NC STATE UNIVERSITY
DEPARTMENT of SOIL SCIENCE

Continuous Conservation and Conventional Tillage in North Carolina's Piedmont Soil Region: An Appraisal

COLLEGE OF AGRICULTURE & LIFE SCIENCES
ACADEMICS ▲ RESEARCH ▲ EXTENSION

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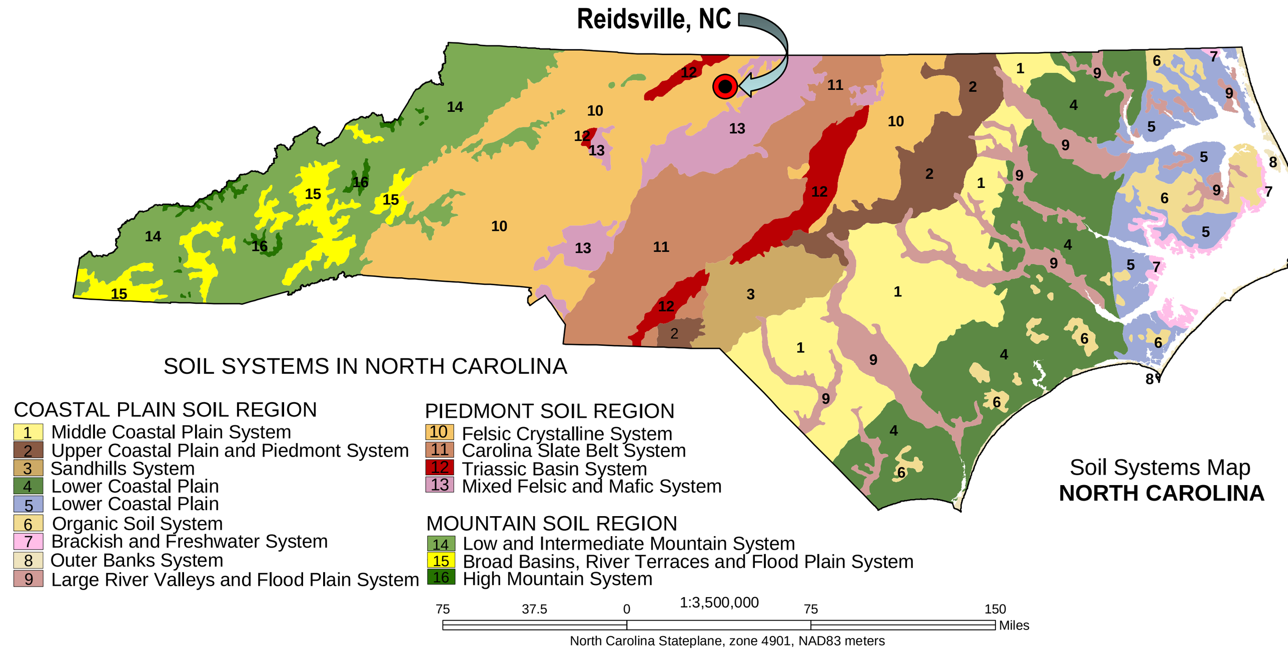
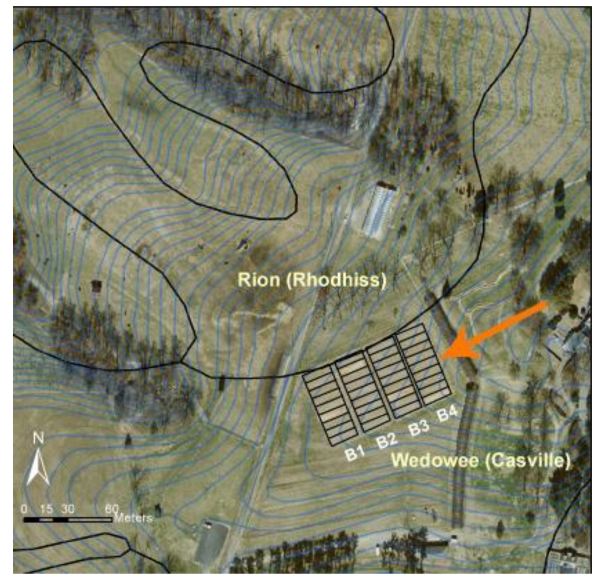
THE HISTORY

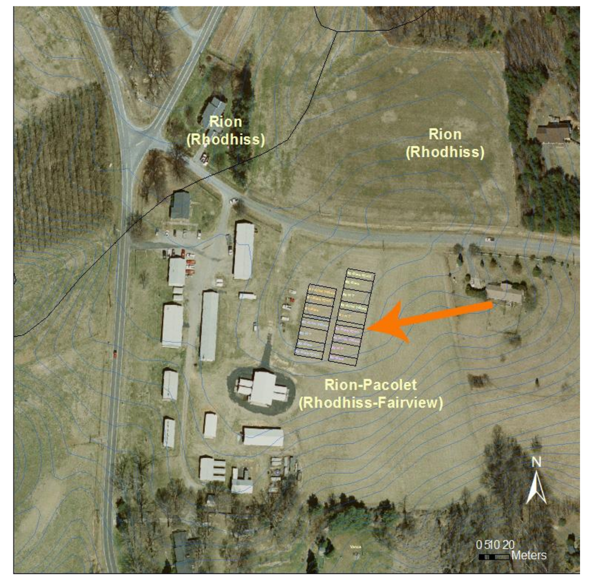
In 1984, the Department of Soil Science established two tillage trials, both on fine, kaolinitic, thermic Typic Kanhapludults at the Upper Piedmont Research Station, Reidsville, NC. On a Wedowee sandy loam soil, one trial examines nine tillage treatments varying in timing and intensity: fall or spring moldboard plowing, fall or spring chisel plowing with or without disking, spring disking only, no-tillage, and no-tillage with shallow in-row ripping. The other trial, on a Pacolet sandy loam soil, tests annually alternating tillage (conventional and no-till; no-till and shallow cultivation) compared with continuous conventional and no-till. Both trials are randomized complete blocks with traffic limited to alternating crop interrows and have been maintained in a corn or corn-soybean rotation since inception.

The Reidsville tillage trials have provided an ideal platform for diverse investigations related to soil and crop productivity and environmental stewardship over a quarter century. The underlying research objectives have changed over time, motivated by questions and timely concerns voiced by individual investigators. Here we present a summary of this research in an interpretive context, sharing insights we have gained about tillage effects on key soil properties and soil productivity in North Carolina's Upper Piedmont.





Aerial image of the Wedowee trial with 0.61-m contours and soil map units. The field site (pointer) has sloping topography typical of the southern Piedmont physiographic region. Blocks are oriented NW-SE, labeled B1 to B4. Cropping is roughly across the contour on an ~5% slope.



Aerial image of the Pacolet trial with 0.61-m contours and soil map units. The field site (pointer) is on the upper shoulder of a ridge tilting slightly westward.

Nine tillage systems established in 1984 on a Wedowee sandy loam soil at Reidsville, NC.

Early post-emergence view of soybean in two adjacent tillage systems on a Pacolet sandy loam, Reidsville, NC.

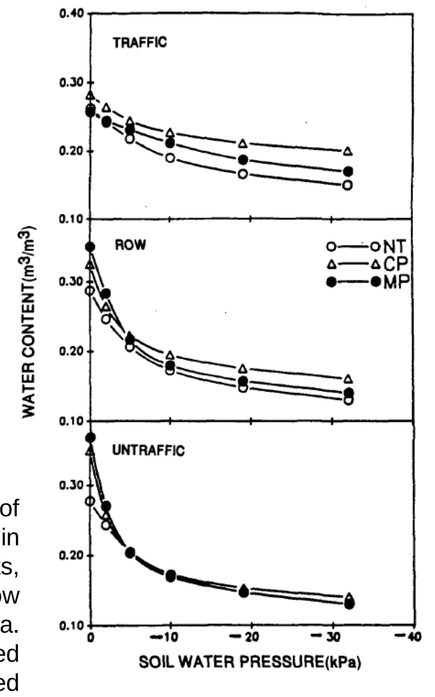
Two contrasting tillage systems in the Wedowee trial. *Inset:* Corn seedling 'whipsaw' due to soil crusting after moldboard plowing.

1980s: PHYSICAL PROPERTIES & CROP RESPONSE

Work conducted during 1986-87 in the Wedowee plots compared three tillage systems and traffic patterns on soil physical properties and corn root length density and productivity (Cassel et al., 1995). From the outset, the fragile nature of Piedmont Ultisols was exhibited by severe crusting under moldboard plow and disk tillage, a problem that continues to affect corn and soybean germination and growth in both trials.

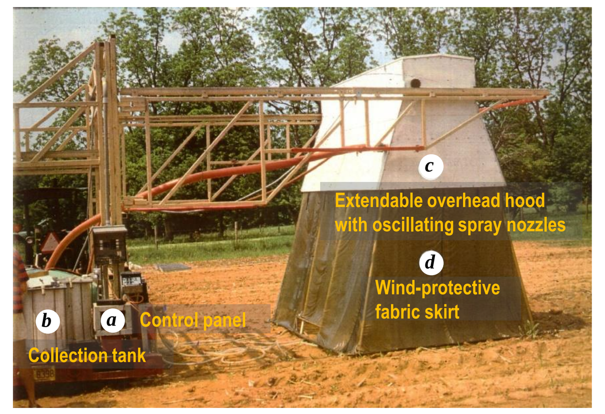
Tillage treatment	Depth	Reidsville TI	R	UI
	cm			
		Bulk density, 1986, Mg m⁻³		
No-till	0–10	1.59	1.47	1.49
	10–20	1.58	1.55	1.56
Chisel	0–10	1.55	1.41	1.23
	10–20	1.56	1.45	1.36
Moldboard	0–10	1.64	1.37	1.21
	10–20	1.63	1.38	1.36
		Cone index, 1986, MPa		
No-till	0–10	3.14	2.11	2.17
	10–20	3.90	2.74	4.27
Chisel	0–10	3.00	1.28	1.03
	10–20	3.24	1.32	1.95
Moldboard	0–10	4.41	1.11	0.45
	10–20	3.78	1.35	0.99

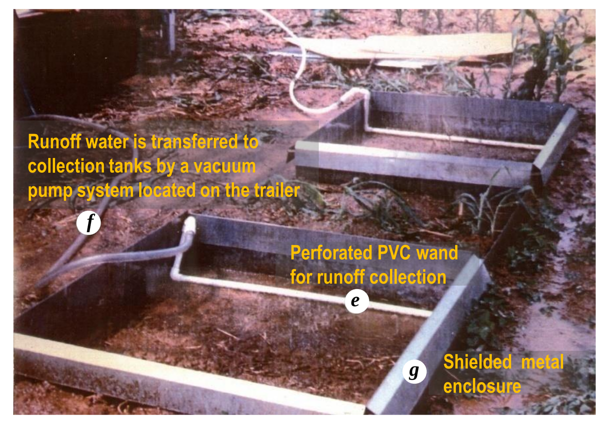
Bulk density (ρ_b) and cone index (CI) as functions of tillage system, row position, and depth, measured in 1986 by Cassel et al. For all tillage treatments, wheel compaction in the trafficked interrow increased ρ_b and CI, with all CI values above 3 MPa. Cone index values above 3 MPa are considered root-restrictive for many crops. TI= trafficked interrow, R=row, UI=un-trafficked interrow.



Soil water characteristic curves for three field positions and tillage treatments measured in 1986. Averaged over 0-20-cm depth, total porosity and macroporosity (>0.05-mm dia.) were greatest in the row and un-trafficked interrows. The least amount of water retained at -10 to -32 kPa in the trafficked interrows was under no-tillage. The authors noted, "While less crusting and more residue can get more rainfall into the soil, the resulting improved growth (tops and roots) can cause depletion of those reserves." Later work (2008) validated this claim, suggesting that surface residue and profile moisture accumulation were the primary factors controlling productivity.

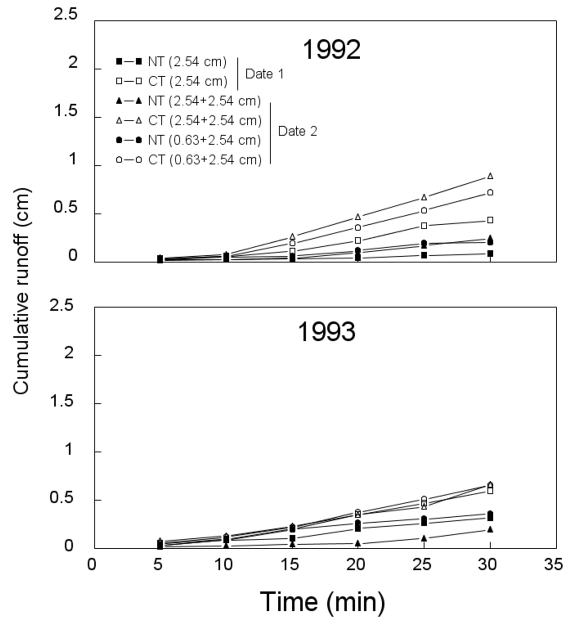
1990s: FOCUS ON THE ENVIRONMENT





Growing concern over agriculture's impact on the environment prompted researchers to examine runoff, infiltration, and sediment transport in tillage systems. A portable, variable-rate sprinkling rainfall simulator (shown above) was designed and built by the Department of Soil Science and deployed at Reidsville for this purpose.

1990s: FOCUS ON THE ENVIRONMENT, cont'd



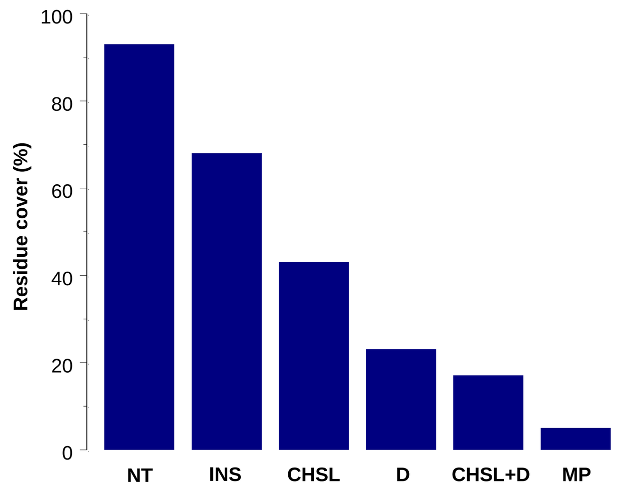
Cumulative runoff over 30 minutes measured in August 1992 and June 1993 (Afyuni et al., 1997). Pesticides (chlorimuron, nicosulfuron) in the runoff water were also measured. Chart above compares no-till (NT) and conventional chisel plow + disk tillage (CT) runoff from a Pacolet sandy clay loam. Date 1= first high rainfall (5.08 cm h⁻¹) simulation. Date 2= second simulation 1 week later at which high rainfall was applied to initial low (1.27 cm h⁻¹) and high rainfall plots. Cumulative runoff from NT was less than CT at both dates and rainfall intensities, reducing offsite transport of agrochemicals.

Tillage treatment	Rate (cm h⁻¹)	Sediment (kg ha⁻¹) 1991	1992
Early season			
CT	5.08	397	417
NT	5.08	203	21
Mid-season			
CT	5.08	932	1608
NT	5.08	208	53

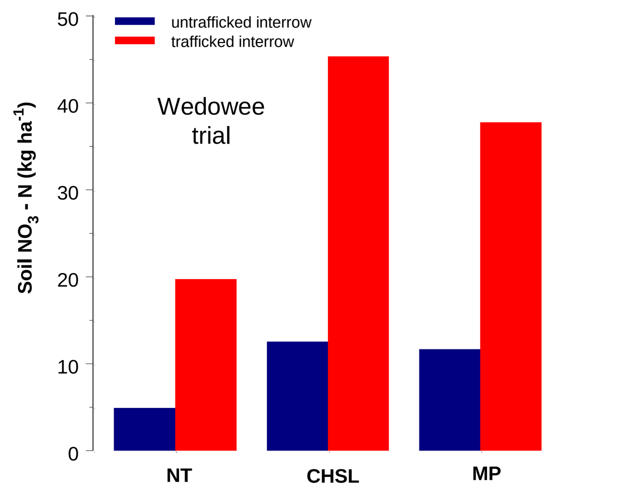
Sediment in runoff under simulated rainfall in conventional disk + chisel (CT) and no-till (NT) from a Pacolet sandy clay loam in 1991 and 1992 (Myers et al., 1996). The high sediment loss from CT compared to NT point up extreme sensitivity of weathered, low carbon Ultisols to clean-cultivation, where the risk of crusting and erosion are ever-present concerns.

Simulation time	Untrafficked NT	CP	MP	Trafficked NT	CP	MP
Pre-tillage	2.54	2.51	2.09	1.91	1.59	1.52
Early-PE	2.01	1.97	0.96	1.18	0.84	0.34
Post-harvest	2.38	2.32	2.07	1.74	1.00	0.93

Above, cumulative infiltration (cm) after applying 2.60 cm of water over a 30-min period in no-tillage (NT), chisel plow (CP) and moldboard plow (MP) at two row positions reported by Freese et al. (1993) on a Wedowee sandy clay loam. Field traffic significantly reduced infiltration in three rainfall simulations and in all tillage systems. The authors hypothesized that residue cover left after combine harvesting was responsible for post-harvest increase in infiltration observed in the tillage-row position treatments.



Residue cover can enhance available water capacity via more infiltration and reduction in surface evaporation. The chart above compares the measured percent residue cover after corn planting under no-tillage (NT), in-row subsoil (INS), chisel (CHSL), disk (D), chisel + disk (CHSL+D), and moldboard plow (MP) tillage in the Wedowee tillage plots. *(Data source: Walters and Wagger)*



Soil compaction is often called the 'silent thief'. Compaction via uncontrolled field traffic limits crop rooting and nutrient uptake as show above. Fertilizer NO_3^- - N that is not assimilated by the crop inevitably finds its way into groundwater or local waterways in runoff. (*Data source: Walters and Wagger)*

2000 ➡ PRESENT

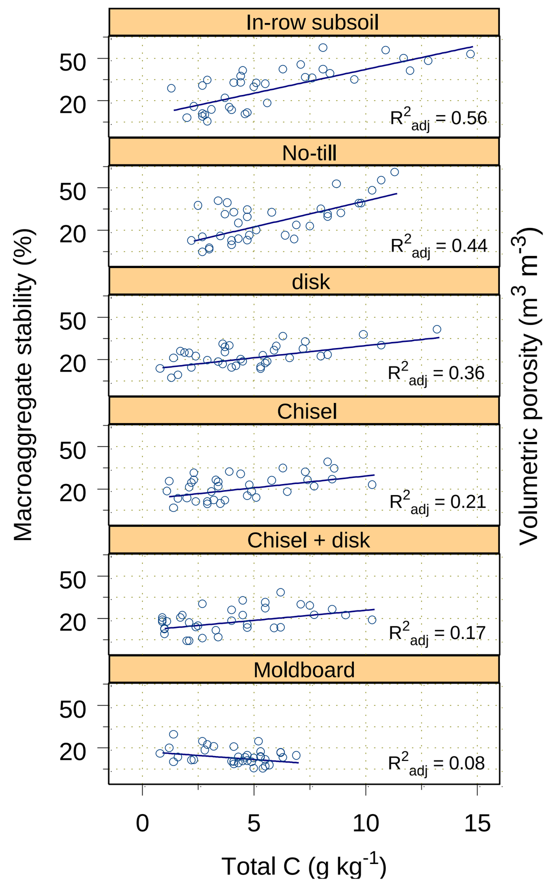
Recent investigations have attempted to characterize soil physical properties and their effect on short and long-term corn and soybean productivity. In 2006-07 bulk density, porosity, Ksat, aggregate stability, and C were measured in selected systems and row positions. Beginning April 2008, weekly soil moisture monitoring at 10, 20, 30, 40, 80, and 100 cm was initiated beneath soybean and in 2009 beneath corn using a Dynamax PR2/6 capacitance probe (Delta-T Devices Ltd., Cambridge, UK). Scanning lidar, ground penetrating radar, and electromagnetic induction measurement of soil electrical conductivity, which were unavailable earlier, are now being used to assess soil surface and profile characteristics in the tillage plots. Interest in soil quality and health is also gaining national attention in which the Reidsville tillage plots may play a pivotal role.

Monitoring profile moisture content in soybean with the PR2/6 capacitance probe. The probe is inserted into a 2.5-cm diameter plastic access tube (above) during measurement.

Remote sensing deployed to assess soil surface and profile characteristics: scanning lidar (above) for topography, ground penetrating radar (GPR) and electromagnetic induction measurement of soil electrical conductivity for profile characteristics, and aerial L-Band radar for surficial soil moisture.

Tillage treatment	Depth, cm	Wedowee TI	R	UI
		Bulk density, 2006, Mg m⁻³		
No-till	0-10	1.61	1.41	1.41
	10-20	1.61	1.57	1.55
In-row subsoil	0-10	1.61	1.21	1.38
	10-20	1.69	1.32	1.61
Chisel	0-10	1.54	1.25	1.16
	10-20	1.63	1.33	1.36
Disk	0-10	1.53	1.28	1.31
	10-20	1.63	1.46	1.52
Chisel + disk	0-10	1.53	1.20	1.20
	10-20	1.65	1.41	1.39
Moldboard	0-10	1.62	1.31	1.30
	10-20	1.54	1.45	1.22

Bulk density was measured again in June 2006, see above. Tillage treatments highlighted in red correspond to those measured in 1986 by Cassel et al. We observed marginal change in ρ_b under no-till and moldboard plow; under chisel plowing ρ_b decreased in the row (R) and untrafficked interrow (UI). TI = trafficked interrow.

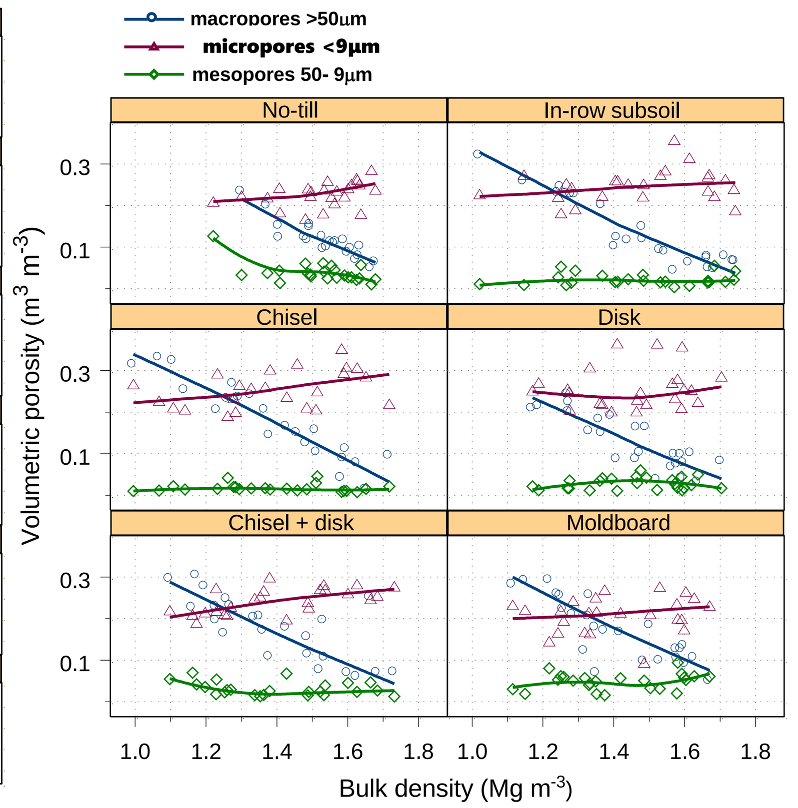


Water-stable macroaggregates (1-4 mm) and soil C (Wedowee trial) were positively related and sensitive to tillage. Panels are ranked bottom to top in order of increasing mean aggregate stability and C content. Surficial (0-10 cm) aggregate stability did not exceed 50 and 25% in the Wedowee and Pacolet soils, respectively.

Trial	Tillage treatment	PAW†, m³ m⁻³	Ksat, cm hr⁻¹ 0-15cm	15-30cm
Wedowee	No-till	0.10	0.32	0.25
	In-row subsoil	0.09	---	---
	Chisel	0.10	1.21	2.36
	Disk	0.11	---	---
	Chisel + disk	0.10	---	---
	Moldboard	0.10	2.76	1.54
Pacolet	No-till	0.17	---	---
	Disk	0.16	---	---
	Alt. no-till-disk	0.16	---	---

†0-7.5cm depth, expressed as H_20 held between -32 and -1500 KPa.

Above, together with rainfall simulation data from the 1990s suggests that improved corn and soybean grain yields under conservation tillage were related to increased infiltration and slower internal drainage, runoff, and evapotranspiration, as tillage systems did not affect surficial plant-available water (PAW).



Above, the relationship between surficial pore size distribution (0-15 cm) and bulk density under six tillage systems and three row positions in a Wedowee sandy loam soil is shown. Compaction reduced macroporosity but had little effect on capillary microporosity in all tillage systems. Compaction reduced mesoporosity more under no-tillage compared to other systems. Mesopores can be thought of as precursors to macropores, and intermediate to macro- and micropores, in their effect on soil aggregation, drainage, aeration, thermal and capillary properties. Trend lines are locally-weighted regression (loess) smoothers. (*Data source: Walters and Wagger)*

Soybean yield and profile moisture 2008

Trial	Tillage treatment	Yield, (Mg ha⁻¹)	Profile increase in H_20 (mm)
Wedowee	No-till	1.31	36
	In-row subsoil	1.08	37
	Chisel	1.13	33
	Disk	1.25	32
	Chisel + disk	0.71	27
	Moldboard	0.71	29
Pacolet	No-till	1.71	18
	Disk	1.72	19
	Alternating no-till-disk	1.24	26

Average grain yield 1988-2008

Trial	Tillage treatment	Corn (Mg ha⁻¹)	Soybean (Mg ha⁻¹)
Wedowee	No-till	4.88	2.19
	In-row subsoil	4.25	2.13
	Chisel	4.09	2.18
	Disk	3.73	2.04
	Chisel + disk	3.50	1.86
	Moldboard	2.85	1.70
Pacolet	No-till	4.86	2.31
	Disk	4.49	2.09
	Alternating no-till-disk	4.41	1.98

Preliminary results (2008) from seasonal profile moisture monitoring suggest that soybean yield was positively related to profile soil moisture associated with reduced and no-tillage in a Wedowee sandy loam soil, whereas an opposite effect was observed in the Pacolet soil. We hypothesize that differences in physical and chemical attributes in the soil root zone are responsible for these contrasting yield-profile moisture relationships, a research topic we continue to explore.

Averaged over 1988-2008, grain yield increased 2.03 Mg ha⁻¹ for corn (+ 71.2 %), and 0.49 Mg ha⁻¹ for soybean (+ 28.8 %) under continuous no-tillage vs. conventional moldboard + disk on a Wedowee sandy loam which are indicators of long-term productivity gains associated with conservation tillage on some soils. On a Pacolet sandy clay loam, differences in corn and soybean grain yield were less pronounced. Corn grain yield under no-tillage was about equal on the two Piedmont soils; soybean yields slightly higher on the Pacolet SL soil than the Wedowee SL soil. This suggests that conservation tillage can build productivity in rainfed cropping systems, but the response is crop and soil dependant.

INTERPRETIVE SUMMARY

- Percent residue cover under continuous conservation and conventional tillage has influenced corn and soybean yield more than bulk density, porosity, and soil carbon (C) content.
- Average crop yields are likely related to increased infiltration and reduced runoff and evaporation as a function of residue cover.
- Aggregate stability and C were positively related and sensitive to tillage, but the low percentage of water stable aggregates suggests that without continuous residue cover, cultivated soils in the southern Piedmont remain highly susceptible to crusting and erosion.
- Generally, mesopore and micropore fractions in Wedowee and Pacolet SL soils have not changed significantly due to bulk density or tillage factors.

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