiment was Cecil sandy loam (clayey, kaolinitic, thermic, Typic Hapludult). Profile characteristics from a nearby site are given in Table 1 (Bruce et al., 1983). The soil typically has a sandy topsoil and clayey subsoil with a transition zone of high bulk density.

## Results

Water contents at the time cone index was measured were similar between treatments and positions. Because more than 2 inches of rainfall occurred in the week prior to the measurements, it can be assumed that the top 12 inches of profile were near field capacity.

The first step in the analysis of the penetrometer measurements was to determine if the nine samples along each transect could be combined into five positions relative to wheel traffic. We found that the pairs of samples (1 and 9, 2 and 8, 3 and 7, 4 and 6) were not significantly different except in the minimum tillage treatment with grain sorghum. The summer crop in 1987, had to be replanted because the wrong seed was placed in the hoppers the first time. To do this, planting was offset approximately 4 inches from the previously planted rows. When we made our penetrometer measurements in the fall of 1987, we used the replanted rows as our reference, thereby displacing each sample relative to wheel traffic that occurred in all but the last summer. In view of these facts, the MT grain sorghum treatment was eliminated from further analysis. The detection of a 4-inch offset in tillage with our penetrometer analysis reflects the precision of the measurement.

When the penetrometer measurements were combined into five positions, overall analysis indicated there was a tillage by position by depth interaction. To compare positions at a given depth, an LSD (0.05) was computed for each depth and tillage treatment. For clarification purposes, only three of the five positions are shown in the figures that follow. These are in the wheeltrack center (position I), in the row (position 3) and in the nontraffic center (position 5).

Cone indexes fc: the three positions in CT soybeans are shown in Figure 2. All positions indicated that there was a layer of high strength 6-12 inches below the surface. The effect of wheel traffic on soil compaction can be seen by comparing the wheeltrack position (one) with position five, which was free of traffic (other than that of the small-plot combine) and planter disturbance. Wheel traffic caused compaction to a depth of 12inches (significant at the .05 level). Traffic not only increased maximal cone index, but also caused it to occur at a shallower depth. There appeared to be little lateral compaction from wheel traffic in the row in that positions 3 and 5 were not significantly different. There was an effect of traffic 6 inches away from the row on the side where traffic occurred, in that cone index in position 2 was higher than that in position 4 (data not shown). The results for CT grain sorghum (not shown) were similar hut the effect of wheel traffic was not quite as deep (10 inches).

Traffic rffects in NT were identical for the two crops so only the grain sorghum data are shown (Figure 3). Cone index in position 1 was significantly higher than that in position 5 to a depth of 8 inches. Positions 3 and 5 were similar, indicating little lateral effect of wheel traffic in the row.

The effect of in-row subsoiling was apparent in MT soy-

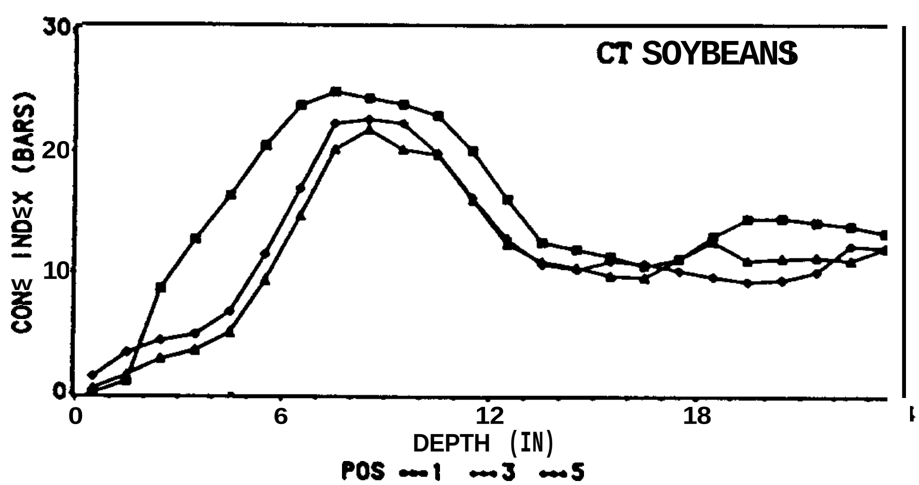


Figure 2. Cone index with depth in conventionally tilled soybeans in positions one (squares), three (diamonds), and five (triangles).

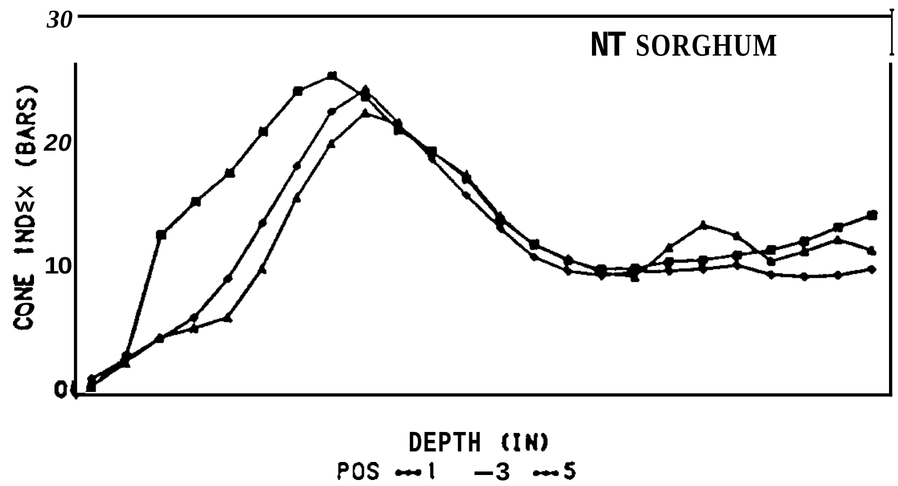


Figure 3. Cone index with depth in no-till grain sorghum in positions one (squares), three (diamonds), and five (triangles).

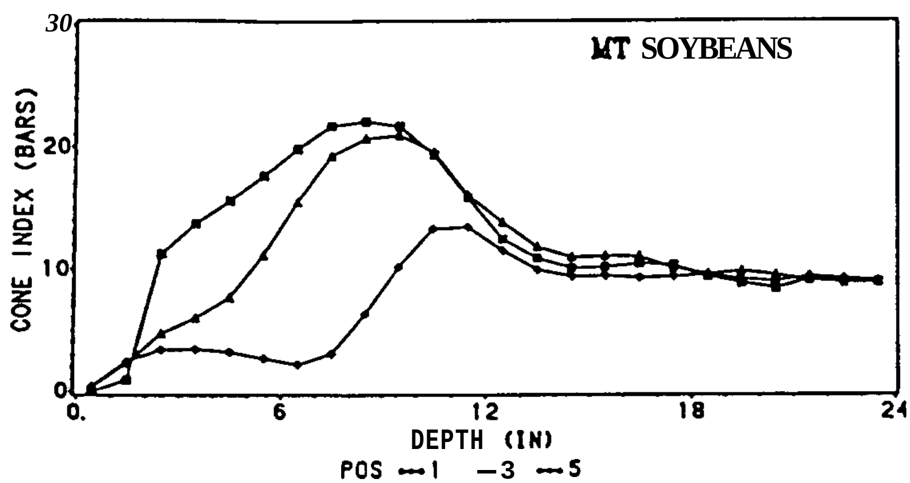


Figure 4. Cone index with depth in minimum tillage soybeans in positions one (squares), three (diamonds), and five (triangles).

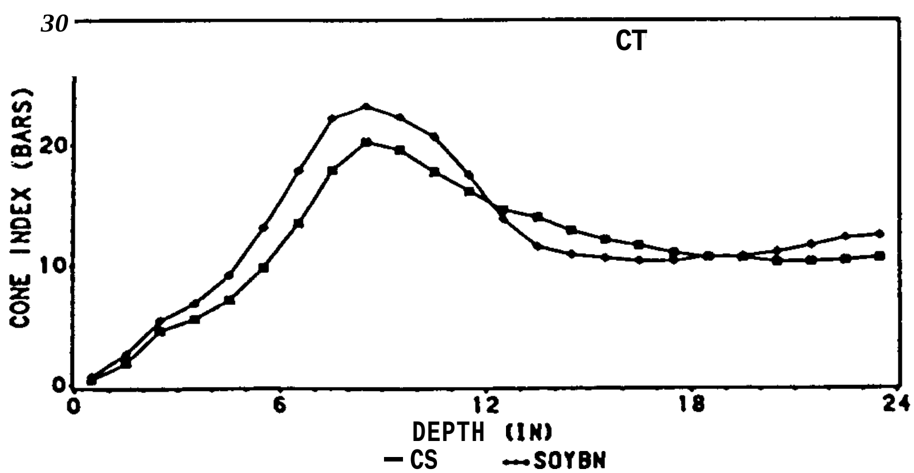


**Figure 5.** Cone index with depth in conventionally tilled soybeans (diamonds) and grain sorghum (squares) averaged over all five positions.

Table 2. Effect of crop and tillage on organic carbon percentage in November, 1987.

| | % Organic Carbon | | | |
|---|---|---|---|---|
| | CT | | NT | |
| Depth (in) | Grain sorghum | Soybeans | Grain sorghum | Soybeans |
| 0-3 | 1.169 | 1.093 | 1.011 | 0.971 |
| 3-6 | 1.015 | 0.851 | 0.800 | 0.807 |
| 6-12 | 0.529 | 0.362 | 0.440 | 0.459 |
| 12-18 | 0.285 | 0.259 | 0.254 | 0.280 |

Table 3. Effect of tillage on 8-year mean crop yield.

| | Yield (bu/acre) | |
|---|---|---|
| Tillage | Grain sorghum | Soybeans |
| CT | 73 a | 33 a |
| MT | 78 b | 32 a |
| NT | 70 a | 32 a |

Values in the same column followed by different letters are significantly different at the 0.05 level.

beans (Figure 4). Cone index in the row position (3) was significantly reduced compared to both positions 1 and 5 to a depth of 10 inches. Chiseling to an approximate depth of 9 inches was sufficient to break through the hardpan in this soil. The apparent effect of traffic was less in this treatment in that the differences between positions 1 and 5 were confined to the top 6 inches. This may have been due to a reduction in cone index under the wheeltrack caused by the shattering effect of subsoiling.

Analysis of the penetrometer measurements also indicated that there was an interaction between crop and depth in CT. Cone index averaged over all positions tended to be lower in grain sorghum compared to soybean. Organic carbon levels were slightly higher in grain sorghum compared to soybean under CT (Table 2) and this was probably due to the higher levels of residue which were being incorporated into the soil.

## Discussion

The compacted layer at 6 to 12 inches in this study is a common feature of soils of the Southern Piedmont. Cone index in the pan exceeded 20 bars and was in the range that could reduce root growth (Taylor and Gardner, 1963). Since these measurements were made at a time when water contents were near field capacity, the values of soil strength represent seasonal minimums. Soil strength was high enough to reduce yield in grain sorghum in the NT and CT treatments compared to MT, but there was no effect in soybeans (Table 2). This may have been due to an added response to subsoil nitrogen in grain sorghum under MT, or it may have been due to a difference in root growth characteristics of the two crops under high mechanical impedance.

Our results show that wheel traffic contributed to the formation of the hardpan at 6 to 12 inches below the surface because cone index was higher in the traffic position in this depth range in CT and NT. Fall disk tillage very likely contributed to the formation of the pan. There may have also been a natural component to formation in that the transition zone between the A and B horizons, which often occurs at 6 to 12 inches, may have the optimal combination of sand and clay to be easily compacted. Once a denser layer starts to form at a depth, either by tillage or natural consolidation, the stresses caused by wheel traffic will be confined in part, above the layer and more severe compaction will result than if there was no confining layer (Taylor et al., 1980). In this manner, traffic can be expected to interact with tillage and natural consolidation in the formation of hardpans in these soils.

## References

Bruce, R. R., J. H. Dane, V. L. Quisenberry, N.. L. Powell, and A. W. Thomas. 1983. Physical characteristics of soils in the Southern region: Cecil. Southern Cooperative Series Bull. 267. Ga. Ag. Exp. Sta. Athens, GA.

Clark, R. L., D. E. Radcliffe, and E. W. Tollner. 1986. Microcomputer-based instrument and software for a tractor-mounted penetrometer. Paper No. 86.1040. American Society of Ag. Eng. St. Joseph. MI.

Langdale, G. W., and R. L. Wilson, Jr. 1987. Intensive cropping sequences to sustain conservation tillage for erosion control. J. Soil and Water Cons. 42:352-355.

NeSmith, D. S., D. E. Radcliffe, W. L. Hargrove, R. L. Clark, and E. W. Tollner. 1987. Soil compaction in doublecropped wheat and soybeans on an Ultisol. Soil Sci. Am. J. 51:183-186.

Radcliffe, D. E., R. L. Clark, S. NeSmith, W. L. Hargrove, and G. W. Langdale. 1985. Penetrometer measurements in conventional and minimum tillage. Proceedings Southern Region No-Till Conference. July 16-17. Griffin, GA. 98-102.

Radcliffe, D. E., E. W. Tollner, W. L. Hargrove, R. L. Clark, and M. H. Golabi. 1988. Effect of tillage practices on soil strength and infiltration of a Southern Piedmont soil after ten years. Soil Sci. Soc. Am J. 52 (in press).

Taylor, H. M. and H. R. Gardner. 1963. Penetration of cotton seedling taproots as influenced by bulk density, moisture content, and strength of soil. Soil Sci. 96:153-156.

Taylor, J. H., E. S. Burt, A. C. Bailey. 1980. Effect of total load on subsurface soil compaction. Trans. ASAE.

Tollner, E. W., W. L. Hargrove, and G. W. Langdale. 1984. Influence of conventional and notill practices on soil physical properties in the Southern Piedmont. J. Soil and Water Cons. 39:73-76.