Long-Term Tillage Effects On the Least Limiting Water Range in the North Carolina Piedmont

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Preliminary investigation of long-term effects of tillage, traffic, and depth on soil physical properties

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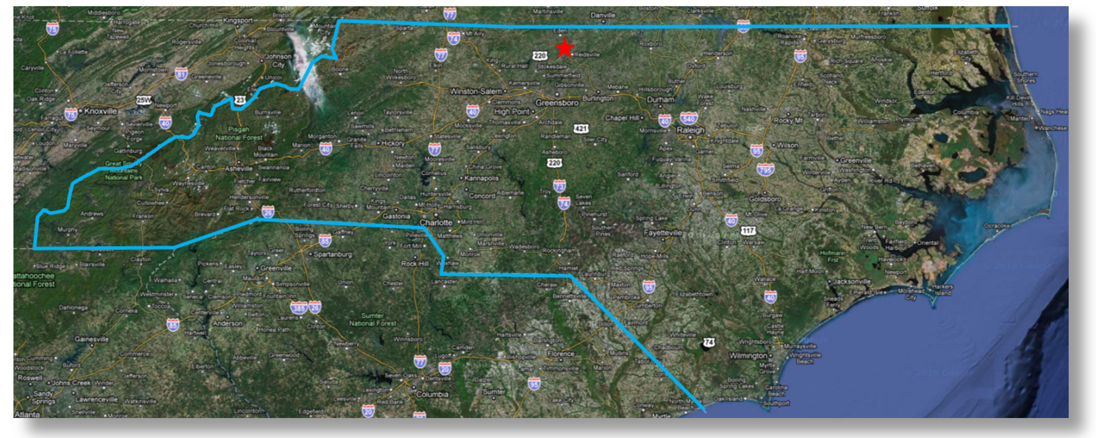
Introduction

- Periods of limited rainfall in the Piedmont region of the southeastern USA often limit crops from reaching yield potential.
- Long-term yield history at our research site indicate an inverse relationship between crop yield and tillage intensity. (NT is the top yielder)
- The Least Limiting Water Range (LLWR) incorporates bulk density, soil strength, and aeration into a model of water availability (da Silva and Kay, 1997).
- Incorporation of these parameters allows this model to be more sensitive to soil management than the typical model based solely on field capacity and permanent wilting point.
- We analyzed a host of soil physical properties from core samples taken at our site in 3 row positions and six depths from nine tillage treatments at a long-term (28 yr) tillage study, in the North Carolina piedmont.
- *We deemed it appropriate to present these results prior to pursuing the LLWR analysis. Some of these results are shown here.*

Objective

- To examine the effects of tillage, row position, and depth on bulk density; percent sand (S), silt (Si), clay (Cl); water retention; plant-available water; humic matter content; and yield.



Location of Nine Tillage Study in NC Piedmont, roughly 100 miles NW of Raleigh, NC.

Materials & Methods

- Experiment: Nine-Tillage Study
- Duration: 1984 - present
- Soil: Casville sandy loam: Fine, mixed, semiactive, mesic, Typic Kanhapludult
- Rotation: corn – soybean
- Controlled Traffic (every other interrow)
- **Main Plot (Tillage)**:

Code	Tillage Treatment
NT	No-Till
IRS	In-row subsoiling
D	Disk
CHsp, CHfa	Chisel plow in spring or fall
CHspD, CHfaD	Same as above, plus Disk in spring
MPspD, MPfaD	Spring or fall moldboard plow plus spring disk

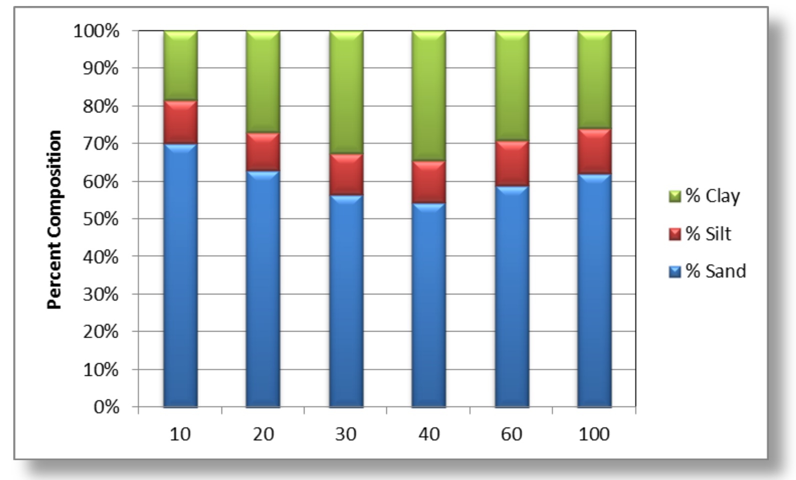
- **Depths**: 10-cm, centered at depths of 10, 20, 30, 40, 60, and 100 cm
- **Row positions** sampled: Untrafficked (UT) and Trafficked (T) interrows, In-row (R)
- Soil cores extracted in March, 2010, ahead of spring tillage
- **Parameters measured**: bulk density (BD); water retention (WR) at 10, 30, 100, 500, and 1500 kPa; plant-available water using field capacity of 30-kPa (PAW); soil texture (% S, Si, Cl); Humic Matter (HM) content
- **Experimental Design:** Split-split plot with main plot in RCBD in four blocks. Main plot: tillage; Split plot: row position; Sub sub plot: depth.
- **Analysis of Variance:** Mixed models with spatial autocorrelation of depth modeled in repeated measures.

Effect	ρ_β	Θ_v	S	Si	Cl	θ_{10}	θ_{30}	θ_{100}	θ_{500}	θ_{1500}	PAW_{10}	PAW_{30}	HM	C	HMSR	CSR
	Parameter															
	Pr > F															
T	0.05	0.65	0.22	0.74	0.37	0.1	0.004	0.05	0.2	0.22	0.38	0.05	0.12	0.17	0.0008	0.31
D	<0.0001	<0.0001	<0.0001	0.01	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	-	-
T x D	0.09	0.004	0.81	0.23	0.87	0.68	0.95	0.22	0.64	0.79	0.46	0.99	0.16	0.53	-	-
P	0.08	0.19	-	-	-	-	-	-	-	-	-	-	-	-	-	-
T x P	0.07	0.29	-	-	-	-	-	-	-	-	-	-	-	[illegible]	[illegible]	[illegible]
P x D	0.0001	0.0003	-	-	-	-	-	-	-	-	-	-	-	[illegible]	[illegible]	[illegible]
T x P x D	0.63	0.87	-	-	-	-	-	-	-	-	-	-	-	[illegible]	[illegible]	[illegible]

T, tillage; P, position; D, depth; T x P, tillage x position; T x D, tillage x depth; P x D, position by depth; T x P x D, tillage by position by depth; ρ_β, bulk density; θv, volumetric water content; θ_{10}, θ_{30}, θ_{100}, θ_{500}, θ_{1500}, volumetric water retention at matric pressures of 10, 30, 100, 500, and 1500 kPa, respectively; PAW_{10}, PAW_{30}, plant-available water using 10-kPa and 30-kPa field capacity respectively; PAW_T, total plant-available water through top 4 sampling depths; HM, humic matter; C, carbon; HMSR, humic matter stratification ratio of upper sampling depth vs. that of the bottom five sampling depths.

Results of mixed models analysis. Interactions with p-values >0.05 and <0.15 were examined per Snedecor & Cochrane (1989)

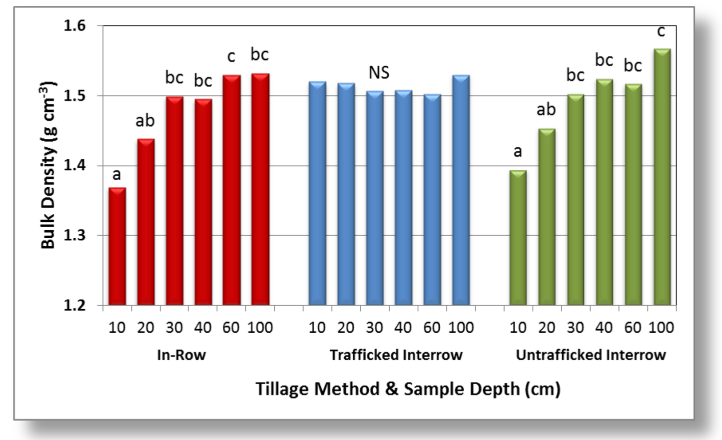
- 3-way interactions tillage, position and depth were not found.
- 2-way interactions were found in some cases.
- Main effect of depth was consistently signficant.

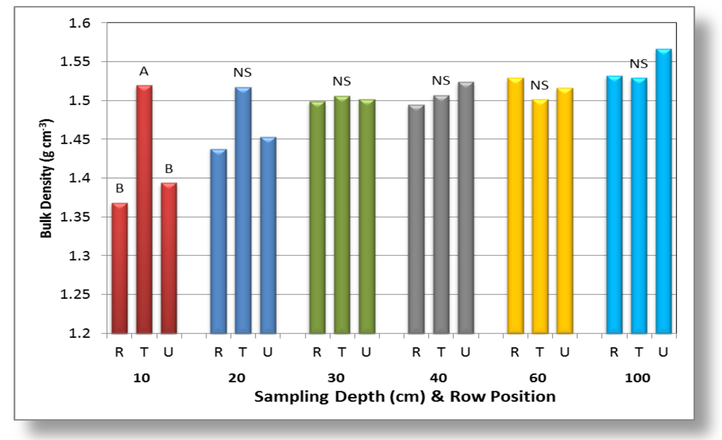


Soil particle size distribution: Sand content decreased with depth through 40 cm, increasing beyond that depth. Clay content was inverse of sand. Silt content remained constant through all depths.

Depth	CHfa	CHsp	CHfaD	CHspD	D	IRS	MPfaD	MPspD	NT
	Bulk Density by Tillage Method								
cm	g cm^{-3}								
10	1.39 b	1.47	1.40	1.42	1.40	1.43	1.35 b	1.49	1.49
20	1.45 ab	1.48	1.46	1.43	1.45	1.42	1.54 a	1.53	1.47
30	1.46 ab	1.59	1.51	1.47	1.42	1.45	1.59 a	1.54	1.50
40	1.48 ab	1.56	1.48	1.49	1.47	1.50	1.58 a	1.52	1.49
60	1.49 ab	1.53	1.49	1.52	1.48	1.53	1.54 a	1.55	1.51
100	1.58 ab	1.49	1.47	1.52	1.50	1.59	1.60 a	1.59	1.55

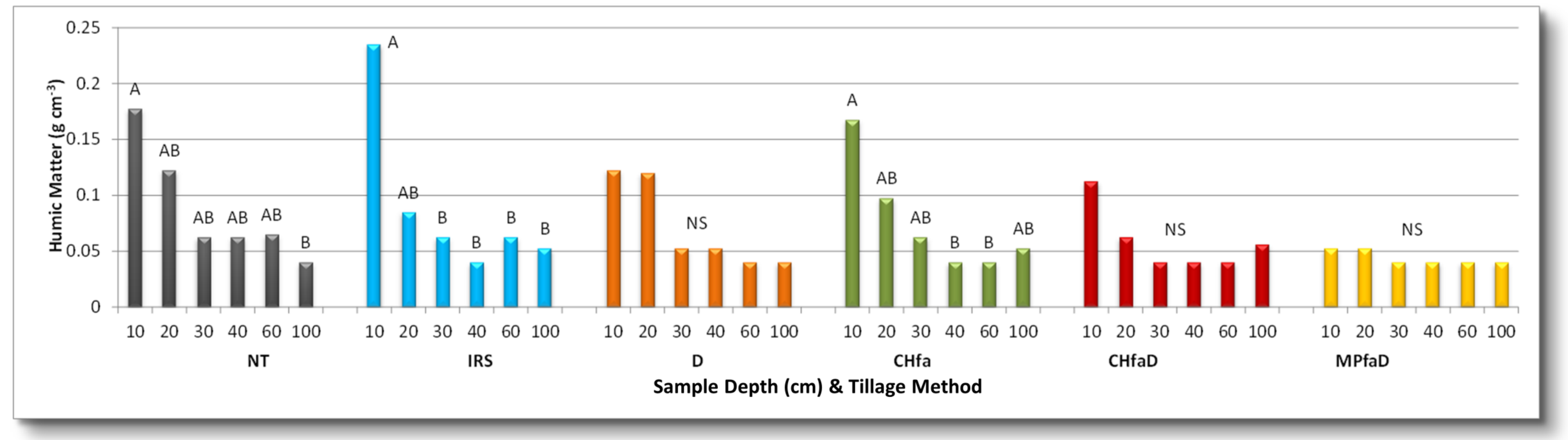
Tillage by Depth Interaction on bulk density: Bulk density was lower at upper depths for Chfa and MPfaD plots. This was perhaps due to timing of tillage and core sampling. These plots had been tilled only 5 months earlier… other plots 12 months prior. Soil loosening effects may have persisted.





The **interaction of row position on bulk density** was significant. Bulk density was lower was lowest at shallow depths in the untrafficked interrow and in-row positions. This effect was significant only for the 10-cm depth.

Letters within groups of columns indicated significant differences at α=0.05

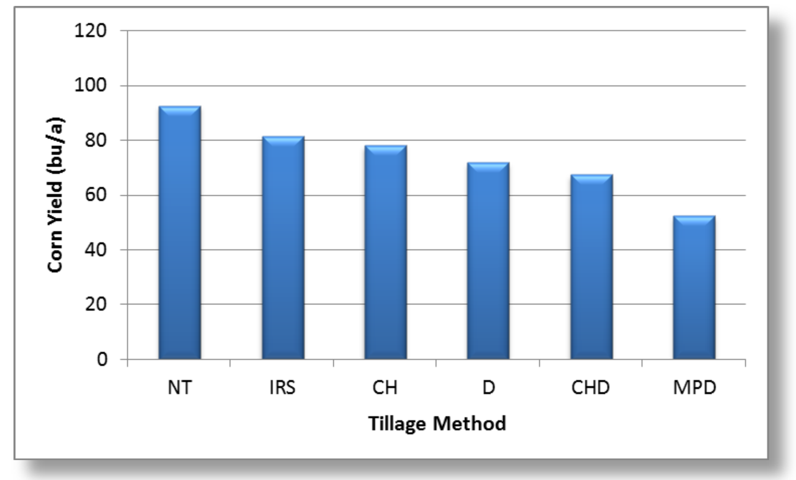


Main effect of row position on humic matter content within treatment:

Less-intense and shallower tillage methods had decreasing humic matter content with depth vs. other treatments.

Letters within groups of columns indicated significant differences at α=0.05

What goes around, comes around: Crusting is prevalent at this site in intensely-tilled plots, reducing infiltration and water storage. Effects of tillage on crusting and seasonal plant growth are obvious in drier years.



Long-term crop yields: Long-term (28+ yr) corn yields (shown at left) indicate a pattern of decreasing yield with increased tillage intensity and decreased surface residue. A similar pattern exists for soybeans.

Discussion

- Depth consistently affected all parameters studied.
- Row position (traffic) effects were detected only in interactions with tillage (T x P), and with depth (P x D) for bulk density.
- Humic matter decreased with depth for NT, IRS, and CHfa.
- The predominant factor in this trial was depth. However, limited interactions related to depth, tillage, and row position did not readily explain long-term yield trends, giving thought that the LLWR may not readily explain these differences either.
- We are examing stratification ratios of humic matter and carbon to help explain yield differences.
- We are currently examing five years of soil profile moisture content information as well.