CONVERSATION TILLAGE AND TRAFFIC EFFECTS ON SOIL CONDITION

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ABSTRACT. *The soil condition resulting from a five-year cotton-wheat double cropping experiment in a sandy loam Coastal Plain soil was investigated using intensive measurements of cone index and dry bulk density. Four tillage treatments including a ship-till (no surface tillage with in-row subsoiling) conservation tillage practice were analyzed. The traffic was controlled in the experimental plots with the USDA-ARS Wide-Frame Tractive Vehicle. Besides the environmental benefits of maintaining the surface residue, the strip-till treatment decreased cone index directly beneath the row, decreased surface bulk density, increased surface moisture content, decreased energy usage. and increased yields. Controlled traffic was beneficial only when in-row subsoiling was not used as an annual tillage treatment. Although differences in soil condition were seen beneath the row middles where traffic occurred. this did not affect the soil condition directly beneath the row.* **Keywords.** *Penenometer. Strip-till, Bulk density, Controlled traffic, Cotton.*

Soil compaction has long been known to cause mot restrictions and yield reductions in many crops, but cotton *(Gossypium hirsutum* L.) is particularly susceptible in the southeastern United States (Cooper et al., 1969; McConnell et al., 1989; Mullins et al., 1992). Two primary techniques have arisen concerning control and management of soil compaction. The first method of controlling soil compaction and recovering soil productivity is subsoiling to a depth of 0.3 to 0.5 m (Gamer et al., 1984; Reid, 1978; Campbell et al., 1974). Subsoiling is done on an annual basis in some Coastal Plains soils because of their susceptibility to soil compaction. The amount of this compaction that occurs naturally and the amount that is caused by wheel traffic has not been well quantified.

The second method of controlling soil compaction from wheel traffic is by originally preventing it. One method of prevention is to control the traffic patterns in the field (Dumas et al., 1973). If a row could be maintained year after year, then the tractor tire could be kept in the same trafficked area without passing over the growing zone. It was this desire to be able to maintain a traffic-free area that led to the idea of controlled traffic. This concept has been investigated by several researchers (Williford, 1980; Carter, 1985; Carter et al., 1989) who used either conventional tractors with extended axles or specially designed spanner-type vehicles. Most of the studies to date have proposed two major conclusions. The first conclusion is that controlled traffic enhances soil condition for some soils and can enable roots to penetrate to deeper depths, therefore enhancing drought tolerance. The second conclusion is that crop yield is variable and the crop is not able to take advantage of this improved soil condition unless weather patterns exist which cause water stress.

The validity of these two conclusions under different tillage systems was examined in an experiment conducted by a team of researchers from the National Soil Dynamics Laboratory using a Wide-Frame Tractive Vehicle (WFTV). This experiment was conducted from 1987 to 1991 to investigate the effects of crop response to tillage and traffic treatments. The WFTV, as reported by Monroe and Burt (1989), allows a 6-m cropping zone to be kept free of field traffic. Raised traffic paths for the wheels allow the vehicle to completely span this area. This vehicle allows the necessary research to be conducted to determine the effects of traffic and tillage on soil condition without any confounding effects from nearby traffic.

In studies that reported yield results from this research (Reeves et al., 1989; Torbert and Reeves, 1991), the effect of traffic was again variable. Generally, no great advantage resulted from removing traffic from plot areas. Crop yields, however, were largely dependent upon crop species, year, and prevailing weather patterns. Significant tillage effects were noted on crop yields, however, in most years. Therefore, to help explain the variable effects on crop yields, we intensively sampled the soil to determine how the soil condition had been altered due to the imposed tillage and traffic treatments.

METHODS AND MATERIALS

The experiment to determine the effects of traffic and tillage systems on crop response in Coastal Plain soils was conducted at the Alabama Agricultural Experiment Station,

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Auburn University, Agricultural Engineering Research Farm at Shorter, Alabama. The soil is a Cahaba-Wickham-Bassfield sandy loam complex (Typic Hapludults). This soil contained a well-developed 0.08- to 0.15-m-thick hard pan at a 0.2 to 0.3 m depth. A road grader was operated in a moldboard plow furrow incrementally across the field at a 0.2 m depth in June of 1987 prior to initiating the cropping experiment to reduce the natural variation in the depth and thickness of the hard pan.

A cotton-wheat *(Triticum aestivum* L.) double cropping experiment was designed as a split-plot with four replications. The main plots were conventional traffic and no traffic. The subplots contained various cotton tillage systems* including:

- Complete surface tillage (disked and field cultivated) and annual in-row subsoiling to a 0.4 m depth at planting (designated D, FC, SS+P).
- Initial complete disruption of hard pan (but with no annual subsoiling thereafter), complete surface tillage, and planting (designated CD, D, FC, P).
- Complete surface tillage and planting (designated D, FC, P).
- In-row subsoiling to a 0.4 m depth (strip-tillage) with no surface tillage (designated SS+P).

A V-frame subsoiler on 0.25-m centers and operating to a 0.5 m depth was used in November of 1987 on the plots that received the initial complete disruption of hard pan treatment (CD, D, FC, P). The strip-tilled cotton (SS+P) was planted into wheat stubble with a KMC in-row subsoiler-planter. This planter was also used to plant the annual subsoiling treatment, but in a conventional surface tillage environment.

Cotton (McNair 220) was planted in 0.76-m (30-in.) rows at 220 000 seeds/ha (90,000 seeds/acre) as close to June 1 as possible from 1988 to 1991. All tillage treatments were carried out with the WFTV, even in plots that received the traffic treatments. Immediately after each operation, the trafficked plots received traffic from a John Deere® 4440 that would have been used if the operations had not been performed with the WFTV. All plots were eight rows in width and four-row equipment was assumed during the application of the traffic treatments. Recommended weed and insect control practices were used throughout the growing season for all plots. A high-clearance sprayer was operated in the trafficked plots immediately after each spraying operation with the WFTV. The cotton was hand-harvested each year for yield determination.

The various tillage and traffic treatments were applied to the plots during the years 1987 to 1991. At the end of the five-year cropping experiment, during the fall of 1991, the plots were intensively sampled to determine the changes in soil condition that had occurred during this period of time. A penetrometer (ASAE, 1991). with base area of 323 mm^2, mounted on the WFTV was used to sample each subplot at five different locations. These five locations were distributed at approximately equal distances within the subplot At each of these locations, five penetrations were made, starting from the row middle on the untrafficked side of the row and moving in 0.19-m (7.5-in.) increments across the row and into the trafficked row middle (corresponds to traffic middle in treatments that received traffic). This sampling procedure should allow changes caused by both tillage and traffic to be noted. Four replications x 2 traffic main-plot treatments x 4 tillage subplot treatments x 5 subsample locations x 5 positions across the row were sampled to give a total of 800 penetrometer sets of force-distance. data Cone index data were taken at every 0.003 m depth down to an approximate maximum depth of 0.7 m giving 230 data points per dataset. These data were reduced by averaging the data in **0.05-m increments.**

Soil samples were also taken from beneath the row at a depth of 7.6 cm and within the hard pan, and their dry bulk densities and gravimetric moisture contents were measured. Three locations within each subplot were sampled.

RESULTS AND DISCUSSION

Several analyses were used to determine the effect of traffic and tillage on cone index. First, the data were visually examined for important trends. The most revealing set of soil cone penetrometer data is presented in figures 1 through 4. Figures 1 and 2 are plots of data from beneath the row middle that would have received traffic in the traffic treatment. Figures 3 and 4 are from beneath the row. From these graphs. the original hard pan can be found in the D, FC, P tillage treatment. This hard pan is present both underneath the row and in the trafficked middle and occurs at a depth of between 0.2 to 0.25 m. When traffic is applied, the hard pan is closer to the surface by approximately 0.05 m. Another observation is that when the hard pan is completely removed, as in the CD, D, FC, P tillage treatment, traffic must be controlled or recompaction of this layer can occur

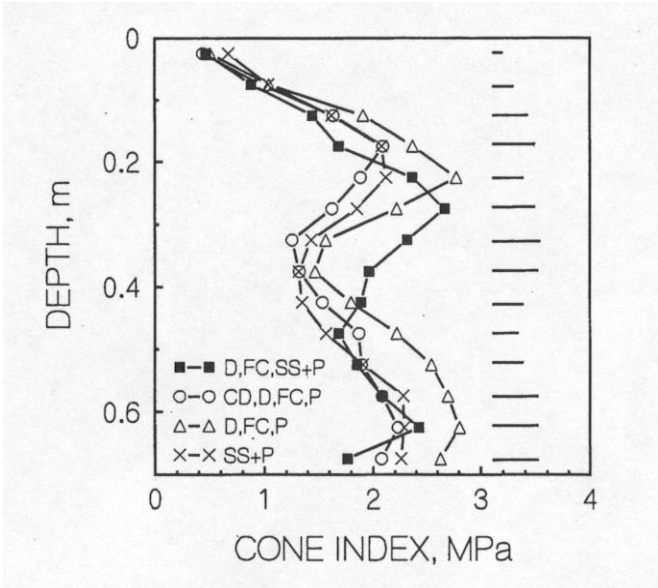

Figure 1–Cone index for the four tillage treatments (see table 2 for key) in the trafficked middle location in plots where traffic was applied. The horizontal bars indicate the $LSD_{0.05}$.

* The tillage treatments are defined by the following key: D (disk), FC (field cultivate). SS+P (in-row subsoil and plant), CD (complete distruption), and P (plant).

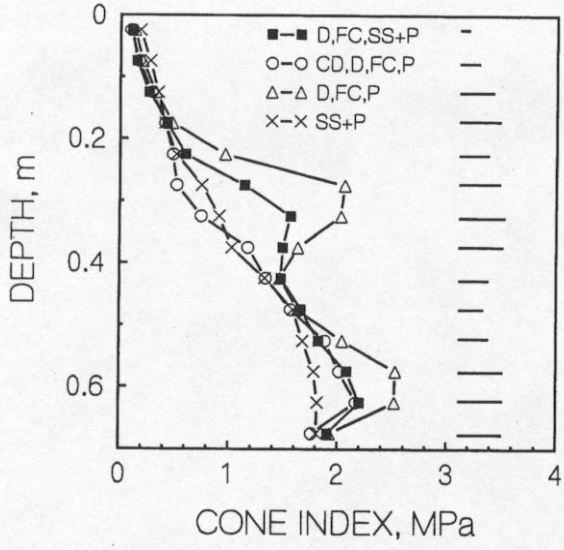

Figure 2–Cone index for the four tillage treatments (see table 2 for key) in the trafficked middle location in plots where no traffic was applied. The horizontal bars indicate the $LSD_{0.05}$.

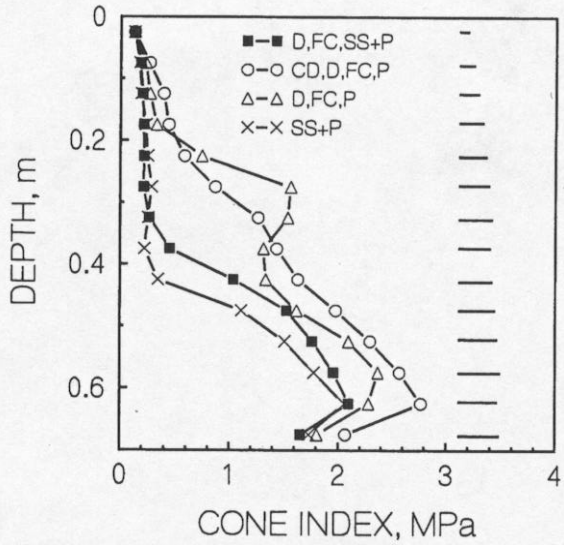

Figure 4–Cone index for the four tillage treatments (see table 2 for key) in the row location in plots where traffic was not applied. The horizontal bars indicate the $LSD_{0.05}$.

If figures 1 and 2 are compared, the overall effect of traffic on soil condition is seen for all four tillage treatments. If a hardpan does not exist, the effect of traffic is to create one. If a hard pan already exists, the soil above it becomes compacted and the pan becomes closer to the surface.

The effect of traffic on soil directly beneath the trafficked middle has been noted. The information that may be more important to plant growth is found directlv beneath the row (figs. 3 and 4) where similar traffic effects are found on the nonsubsoiled tillage treatments (CD, D, FC, P and D, FC, P). This trend is not seen, however, when the subsoiling tillage treatments are analyzed (D, FC, SS+P and SS+P). In these tillage treatments, the hard pan is eliminated down to a 0.4 m depth. The dramatic traffic effects seen underneath the tire tracks and in the nonsubsoiled tillage treatments are eliminated when in-row subsoiling is used. The impacts of this trend are worth further discussion.

The depths at which tillage and traffic differences became statistically significant were determined at three locations laterally across the row. Tillage affects cone index beneath the row for depths down to 0.55 m (table 1). The effect of traffic on cone index is particularly strong beneath the trafficked middle, but are also found down to 0.50 m beneath the row, and down to 0.30 m in the untrafficked middle. The explanation for the latter seems to be related to the random traffic that was applied in the fall of the year to the trafficked plots to simulate a cotton harvester and the wheat planting operations. During these operations, traffic was randomly applied throughout the field and not necessarily in the four-row fanning patterns.

Immediately beneath the row, traffic and tillage effects are seen at depths down to 0.55 m (table 1). Of particular interest is the depth at which the in-row subsoiler should

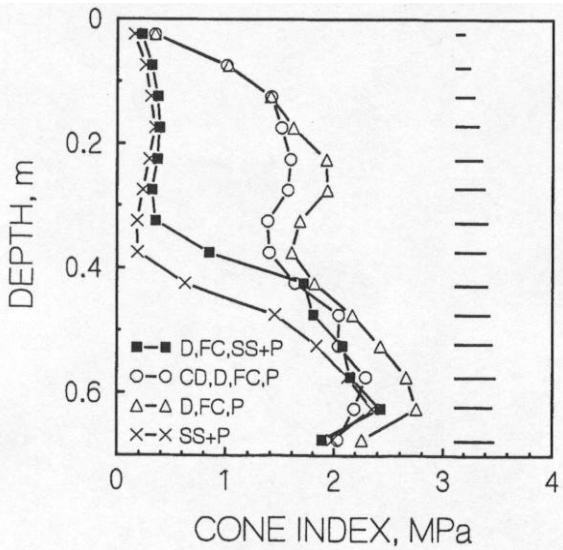

Figure 3–Cone index for the four tillage treatments (see table 2 for key) in the row location in plots where traffic was applied. The horizontal bars indicate the $LSD_{0.05}$.

Table 1. Effects of traffic, tillage, and traffic by tillage interaction on cone index at the 5% level of significance

Depth (m)	Untrafficked Middle	Row	Traffic Middle
0-0.05	T	T	T,t
0.05-0.10	T	T,t,T*t	T
0.10-0.15	T,t,T*t	T,t,T*t	T
0.15-0.20	T	T,t,T*t	T
0.20-0.25	T,t	T,t,T*t	T,t
0.25-0.30	T,t	T,t	T,t,T*t
0.30-0.35	t	t	t
0.35-0.40		T,t	
0.40-0.45		T,t	T
0.45-0.50		T,t	T
0.50-0.55		t	T,t
0.55-0.60			
0.60-0.65			

Note: T = traffic; t = tillage; T*t = traffic by tillage interaction.

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