10. Soil surface crusting—often overlooked, is easily prevented! Naked soil surfaces form a crust, leading to problems such as:

- poor stands, especially of cotton and soybeans
- increased water runoff
- increased soil erosion
- decreased soil moisture
- impedance of air exchange from soil to atmosphere
- erratic stream flow
- impaired stream habitat
- reduced wildlife food (amount and variety)

Surface Crust Prevention:

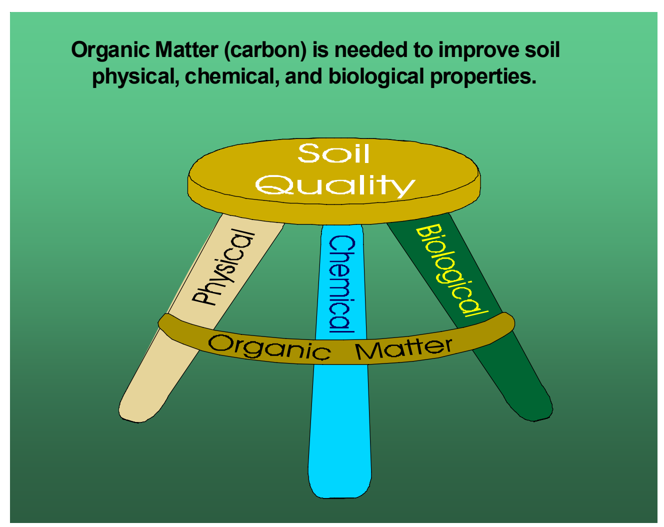
- through complete soil surface cover by the residues of previous crops or from cover crops

How much surface residue is enough?

—As much as you can manage and still get good crop stands, using good equipment and a careful operator!

11. Soil Organic Matter—A key to soil quality, economic stability, and environmental stewardship:

- Consider soil quality as a three-legged stool. The three legs represent physical, chemical or biological soil properties. All of these are inter-related and interdependent. Organic matter (soil carbon) af the extent and the nature of influences on crop fects production for each of these soil properties.



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Long Term No-Tillage: Effects on Soil Carbon and Soil Density Within the Prime Crop Root Zone

Project Report
January, 2006

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- Corn Growers Association of NC, Inc.
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- Innovative farmers committed to economical and environmentally sustainable production through the use and improvement of no-tillage technology

Part One of This Study

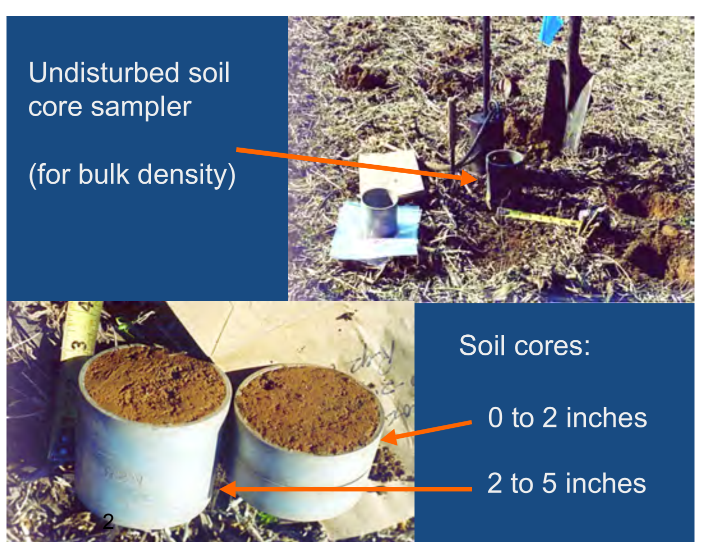
For six years (1996 through 2001 crop seasons) a field experiment with large, replicated plots was conducted at the Center for Environmental Farming Systems, located on the Cherry Farm, Goldsboro, NC. The experiment centered on a comparison of continuous conservation tillage with all crops planted by no-till coulter planters, and always into wheat or oat cover crops, versus the same crops planted into plots prepared by conventional tillage (chisel plow/disk/field cultivate) with no preceding cover crop. Each year the following rotations were followed under both forms of tillage: Corn/Full Season Soybean, Corn/Double-Cropped Soybean and Corn/Peanut/Cotton. All crops were present every season, using recommended agricultural pesticide applications, crop varieties and seeding rates. The same fertilization, planting dates and varieties were used for the Conservation Tillage and Chisel Plow/Tilled plots. An unusually detailed soil map of the 50-acre experimental area was developed. It revealed a high degree of soil variation, in several cases at least two soil map units in the individual 2/3-acre field plots.

In general, yields were quite variable even within individual plots, but this variability was greater for the Conservation Tillage plots than the Chisel/Tilled plots. This high degree of yield variability kept long-term average No-Till yields somewhat below Chisel/Till yields, but in some years the NT yield disadvantage was up to 1/3 less. This depended greatly on occurrence of periods of agronomic wetness, more so than on periods of drought stress. It was especially apparent for the corn and soybean crops. In some seasons it was caused by increased insect, disease and weed pressures for corn, wheat and peanut crops, and in digging and harvest losses for peanut.

Late summer view of Full Season Soybean (30 inch rows) in a Chisel/Tilled Treatment

Same-day view of a plot of No-Tilled, Full Season Soybean in 30 inch rows. Note the increasing loss of vigor (due to wetness) in the picture foreground.

More specific possible causes for these growth problems were also explored, using regular soil testing, plant tissue tests, soybean nodulation effectiveness and examination for plant root diseases. No other specific cause was identified.



In early spring, 2003 areas within the experiment were carefully selected for study, chosen according to the differing crop rotations, history of production under No-Till or Chisel/Till culture and within areas of six different mapped soils. Within each area four replicate samples were collected for determination of soil bulk density and the measurement of total soil carbon and nitrogen contents. In each case samples were taken at soil depths of 0 to 2 inches and 2 to 5 inches.

Shown at left is the special equipment used to collect these soil samples at the two depths. In each case, sampling was done at about 8-12 inches beside any evident previous crop row, and any apparent previous wheel track was avoided.

Part Three: Building and Managing for Soil Quality

1. Additional information from this study shows:

- Organic matter increases in the top 2" are not that hard to achieve, and
- It takes lots of biomass to get those increases, so just parking the plow is not sufficient! And,
- You can expect a more friendly root zone with higher soil organic matter content, but
- Organic matter content increases below 2" are harder to achieve, **especially** in "coarse" textured soils!

2. More Results from this study:

- The lowest soil organic matter levels were found under the lowest amounts of estimated biomass returned to the soil (average 3,400 lbs./ac/yr).
- The highest soil organic matter levels were found under the highest amounts of biomass returned (average 11,800 lbs./ac/yr).
- Number of years in no-till are important, but cannot offset lower amounts of biomass returned to the soil surface.

3. Now, this raises some questions:

- SHOULD we try to raise O.M. in lower root zones?
- WHAT are the benefits if we do?
  —better bulk density, aeration, soil moisture, and conditions for efficient nutrient utilization
  —easier root growth and more extensive root system
  —better balanced biological community
- CAN we do that ? Economically ? ?
- HOW ?? By using tap-rooted cover crops? Deeper rooted cover crops? Perennials? Bio-drilling (radish)? Vertical tillage? Use of gypsum? A combination?
- These ideas and others deserve further testing.

4. How About Carbon Storage?

- Each 0.1% increase in organic matter = 1160 pounds of soil carbon/acre.
  —Example: An increase from 2.9% to 3.6% OM would store four tons more carbon/acre. On 100 acres, this means there would be 400 tons more carbon stored within the surface three inches of the land.
  —Example: Increase from 2.9% to 4.3% will store eight tons more carbon/acre; on 100 acres, this will store 800 tons more carbon to three inches soil depth.
  —Fact: One ton carbon added to soil equals 3 2/3 tons of CO^2 taken from the air. Will we see carbon traded?

5. The Conservation Security Program (CSP):

- Emphasizes "Reward the best—Challenge the Rest."
- A new direction in farm financial assistance, it is pointed toward environmental improvements.
- Rewards the best for their soil quality contributions, with increasing soil organic matter as a key.
- Increase in the soil conditioning Index is rewarded

6. The Soil Conditioning Index is:

- A weighted value that accounts for:
  — Extent of erosion control
  —Amount of biomass returned to the soil
  —Type and intensity of tillage used
- Calculated automatically as part of the RUSLE2 calculation.
- ***Basically you need lots biomass and not much tillage***

7. We Can Use No-Till and Cover Crops to Help:

- Improve soil organic matter
- Capture soil nitrogen and control nitrogen release
- Carbon sequestration
- Cation exchange capacity
- Farm program eligibility
- Soil fertility maintenance
- Erosion control
- Overall soil quality improvements

8. Is Crop Residue Enough?

- First, organic matter in most fields needs to be rebuilt; then the level should be maintained.
- Here are estimates of residue returned to land:
  —Corn (100 bu) = 5600 lbs. residue/acre
  —Wheat (50 bu) = 5100 lbs. residue/acre
  —Soybeans (35 bu) = 4200 lbs. residue/acre
  Total = 14,900/2 = 7450 lbs. average/acre/year
  But, if the straw is baled the returned residue drops to 5400 lbs./acre (only the amount for maintenance).
  —Cotton (960 lbs) = 4320 lbs. residue/ac. (not enough)
  Add cover crop of 6000 lbs.=10,320 lbs.total/ac./yr.
  —Corn silage (20 tons) = 500 lbs.residue (not enough)
  Add small grain cover of 8,000 = 8,500 lbs./ac/yr
  —Maintenance needs = about 5,000-6,000 lbs./acre/yr

9. Can your soil hold its nutrients? These studies also showed that under continuous no till:

- Conservation tillage helps increase topsoil nitrogen
- Higher rates of plant materials (biomass) are needed.
- Remarkably good levels of fertility and pH are maintained with no-till culture and lots of biomass.

Conservation Tillage:
More Carbon "Sequestered" and more N Captured

Soil (Drainage Cl.)	Av. Sand	Av. Silt	Crop Rotation	Soil C	Soil N
				Difference for NoTill VS CP/Disk	
	%	%		----------(Lbs/A-5 in.)----------	
State (Well)	52	34	Corn/FS SB	+ 2,116	+ 201
State (Well)	52	34	Corn/Pnut/Cot	+ 1,093	+ 92
Altavista (Mod. Well)	45	38	Corn/FS SB	(-) 880	(-) 54
Newbegun (Well)	31	53	Corn/Wh-DC SB	+ 2,206	+ 287
Newbegun (Well)	31	53	Corn/Pnut/Cot	+ 637	+ 76
Yeopim (Mod. Well)	31	50	Corn/FS SB	+ 2,819	+ 123
McQueen (Well)	52	41	Corn/FS SB	+ 3,185	+ 421
Dogue (Mod. Well)	48	40	Corn/FS SB	(-) 800	+ 143
Dogue (Mod. Well)	48	40	Corn/Wh-DC SB	+ 1,730	+ 704
Dogue (Mod. Well)	48	40	Corn/Pnut/Cot	+ 185	(-) 311

Note (above) the biomass of winter annual weeds and the wheat cover crop that was killed at advanced head stage before planting the cotton crop, shown emerging in the Tillage Systems Experiment at CEFS.

- **Winter cover crops and no-tillage culture allowed the "sequester" of significant additional amounts of measured soil carbon to 5 inches depth per acre, as compared with the conventional Chisel/Till treatment (shown above).**

- **Note also the increased amounts of biological, non-leaching nitrogen held in the soil because of the Conservation Tillage System. In contrast, approximately these amounts of nitrogen probably leached downward through the topsoil and toward the groundwater under the Chisel/Till system, because the same rates of N had always been applied to both forms of tillage (shown above).**

Soil carbon (organic matter) is a key to good soil quality. These studies confirm the essential role of plant biomass in maintaining a favorable root zone and point to opportunities for further studies.

Technical Conclusions From the CEFS Study

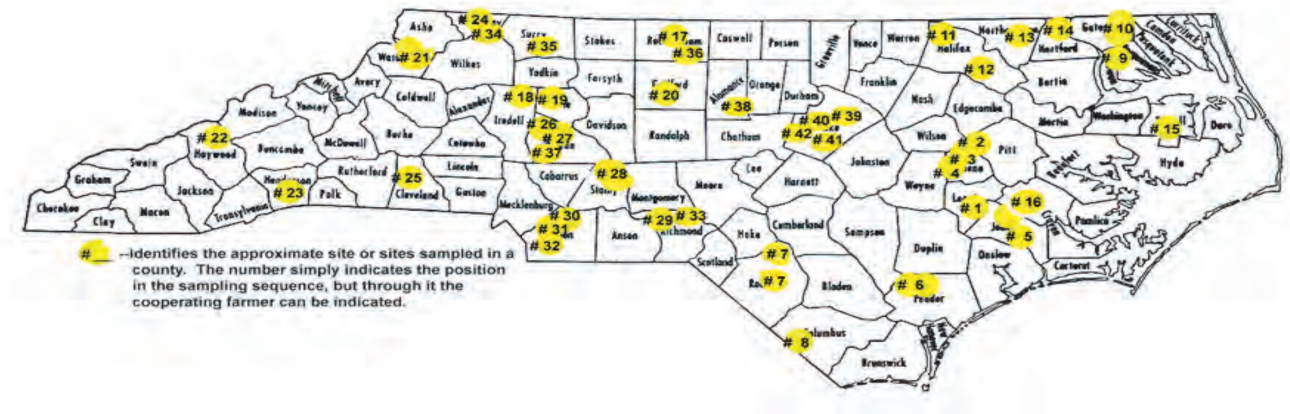
- **To a major extent, an adequate soil carbon content protects and sustains favorable soil density—and thereby, it enhances favorable soil porosity, drainage and soil hardness, especially during periods of soil dryness.**

- **Continuous conservation tillage increases soil C to about 2 inches depth; but just below 2 inches the soil carbon content may be inadequate to keep the soil from becoming too dense.**

- **Conservation tillage, especially with winter cover crop use, does sequester significant amounts of atmospheric carbon. In the CEFS study, after six years of continuous conservation tillage in most comparisons we measured from 1000 to 3000 pounds/acre-5 inches more carbon —compared to the same soils and rotations under Chisel/disk tillage where no cover crops were used and conventional crop residue destruction was practiced annually.**

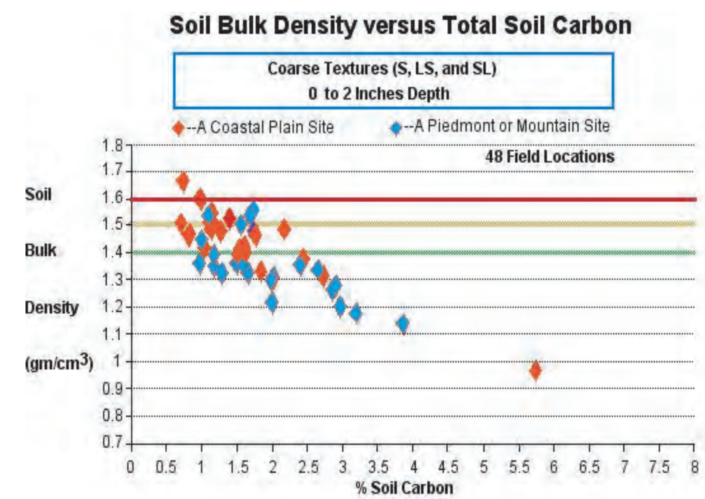
- **Conservation tillage as practiced in the CEFS study over six years also generally had captured 100 to 400 pounds more N per acre-five inch depth, compared to conventionally tilled plots receiving chisel/disk/field cultivator tillage annually.**

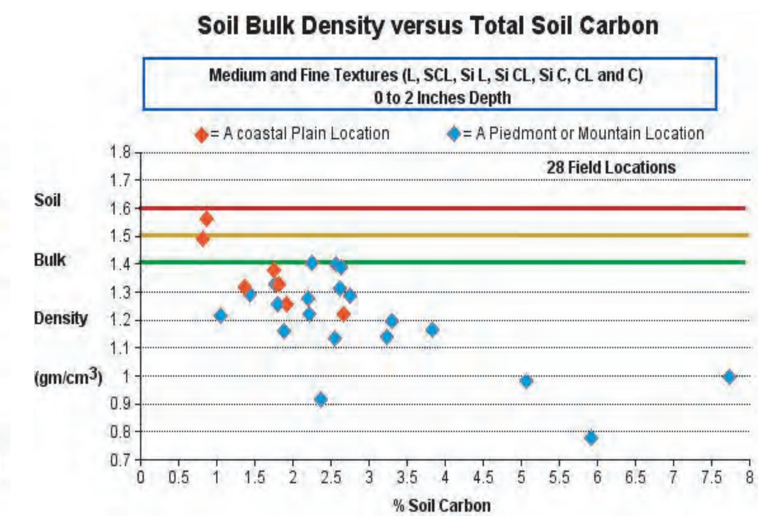
Part Two - Sampling of Farm Fields Across North Carolina

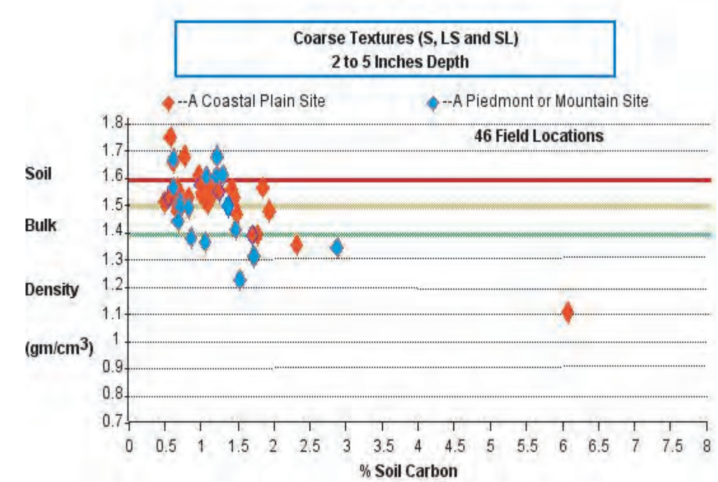


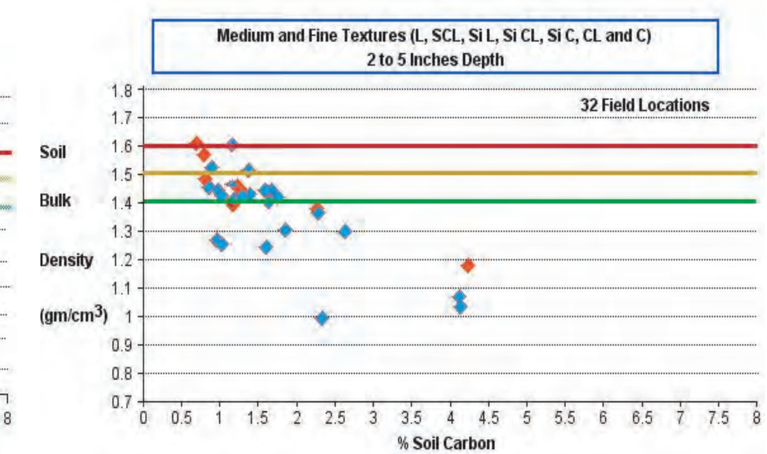
Farm fields were sampled in the North Carolina counties shown above.

The duration of continuous no-till or strip-tillage culture in these fields ranged from six to over 30 years. The same sampling procedure was used as in the CEFS experiment, with four replicate samples at each soil depth for each of 74 field sites. This expanded sampling included 592 pairs of samples, each pair taken within one foot proximity; one member of the pair was for soil bulk density and the other for the carbon/nitrogen determinations.



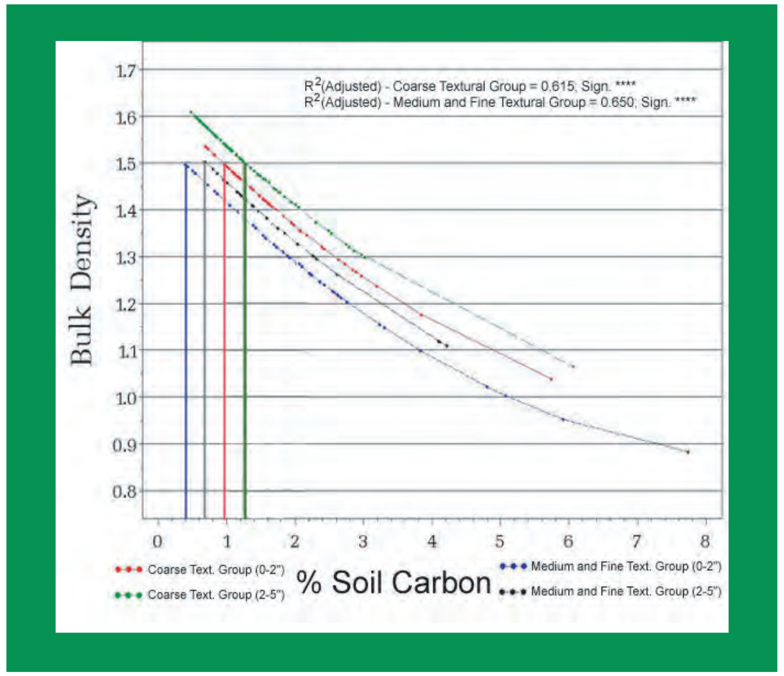






In the charts above colored points are averages (four replicate samples) for Soil Carbon content and Soil Bulk Density of samples in Part Two of the study. Note the number of sites above the yellow line (soil bulk density at 1.5 gm/cm^3), especially at the 2 to 5-inch depth (bottom charts). Soil density above 1.5 gm/cm^3 is less than ideal for root activities, especially when soils are somewhat too wet or dry. Visually contrast the two soil textural groups, noting that in the "Medium and Fine Textures" bulk density was rarely above the yellow line.

Understanding the Influence of Soil Carbon in Managing Soil Compaction



The curves at left were produced by equations, found through statistical analysis of the data on the previous charts (74 areas within farm fields mostly under continuous no-till or strip-till production). Known as regression equations, these allow useful estimates of the soil carbon level typically associated with a given soil density.

Two equations, differing only slightly, correspond to the two soil textural groups. For each textural group the line is higher in density for the 2-5 inch depth. This means about 1/4% higher carbon is needed for a desired density below two inches compared to surface layer.

Note the estimated soil carbon percentage needed to sustain the level of 1.5 gm/cm³ in soil density at each depth of the two soil textural groups. Coarse Textured soils at 2-5 inches (note the green line) need about 1.25% soil C (2.16 % Organic Matter).

Of the 46 field sites with coarse textures, 35% of them had this much soil carbon—but nearly all of those were either naturally dark soils (poorly drained), or these fields were in continuous grass sod. For the Medium and Fine Textures (note the gray line) only about 0.7% carbon (1.2 % Organic Matter) was needed. All 32 field sites in this textural group had at least this level of soil carbon content.

For Farmers Using Conservation Tillage — Practical Conclusions From This Study

• Know your surface soil textures; use the information in your County Soil Survey!

• If you have areas with surface soil textures of Sandy Loam, Loamy Sand or Sand, these areas will be very susceptible to this “low carbon/high density” concern. And/Or:

•Suspect this problem if crop growth is unsatisfactory, especially in rather wet, cool springs or during rapid onset of droughty conditions.

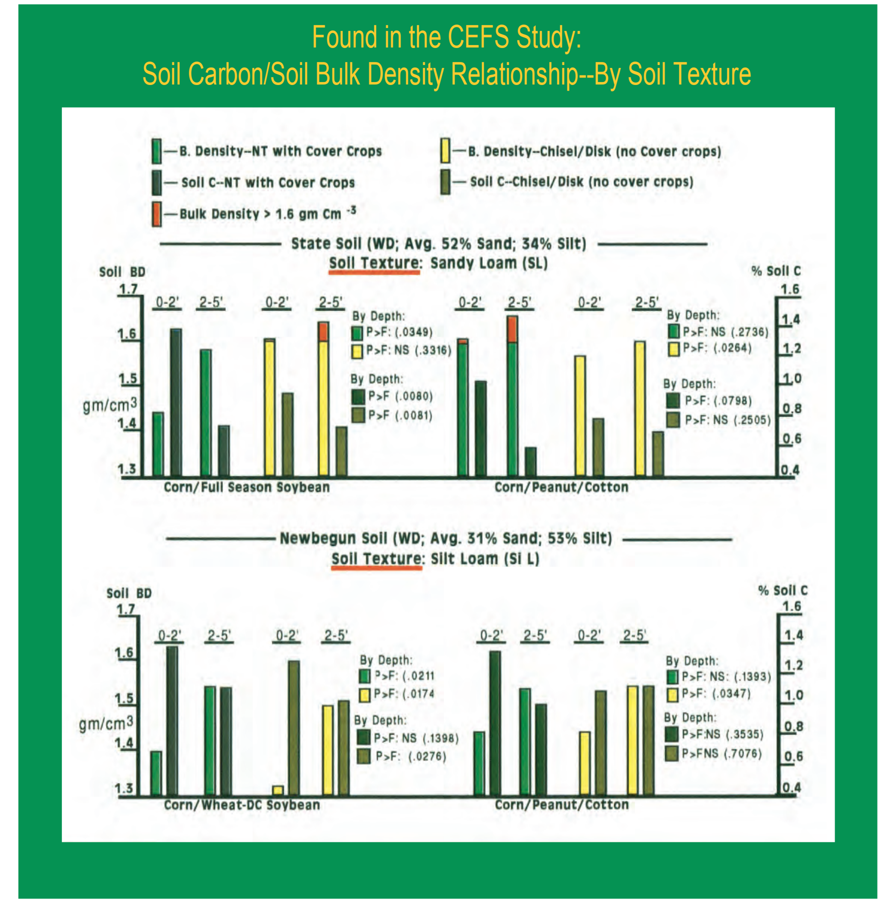
• If high soil density is developing, (soil bulk density above 1.5 gram/cm³) encourage the use of soil loosening by appropriate tillage. To do this we urge the use of non-inversion tools that offer minimum areal disturbance of the soil and surface residue.

• Consider the use of strip tillage equipment for the seed zone, operated no deeper nor more often than needed. Also, follow existing guidelines for deep tillage where appropriate, primarily in the more sandy, “pan-layer prone” soils.

• We urge the use of winter cover crops together with emphasis on all forms of biomass production and conservation, and its return to the soil surface– for all soils, no matter what the texture.

• For the medium and finer textures (Sandy Clay Loam, Loam, Silt Loam, and finer)–it is much easier to sustain soil carbon content (organic matter) and favorable soil density. Don’t abuse these soils by leaving inadequate surface residue cover; because there is major erosion and surface crusting hazards, The soils are best protected by surface residues. If you farm these soils, appreciate the advantage you have for easier soil quality maintenance!

• We urge the exploration of changes in cover crops and management of them, as well as innovations in subsurface soil loosening, to help producers achieve optimum crop productivity with continuous conservation tillage on all soils.

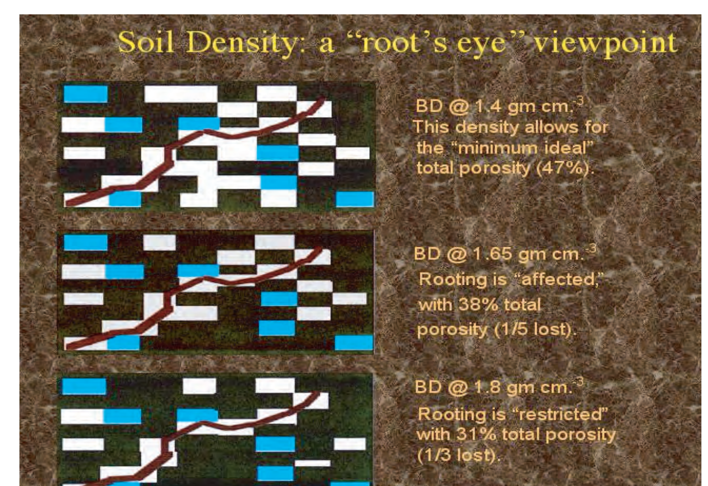


At left note that as soil C (dark gray bars) decreased from the 0-2 inch depth to the 2 to 5 inch depth, the density (degree of soil compaction) — shown by green or yellow bars — always increased to nearly 1.6 gm/cm³. At that density root growth and activity are likely to be limited. This was true for both No-Till and Chisel/Till treatments. With annual tillage this high density is loosened. However, under continuous no-till culture growers assume that a near-ideal rooting environment exists, especially in this prime depth zone for root establishment and early growth.

With the Corn/Peanut/Cotton rotation under no-till culture, there was even lower soil C with excessively high soil density (shown as red bar segments) for the more sandy State soil.

Contrast these effects for the State soil with those of the more silty Newbegun soil (lower chart). This finer-textured soil was “more carbon friendly,” and thus, it was more resistant to developing high density (soil compaction). This was true for both crop rotations.

The results for the more sandy State and more silty Newbegun soils (shown above) revealed a consistently inverse relationship (proven statistically) in which soil density (or degree of compaction) was lower where soil carbon was higher. This was true BOTH for No-Tilled and Chisel/Tilled plots. Conservation tillage increased soil carbon and reduced soil density in the 0 to 2 inch zone, compared to the Chisel/Tilled treatment, but at 2-5 inches soil carbon under NT was often significantly less than under a culture with annual tillage (found in 4 of 10 comparisons). From this sampling in early spring, soil density at 2 to 5 inches was generally similar under No-Till and Chisel/Till treatments. In all cases it was near or above 1.6 gm/cm³ — except where the soil texture was less sandy, with higher silt content.



At left, black indicates the volume of soil minerals. The white (air) and blue (water) make up the volume of “porosity” in the soil. The brown root must grow within such pore spaces. Note that the small increase in bulk density from 1.4 to 1.65 gm/cm³ results in a loss of about 1/5 of total pore volume, but it is likely to”affect” the zone of root development. During the period of root system establishment, this can result in shallow root depth and poor season-long nutrient and water capture. Density of 1.6 to 1.8 gm/cm³ was found in deeper zones of tillage pans — generally with few or no roots present.*

* Kashirad, A., J. G. A. Fiskell, V. W. Carlisle, and C. E. Hutton. 1967. TillagePan Characterization of Selected Coastal Plain Soils. Soil Sci. Soc. Amer. Proc. 31:534-541. (research done in Florida)

*Kamprath, E. J., D. K. Cassel, H. D. Gross and D. W. Dibb. 1978. Tillage Effects on Biomass Production and Moisture Utilization by Soybeans on Coastal Plain Soils. Agron. J. 71: 1001-1005. (research done in North Carolina)