Effect of Soil Texture on The Performance of a Subsoiling Implement

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Summer 2004

Overview

Row crop performance in the southeastern U.S. Coastal Plain is often severely limited by soil compaction. The three principle reasons for soil compaction are (1) uncontrolled wheel traffic; (2) tillage; and (2) presence of a high strength sandy-textured 'E' horizon underlying the A_p (plowed) horizon. The E horizon is a zone where clay has been removed due to the natural process of eluviation, leaving a light-colored sandy residue of mixed particle size where the interaction of wheel traffic, tillage, and natural consolidation over time results in a very dense 'hardpan'.

Managing subsoil compaction typically involves some form of non-inversion tillage such as subsoiling via ripper shanks and points configured for specialized soil-working (Figure 1). The purpose of subsoiling is to break up the compacted subsoil layer, providing roots access to a greater volume of soil for water and nutrients. Cotton and corn producers in the southeastern Coastal Plain often perform subsoiling annually or semi-annually to counter the effect of compaction. Subsoiling is an energy-consuming, costly treatment. In a sandy loam soil, drawbar power ~25 hp per shank is required 30 cm (12 inches) deep. However, on deep, well-drained sandy textured coastal plain soils low in carbon, nutrients, and water holding capacity, deep tillage may net +80-225 kg ha^{-1} of cotton lint and, +15-35 kg ha^{-1} corn grain and is considered profitable[§].

A major problem with subsoiling is unintentional uplift of clayey textured subsoil from the B_t horizon. This typically happens when ripper shanks on the subsoiling implement are set too deep. Clayey B_t soil is brought to the surface as 'blow out' where it dries into hard clods, leaving voids that, upon settling, form a trough where the crop seed is planted. This creates an environment that is unfavorable for cotton germination and seedling growth (Figures 2 and 3).

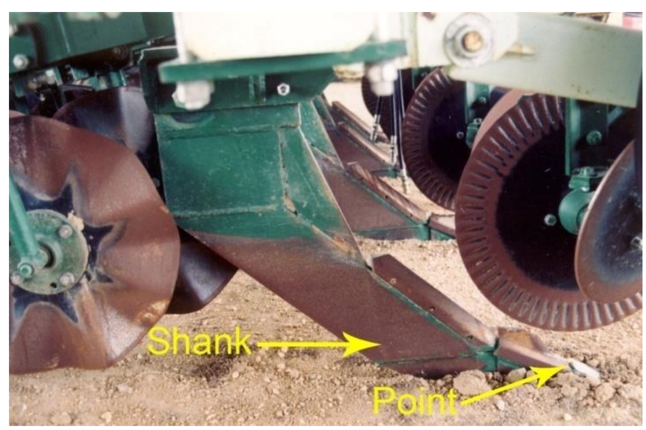

Figure 1. KMC subsoiler shank with principal parts labeled.

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§ Depending on commodity prices

Figure 2. Subsoil-strip tilled cotton showing blown-out sidewalls in tilled strip. The strip was created by a KMC subsoil strip tillage tool before cotton planting.

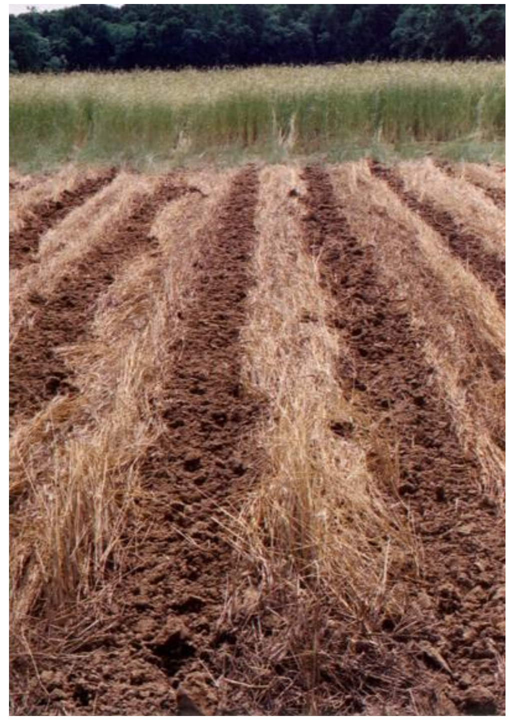

Figure 3. Under ideal conditions the KMC ripper-stripper tool produces a finely worked seedbed. Cover crop residue between the strip helps suppress weeds, reduce erosion, and conserve soil moisture.

Objectives

This 8-week project introduced agriculture interns at the Center for Environmental Farming Systems, Goldsboro, NC, to the art and science agronomic problem solving. Working together as a team, interns were expected to: (1) develop an ability to observe, identify, and differentiate visual indicators of crop health and soil productivity; (2) acquire new skill measuring soil properties and their interpretation; and (3) draw conclusions and make recommendations based on soil-plant-environment data.

Our objectives were:

- Determine if soil 'blow-out' observed after subsoiling was a result of changes in soil texture.
- Understand the basics of diagnostic soil sampling, handling, and processing.
- Employ a quantitative method for measuring particle size distribution at multiple depths across a field transect.

Methods

Our investigation focused on a replicated cotton trial with subsoiling at the Center for Environmental Farming Systems in Goldsboro, NC. The 0.60-ha research area occupied a nearly level terrace close to the Neuse River (Figure 4). Soil was mapped as Wickham sandy loam (fine-loamy, mixed, semi-active, thermic Typic Hapludult). On-site observation of soil cores did not reveal a distinct E horizon however the field had been subject to tillage and machinery traffic over a long period resulting in compaction, confirmed via tile probing, approximately 0.25 – 0.3 m deep. Subsoiling was performed as one of three tillage treatments but the result was inconsistent across experimental blocks. We hypothesized that a difference in soil texture was related to subsoil implement performance.

Sampling

We used the transect method for sampling at each of five positions across experimental blocks (Figure 5). Three soil cores, each 5 cm diameter, were extracted at each of five transect points with a Giddings tractor mounted hydraulic probe (Figures 6 and 7). The cores were sectioned into 0-15, 15-30, 30-60, and 60-90 cm deep increments and placed into paper bags. Soil samples were dried at 105^{o} C in a convection oven for 48 hr. After drying, the soil was passed through a 2-mm sieve. A 50 g sub-sample of <2 mm fraction was analyzed for soil particle separates sand, silt, and clay.

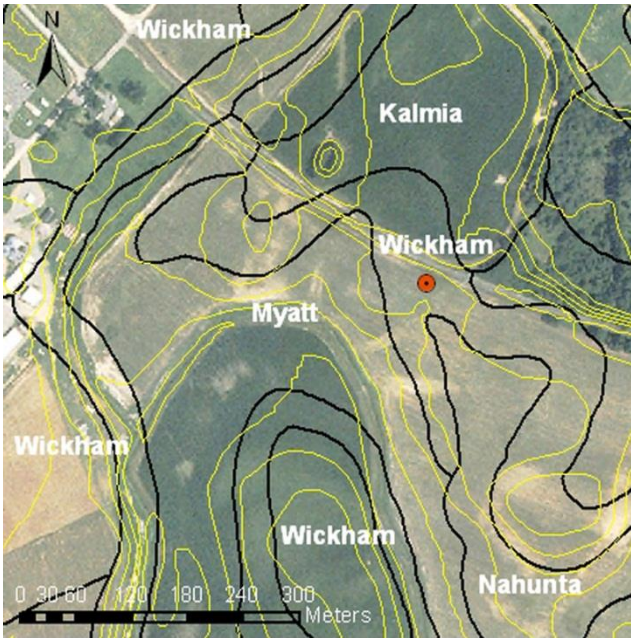

Figure 4. Aerial image of the research area showing local soil map units (black lines) and 2-foot contours (yellow lines). Trial area is marked by red bulls-eye.

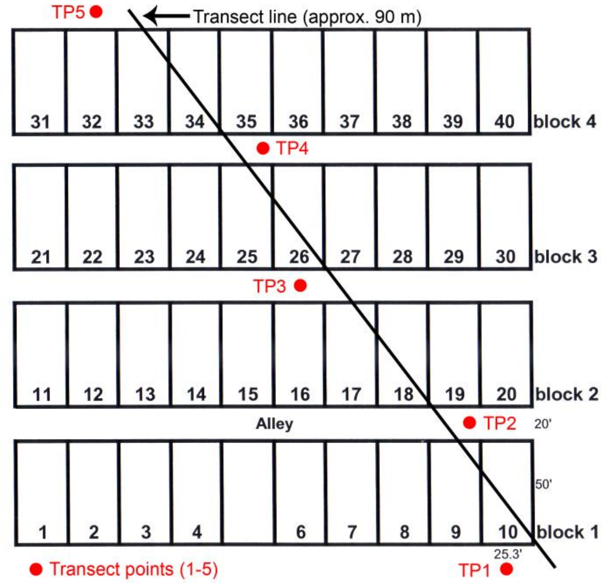

Figure 5. Five transect sampling points offset approximately 15 feet from the transect line in the direction of increasing subsoil blow-out (TP1 through TP 5).

Figure 6. Soil coring with the Giddings hydraulic probe. Interns learned to operate the machine as well as extract, clean, section, and composite soil cores.

Figure 7. View of typical near-undisturbed soil core after extraction from the drive tube. Three cores were obtained at each of five transect sampling points and composited.

Analysis

We used the hydrometer method of Gee and Bauder (1986), slightly modified for this project, to determine particle size distribution (PSD). Particle size distribution is the relative amount of sand, silt, and clay in a soil sample, usually expressed as per cent. In the USDA system, particle sizes are classified as: sand 2.0-0.05 mm, silt 0.05-0.002 mm, and clay <0.002 mm. Materials >2 mm are course fragments like gravel, stone, and cobble, and are not considered as 'soil'. Also, organic matter is ignored.

Laboratory equipment needed for PSD includes a mixer (hand or mechanical), settling cylinder, Bouyoucos hydrometer, dispersant, thermometer, and balance accurate to at least 0.1 g. A convection oven is desirable for soil drying but not absolutely necessary; access to a microwave oven or propane-fired camp stove will suffice in field situations.

The *hydrometer* is a device that compares the density of a soil-water suspension with the known density of water alone. The density of a soil-water suspension is measured with the hydrometer at timed intervals that are computed from Stoke's Law of settlement:

$$v = 2gr^2 (\rho_s - \rho_l) / 9\eta$$

Where v is the sedimentation velocity (m s^{-1}), r the particle radius (m), g the gravitational force per unit mass (9.81 N kg^{-1}), ρ_s the density of the particles (2650 kg m^{-3} is taken as the average), ρ_l is the density of the liquid (998 kg m^{-3} at 20° C for water), and η is the viscosity of the liquid (1.002 x 10^{-3} N s m^{-2} at 20° C for water). Provided standard conditions are imposed, it can be assumed that densities, gravity, and viscosity components do not vary and can be expressed by a constant (K). The simplified form of the equation is then:

$$v = Kr^2$$

A ten per cent solution of chemical dispersant sodium hexametaphosphate was added to the soil-water suspension to disperse one inorganic particle from another. Temperature differences in the soil-water suspension affect the internal resistance to flow (settlement velocity) so temperature of the suspension was measured immediately after each hydrometer reading. In addition, a separate 50 g sub-sample of soil was dried in a container overnight at 105° C to compute results on a moisture-free basis.

To calculate the percent sand, silt, and clay in the soil sample, two correction factors, one for the reagent, and one for the temperature were calculated for each sample as follows:

reagent cf = hydrometer reading (g/L) + 0.36 (°C – 20)

temp. cf = hydrometer reading (g/L) + 0.36 (°C – 20)

The correction factors must be calculated because the hydrometer is calibrated to read "g soil remaining in suspension at 20° C". The hydrometer will float deeper or higher if the suspension is warmer or colder, respectively, than 20° C. Therefore we added 0.36 g/L, or subtracted 0.36 g/L for each 1 degree above or below 20° C, respectively. Similarly, the reagent alters the density of the suspension, so a correction factor must be calculated for it as well.

Per cent sand, silt, and clay for each soil sample was calculated as follows:

$$\%\ silt + \%\ clay = \frac{\text{corrected 2 min reading (g L}^{-1})}{\text{oven-dry mass of soil (g)}} \times 100$$

$$\%\ sand = 100 - (\%\ silt + \%\ clay)$$

$$\%\ clay = \frac{\text{corrected 24 hr reading (g L}^{-1})}{\text{oven-dry mass of soil (g)}} \times 100$$

$$\%\ silt = 100 - \%sand - \%\ clay$$

The USDA system divides all possible mixtures of sand, silt, and clay into 12 textural classes. We used the USDA textural triangle to determine to which class the soil samples belonged, based on particle size distribution (figure 8).

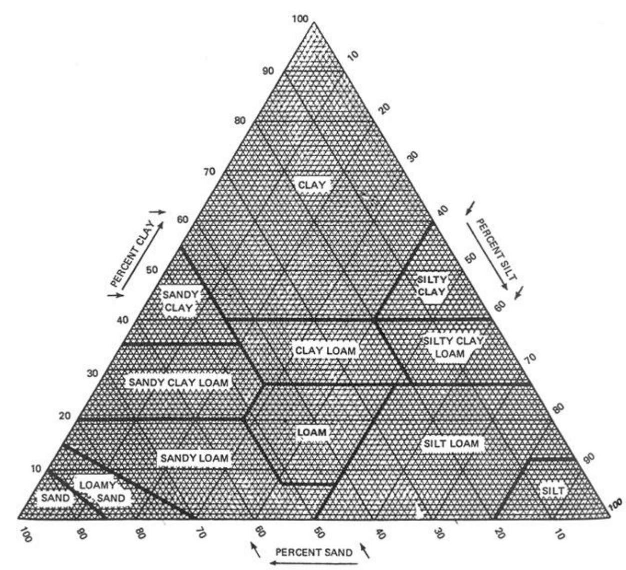

Figure 8. USDA soil textural triangle. Read the per cent sand, silt, and clay in the direction of the arrows on each of the triangle's axes. The intersection of the lines at a single point designates the textural class. There are 12 USDA textural classes.

Results

Due to an unfortunate accident, data from transect points 2, 3, 4 were lost. However, data from transect points 1 and 5 are presented in Table 1. Our interpretation of the data follows.

- Change in soil texture was detected in the 0-15 and 15-30 cm zones between transect points 1 and 5.
- Textural change is most evident in the clay fraction. At transect point 1, clay content was 34 and 40 per cent in the 0-15 and 15-30 cm zones, respectively.
- At transect point 5 the clay content was 6.1 and 20.3 per cent in the 0-15 and 15-30 cm zones, respectively.
- Clay content in the 15-30 cm zone was nearly 2-fold greater at transect point 1 compared to transect point 5.
- Working depth of the KMC subsoiler was approximately 25-30 cm. Higher clay content 25-30 cm deep around transect point 1 may explain the problem with 'blow out' in this area, compared to better performance around transect point 5.

Table 1.

Transect Point 1.

depth (cm)	% sand	% silt	% clay	USDA Textural Class
0-15	64.6	1.4	34	Sandy clay loam
15-30	22.3	37.7	40	Clay loam
30-60	36.8	33.6	29.6	Clay loam
60-90	51.0	19.2	29.8	Sandy clay loam

Transect Point 5.

depth (cm)	% sand	% silt	% clay	USDA Textural Class
0-15	62.4	31.5	6.1	Sandy loam
15-30	35.6	44.1	20.3	Loam
30-60	36.8	43.4	31.7	Clay loam
60-90	31.3	40.1	28.6	Clay loam

Conclusion

The performance of a subsoiling implement depends in part on soil texture at the working depth of the ripper shank. Therefore, it is important to adjust ripper depth such that compaction in the overlying soil is alleviated without disturbing the clayey B_t horizon. Because depth to the B_t horizon varies spatially in the landscape, some problem with clay uplift may be inevitable but this can be minimized by *understanding your soil texture*.

References Cited

Gee, G.W. and J.W. Bauder (1986). Particle Size Analysis. *In*: Methods of Soil Analysis. Part 1, 2nd Ed. A.Klute (ed.). Agron. Monogr. 9. ASA Madison WI, pp. 337-382.