THE EFFECT OF TRAFFIC PATTERNS ON SOIL COMPACTION

Alan D. Meijer[1*]
[1]NC State University, 207 Research Station Rd, Plymouth, NC 27962
[*]Corresponding author's email address: alan_meijer@ncsu.edu

ABSTRACT

Soil compaction is a common problem in the southeastern United States, especially on sandy soils as found in the Coastal Plain of NC. One of the main causes of soil compaction is equipment traffic in fields. The objective of this study was to determine the amount of traffic occurring in North Carolina fields and the effect that the level of traffic had on soil compaction as measured by soil bulk density. GPS was used to map all traffic on these fields in 2006. Using measurements of tread widths and wheel spacing, a series of processes in a GIS was performed to generate a map indicating the level of traffic that occurred in each area of the field. After all field operations were complete as well as the GIS analysis, fields were sampled for bulk density again. Sample locations were then based on the number of passes that had occurred. Initial results showed that 65-85% of the field's area was tracked. Bulk density ranged from 0.5 to 0.8 g/cm^3 in the organic soil, and from 1.6 to 1.8 g/cm^3 in the sandy soils. Initial results show that in the organic soil, areas of the field that were tracked at least four times had significantly higher bulk density in the 0-10 cm depth than the areas that received no tracks.

INTRODUCTION

Soil compaction has been known to be a serious problem in coastal plain soils for years. Many studies have described the negative effects of soil compaction on soil structure and plant growth (Barber, 1971; Unger and Kaspar, 1994; Vepraskas, 1994). One of the main causes of soil compaction is machine traffic in the field (Naderman, 1990; Hillel, 1980). Other studies have shown that around 80% of soil compaction occurs in the first pass of a vehicle (Kelly et al. 2004). Also, research has shown that up to 90% of a field's surface area can be tracked in a given year, when using conventional tillage practices (DeJonge-Hughes et al., 2001). Few studies have involved the use of GPS to track vehicles in a field to actually map the traffic pattern in a crop year.

The objective of this study was to determine what percentage of land area is tracked in a given year using Global Positioning Systems (GPS); and what effect the amount of traffic had on soil compaction, as measured by bulk density.

MATERIALS AND METHODS

This study was carried out on two farms in the lower coastal plain region of eastern NC. Fields L1 and L2 were located in Bertie County adjacent to the Roanoke River, while field P10 was located in Hyde County, in what as known as the Tidewater region of the lower coastal plain – an area characterized by organic soils.

The soil type at the Bertie County site was predominated by Tarboro loamy sand (Mixed, thermic Aquic Udipsamment) and Conetoe loamy sand (Loamy, mixed, thermic Arenic Paleudult). These fields are part of a corn-peanut-cotton rotation. One of these fields, "L1", was strip-tilled and planted in cotton in 2006, while "L2", and was planted in corn after being disked. The soil type in the Hyde County field "P10" was a Ponzer muck (Loamy, mixed, dysic thermic Terric Medisaprist). This field was being managed for organic grain production, and was planted in corn during the 2006 growing season.

Bulk density was determined at each location to get a picture of the current level of soil compaction in the fields. Fields L1 and L2 were sampled in a grid pattern prior to spring field operations in 2006. Soil cores were taken at depths of 0-4", 4-8", 8-12", and 12-16", using an AMS Soil Core Sampler (AMS Inc., American Falls, ID), that had a core of approximately 2" in diameter and 4" in height. Samples of increasing depth were taken adjacent to the spot where the previous (shallower) sample was taken, so as to eliminate the risk of sampling soil that may have been compacted by action of sampling the shallower sample previously. These samples were dried in an oven for 24 hours at 105^{o} C, and weighed. Bulk density was calculated by dividing weight of the sample by the volume of the sample (corer).

Field P10 is located in the Tidewater region of the lower Coastal Plain. This area is traditionally known as "the blacklands" because of the high organic content of the soils. The land here was originally swampland and drained in the early to mid 1900s by logging and the digging of an extensive series of canals and ditches. These fields have a unique history in how they were created that can affect their current management. Ditches were dug 330' apart to drain the land. The trees were cut and the logs removed. After the land was logged, the stumps and residue were pulled to the center of each field where these piles were burned repeatedly until the wood was gone. The fields were shaped with a crown in the center to enhance drainage. These fields were shaped with a crown in the center to enhance drainage. This resulted in some topsoil being pulled from near the ditch bank towards the center of the field. The end result is that there is the topsoil tends to be deeper near the center of the field than near the ditch. Thus, P10 was sampled by transecting the field from ditch bank to ditch bank taking 5 samples across the field and performing 3 such transects down the length of the field. This was done in an attempt to characterize the differences in bulk density that may be present due to the creation and shaping of the field. Bulk density was calculated from these samples in the same manner as those from L1 and L2.

All traffic was mapped on all 3 fields starting after that point. Traffic was mapped by mounting a Trimble AG132 differential-corrected GPS unit (Trimble, Sunnyvale, CA) to the tractor, sprayer, or combine cab, and recording the path the vehicle took using SiteMate software (FarmWorks, Hamilton, IN). For each event, the wheel spacings were recorded as well as tire widths themselves. This was also done for any wagon (i.e., boll buggy) towed behind the tractor.

Tracks were created in ArcGIS software (ESRI, Redlands, CA) by creating polygons that accurately reflected the spacing and widths of the tire tracks. This was done by creating and manipulating a series of buffers based on the measurements taken of each machine. Front and rear (inner) tires were counted as one track, although the maximum width of their combined footprint was used to create the track. This was done for all events for all three fields. Each track was saved as separate file and then converted to a grid. Each grid file consisted of thousands of cells that represented the area of the field. If a tire track crossed a cell, the cell received a value of "1". If there was no tire-track at that location, the cell received a value of "0". Then, using a process called Map Algebra; all the events were "added" together. In this process, the cells are "lined up" and their values are added together. The result is a grid file with cells that contain numerical values equal to the number of tracks that occurred at that particular point. From this file, the area of the field that was tracked, as well as the number of tracks that occurred was determined.

Bulk density samples were taken again in areas of the field that received 0, 1, 2, and 4 tracks to see if the amount of traffic affected bulk density. Fields L1 and L2 were sampled in randomized complete block where the treatment was the level of traffic, and replicated four times. Samples were only taken from the area of the field mapped as Conetoe loamy sand in these fields. At field P10, the experimental design was the same. However, this design was applied to three different sections of the field as noted earlier: P10Center is the middle 5th of the field; P10Ditchbank is the outer 2/5ths of the field, while P10Middle is the 2/5ths of the field that are between the ditchbank and crown areas of the field. Analysis of variance was performed using PROC GLM in SAS (SAS Institute, Cary, NC).

RESULTS AND DISCUSSION

Pre-season Bulk Density

Initial bulk density was much greater in L1 and L2 than at P10 (Figure 1). Bulk density ranged from 1.43 to 1.65 g/cm^3 at L1 and L2, while ranging from 0.68 to 0.75 g/cm^3 at P10.

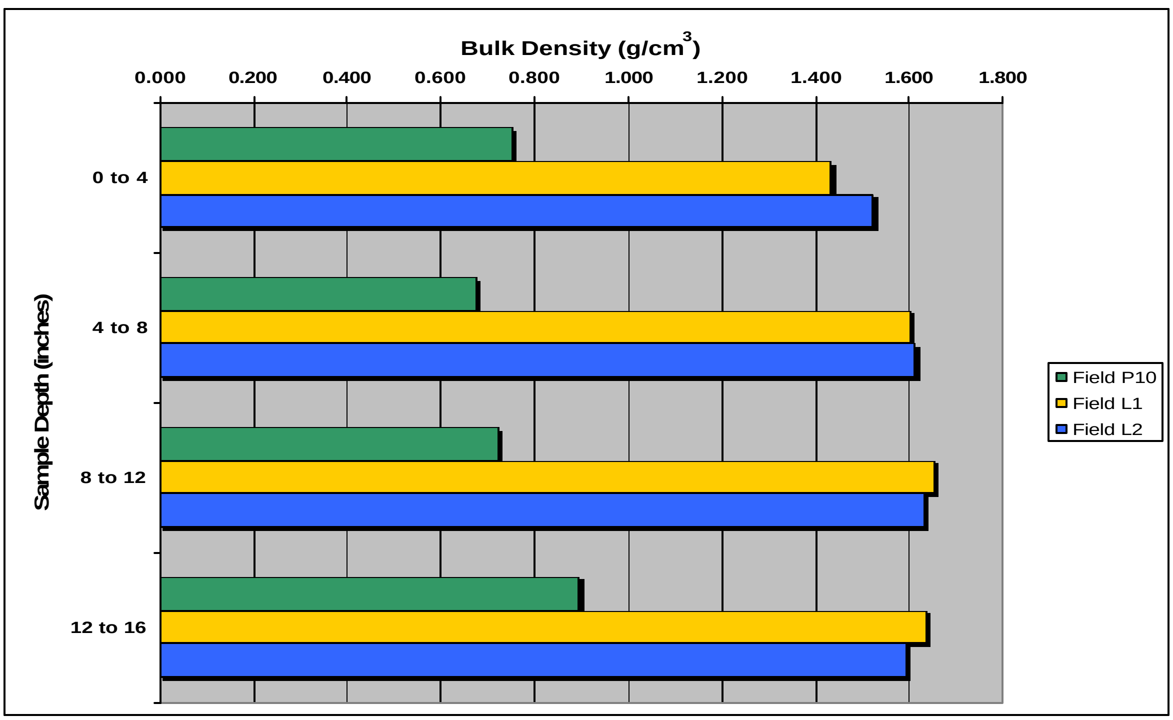

Figure 1. Bulk density for 3 sites at 4 depths prior to start of mapping.

At L1 and L2, bulk density increased noticeably between the 0-4 inch depth and the three samples below. At P10, bulk density actually decreased somewhat below the 0-4 inch depth and then becoming greater than that at the surface at the 12-16 inch depth.

Traffic Mapping

Table 1 shows the different field events that were mapped for each field. Since P10 was being managed for organic grain production, it saw more traffic than L2, which was also planted in corn, but not for organic production.

Table 1. List of field events at all sites in 2006.

P10 – Hyde County	**L1 – Bertie County**	**L2 – Bertie County**
Crop: Organic Corn	Crop: Cotton (Strip Till)	Crop: Corn (Conv. Till)
Chicken Litter Application	Strip-Till	Disk
Dynadrive	Plant	Bed
Field Cultivation	Roundup-Orthene	Plant
Plant	Herbicide (Sequence)	Nitrogen Application
Spring Tooth Harrow I	Pix Application I	Herbicide (Roundup)
Spring Tooth Harrow II	Nitrogen Application	Combine
Spring Tooth Harrow III	Pix Application II	
Danish Tyne Cultivation I	Hood Spray	
Danish Tyne Cultivation II	Defoliation	
Combine	Cotton Picker	
Auger Cart (Grain wagon)	Boll Buggy	
Total: 11 Events	**Total: 11 Events**	**Total: 6 Events**

Significant portions of the field were tracked at least once during the course of the growing season. In fact, 85% of the field surface area in P10 was tracked during the course of the season (Figure 2). While also planted in corn, only 65% of L2 was tracked. This correlates with the fact that P10 was managed for organic corn production and received more trips across the field than L2.

The surface area that received more than one track was calculated as well (Figure 3). Significant portions of the fields received more than one track. For example, more than 5% of the field area in L1 was tracked a total of 6 times. L2 was tracked the least overall, and therefore showed the least amount of area that was tracked multiple times.

Post-season Bulk Density

Bulk density measurements made after the growing season were similar to those made in the spring. Since P10 was divided up into 3 regions, more detail came to light in that field. Figure 4 shows the mean bulk density for each field and depth. Bulk density at L1 and L2 followed a

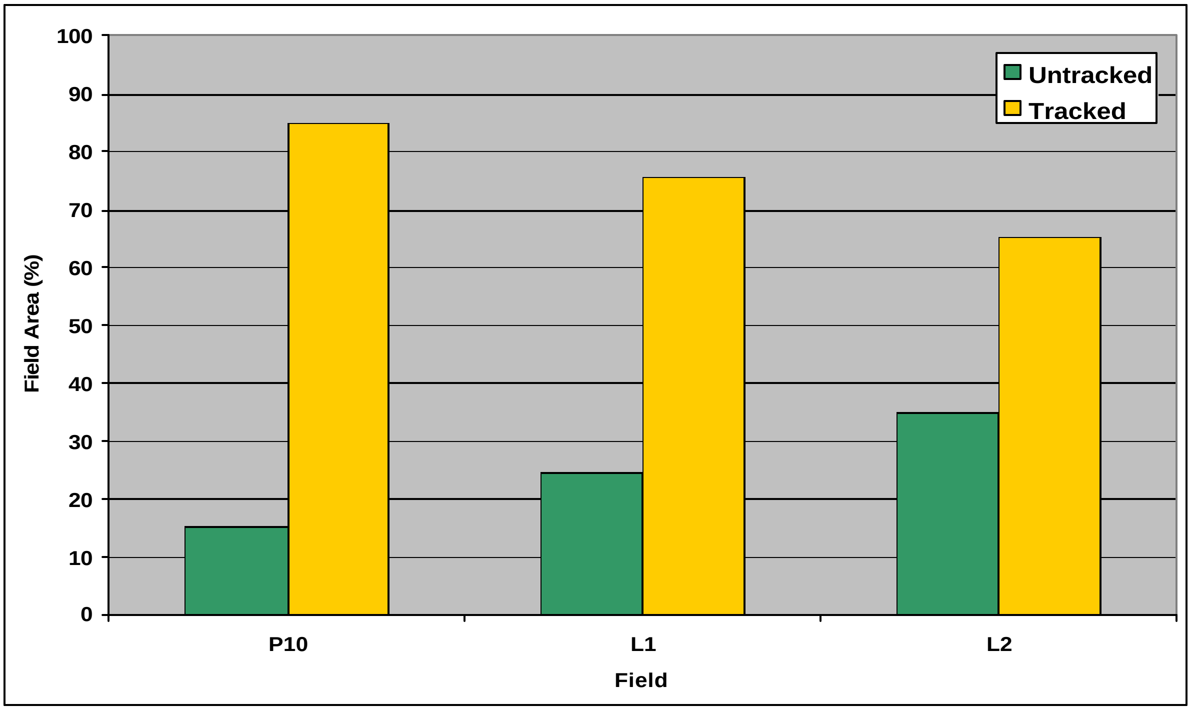

Figure 2. Percent land area tracked or untracked at 3 locations in 2006.

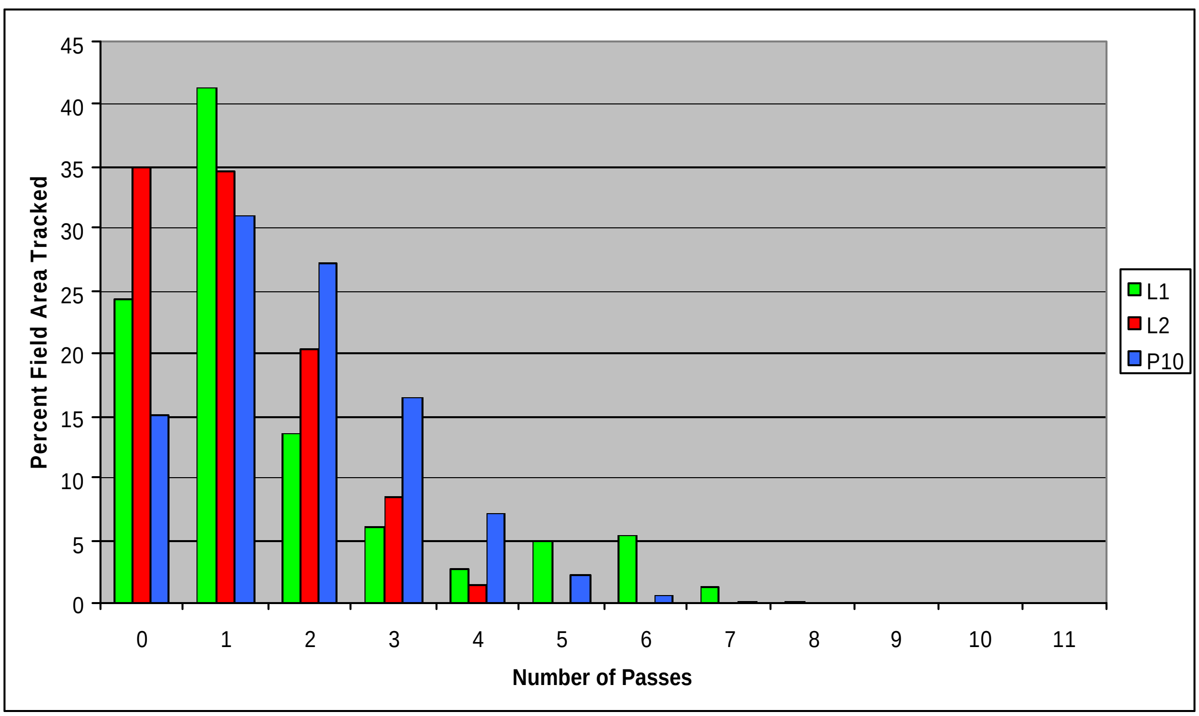

Figure 3. Number of tracks per given land area (percent land area) at 3 locations in 2006.

similar pattern with bulk densities starting at around 1.6 g/cm3 at the 0-4 inch depth and increasing somewhat to around 1.75g/cm3 at the 8-12 inch depth before dropping off slightly one sample deeper. These bulk densities are in the range of limiting root growth. The pattern of increasing bulk density with depth is also common. At P10, bulk densities were much lower, as would be expected in an organic soil. However, there was a distinct difference between the bulk densities of the samples taken from the ditchbank area of the field versus those taken from the center or middle of the field. Bulk densities in the center of the field and adjacent to the center (middle) started around 0.7 g/cm3 at the 0-4 inch depth and decreased some what with depth. In contrast, bulk density at the ditchbank started a little higher at around 0.8 gm/cm3 and rose first a little at the 4-8 inch depth and then increased steadily as the samples were deeper. This reflects the fact that much of the organic topsoil has been removed and the sandy layer is much shallower near the ditches (outer edges of the field).

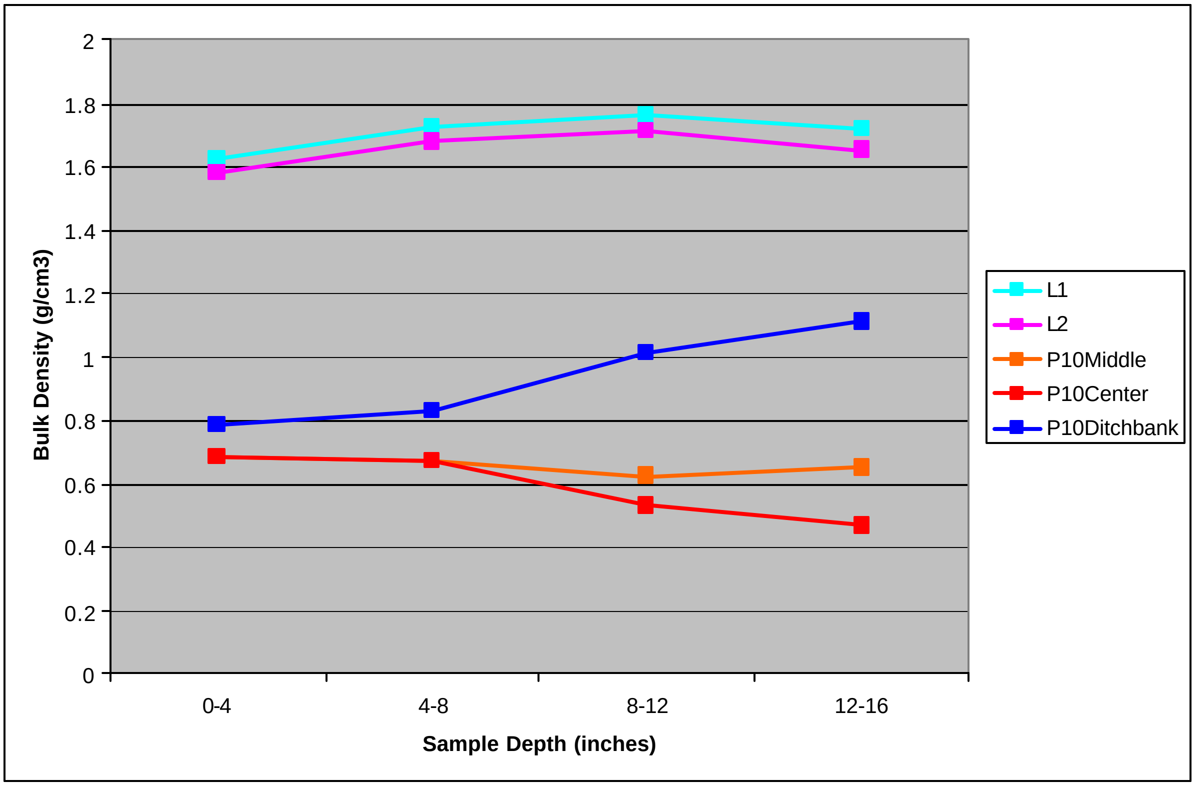

Figure 4. Post-harvest bulk density by sample depth at 3 locations. (P10 divided into 3 separate regions – center, middle, ditchbank.)

The effect of traffic (number of passes) was significant at some depths in some fields (Table 2). In P10Middle and L2, there was a significant difference in bulk density between the level of tracks at the 0-4"depth at the alpha = 0.05 and alpha = 0.10 levels respectively. P10Center was found to have significant differences in bulk density at the alpha = 0.10 level. One reason that differences in bulk density between levels of traffic were not found across the board may be due to the fact that the fields already exhibited a level of compaction prior to the start of the test. Li et al. (2006) stated that the field demonstration of the occurrence and impact of soil compaction is often confounded by the difficulty of establishing a non-compacted control.

Table 2. ANOVA results for the effect of level of traffic on bulk density at all sites in 2006.

Field	Sample Depth 0-4”	4-8”	8-12”	12-16”
L1	0.4029	0.7316	0.7112	0.8266
L2	*0.0645	0.2779	0.414	0.6479
P10Middle	**0.0361	0.5517	0.6321	0.9031
P10Center	0.779	0.6057	*0.0877	0.3603
P10Ditchbank	0.8421	0.2517	0.1694	0.2601

* Pr > F value is significant at the 0.10 level of probability.
** Pr > 5 value is significant at the 0.05 level of probability.

While Table 2 showed that the level of traffic did not affect bulk density in a majority of the treatments, the effect of location was significant at some depth in most fields (Table 3). This basically signifies that there were soil changes throughout the field that resulted in different bulk densities at each site.

Table 3. ANOVA results for the effect of location on bulk density at all sites in 2006.

Field	Sample Depth 0-4”	4-8”	8-12”	12-16”
L1	*0.0945	0.9281	0.4525	0.6699
L2	0.3710	0.1314	0.2714	0.4368
P10Middle	**0.0173	**0.0068	0.1276	0.1509
P10Center	*0.0802	**0.0121	0.3823	0.4191
P10Ditchbank	**0.0071	**0.0007	**0.0003	**0.0033

* Pr > F value is significant at the 0.10 level of probability.
** Pr > 5 value is significant at the 0.05 level of probability.

Figure 5 shows the effect that traffic had on bulk density at P10Middle in 2006. At the 0-4” depth range the bulk density was significantly greater in areas that were tracked four times as compared to areas that were not tracked at all. This might be explained by the relative increase in sand content in the upper layer of this organic soil as organic matter is oxidized over the years. Particle-size analysis will be done on these samples to help determine whether this hypothesis is feasible.

Figure 6 shows the effect that traffic had on bulk density at L2 in 2006. At the 0-4” depth, the bulk density was significantly greater in areas that received 3 tracks when compared to areas that were not tracked at all during the growing season. It is difficult to determine an explanation for why these two treatments were the only ones that differed significantly.

While at most depths at all locations, bulk density was not affected by traffic, a key issue affecting these results is that the fields were not subsoiled or chisel plowed prior to the start of the test in order to reduce their bulk density. In other words, all fields already demonstrated a level of compactness prior to any traffic. Therefore, since it has been discussed that most of the compaction occurs in the first pass of the field, subsequent traffic passes would make little difference. Li et al (2006) noted that it is difficult to obtain an uncompacted control in a field situation.

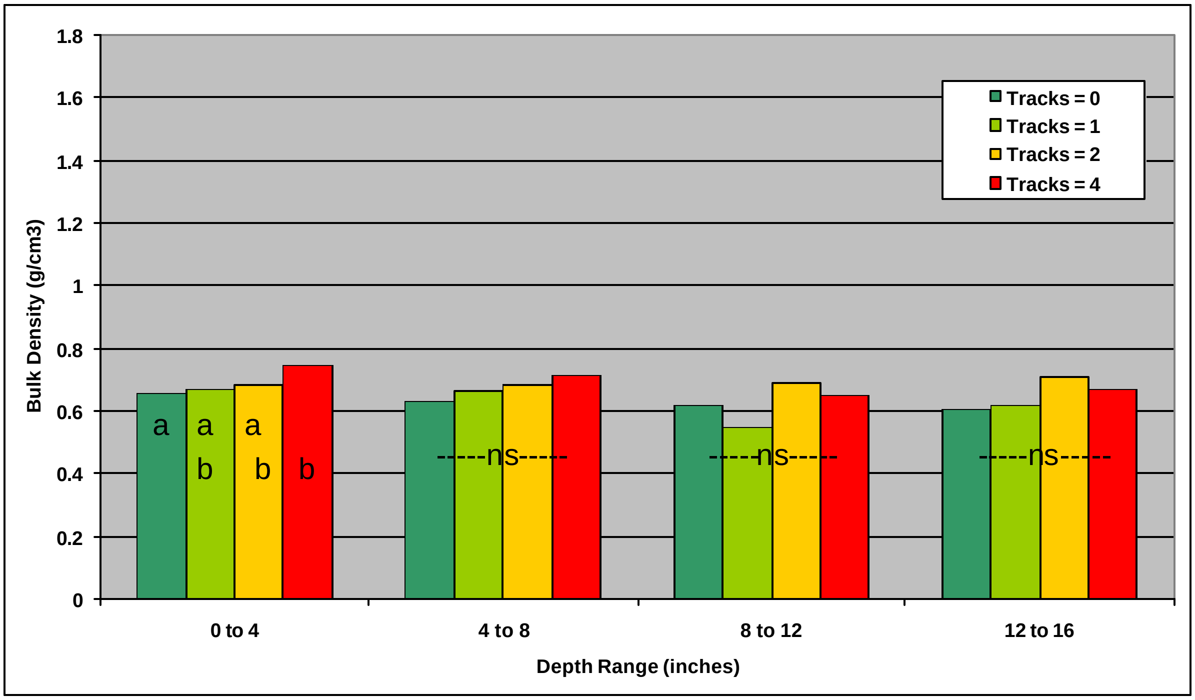

Figure 5. Post-harvest bulk density by sample depth at P10Middle in 2006. Within groups of bars, means labeled by different letters are significantly different at the 0.05 probability level.

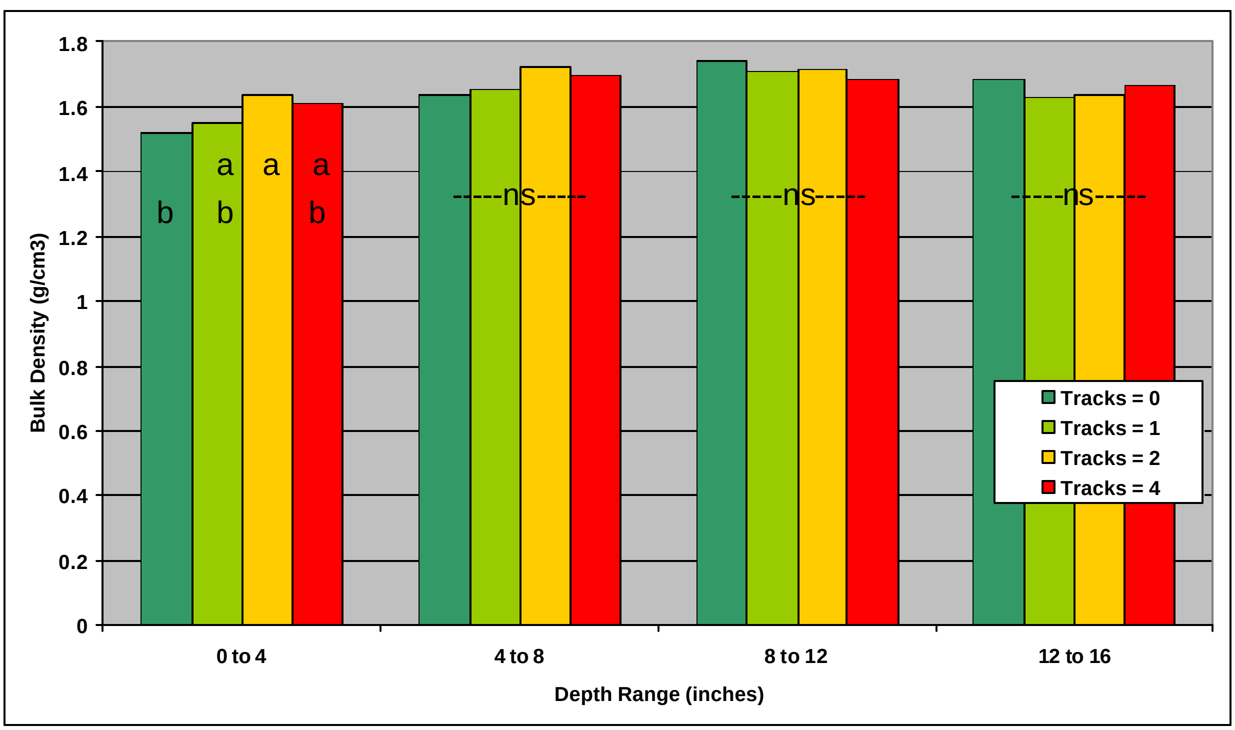

Figure 6. Post-harvest bulk density by sample depth at L2 in 2006. Within groups of bars, means labeled by different letters are significantly different at the 0.05 probability level.

CONCLUSIONS

Soil compaction has been understood to be a problem for a long time, as has the idea that vehicle traffic on fields is the major cause. However, it remains a key issue for growers, extension personnel and researchers to contend with. This study was designed to shed new light on this issue, but using GPS to get a true picture of traffic patterns in various situations in eastern North Carolina.

A key discovery in this study is the significant percentage of land area that is tracked in a given season, under a variety of cropping situations in eastern North Carolina. Results showed that 65-85% of the land area is covered in a cropping season. This does follow what has been reported in the literature. The use of GPS in determining the traffic patterns is also beneficial in that it allows for other analyses to be performed on what occurred. This is very useful from a research point of view, but also for extension, as growers can get a true visual representation on what goes on in their field on a year to year basis.

Significant differences in bulk density between levels of traffic were only noted in a few instances. These results suggest that while organic soils are not compacted near as much as on sandy soils, they are affected by the level of traffic, at least in certain situations like at P10Middle. They also show that more significant and noticeable differences in bulk density may have been discovered had soil compaction been alleviated as much as possible via tillage, prior to the start of the season.

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