Soil and Water Conservation via Reduced Tillage in the Georgia Piedmont

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INTRODUCTION

Piedmont soils have historically been managed under conventional tillage practices and are susceptible to runoff and sediment losses. The Cecil series is the most extensive soil in the Piedmont region, occurring from Alabama to Virginia. Because of its row-crop production history, the Cecil series has experienced accelerated erosion and subsequent degradation of its intrinsic soil properties, productivity, and overall environmental quality.

Most of Georgia receives 48-52 inches of rainfall annually. Rainfall patterns tend to generate runoff producing storms with extended periods of drought during the crop growing season. As a result, supplemental irrigation is often needed to prevent yield-limiting water stress. In Georgia, a major effort has been undertaken to conserve soil resources and reduce water and energy requirements for row crop production through conservation tillage. Conservation tillage systems offer an effective, viable management tool for row crop production and soil and water conservation. Piedmont soils benefit from conservation tillage via reduced runoff and sediment transport and enhanced infiltration and soil resistance to detachment by accumulating surface residue, increasing near surface soil organic carbon with time, and dissipating raindrop impact energy.

Current agricultural water issues and the need to reduce input costs in farming operations add importance to making sound irrigation and management decisions to ensure efficient water use, natural resource conservation, and on-farm profitability. We quantified infiltration, runoff, and sediment losses from a Cecil sandy loam managed under CT and NT systems with commercial fertilizer and poultry litter fertilizer sources.

MATERIALS AND METHODS

The study was conducted near Watkinsville, GA (N 33^{o} 54', W 83^{o} 24'). The site consisted of twelve (12) 39x100 ft plots located on a Cecil sandy loam (Typic Kanhapludult). Since 1991, study plots have been managed under CT and NT systems in a randomized complete block (split plot) design (n=3). Main plots were divided into CT and NT, and subplots were divided into 2 fertilizer treatments: mineral commercial fertilizer (CF) and poultry litter (PL). The 4 tillage-fertilizer treatments were CT-PL, CT-CF, NT-PL, and NT-CF. The study area was planted to corn (*Zea Mays*). Immediately after planting corn, 12 rainfall simulation plots were established on the tillage-fertilizer treatment plots.

Rainfall simulation plots (60-ft^2, 6-ft wide by 10-ft long) were established on each treatment (n=3). Each simulation plot had a slope of 2%. Before simulating rainfall, antecedent water content was determined gravimetrically (Gardner, 1986) at 5 depths (top 12 inches) from 5 locations surrounding each 60 ft^2 plot. The oscillating-nozzled rainfall simulator (Frauenfeld and Truman, 2004) with 80150 veejet nozzles was placed 10 ft above each 60 ft^2 plot. Rainfall was simulated at a constant (2 in h^{-1}) intensity (60 min) (water source=groundwater). All runoff (R) and soil loss (E) were collected from each 60-ft^2 plot (5-min intervals) throughout each simulation, and determined gravimetrically. Infiltration (INF) was calculated (rainfall-runoff).

Four treatments (CT-PL, CT-CF, NT-PL, NT-CF) were replicated 3 times (2 tillage systems x 2 fertilizer sources x 3 reps) for a total of 12 rainfall simulations. Means, coefficient of variations (CV, %), and standard error bars are given for measured data. We perfomred unpaired t-tests to determine significance among treatment means. All test statistics were evaluated at P=0.05.

RESULTS AND DISCUSSION

Hydrology and erosion parameters for fertilzer source (PL, CF) sub-treatments of each tillage treatment were not significanly different at the 0.05 level from each other, thus were combined into overall CT and NT treatments (n=6). Also, the 12-run average rainfall intensity (measured) was 2.21 in/h (CV=4%, NS).

Runoff (R) and infiltration (INF) for combined CT and NT treatments are given in Table 1. CT plots had 2.2 X less infiltration and 6.0 X more runoff than NT plots, eventhough NT plots had 2.5 X higher gravimetric water contents (w) in the 0-1 in soil layer (all at P=0.0001). This translates into 90% of the simulated rainfall infiltrating NT plots (CT plots=45%) and only 10% of the simulated rainfall running off NT plots (CT plots=55%), a 2 and 5.5 X difference among tillage treatments.

Differences occurred for infiltration and runoff amounts (Table 1) and rates (Fig. 1) within each event (infiltration rate curves not shown). For CT plots, runoff rates steadily increased throughout the first 40-45 min of simulated rainfall before reaching quasi-steady-state conditions (1.8-1.9 in/h). Conversely, runoff rates for NT plots increased at a much slower rate than that for CT plots never exceeding a runoff rate of 0.5 in/h. Maximum runoff rate (R_{max}) for CT plots (1.9 in/h) was 3.8 X greater than corresponding values for NT plots (0.5 in/h).

Soil loss (E) for combined CT and NT treatments are given in Table 1. CT plots had 11.1 X more soil loss than NT plots (P=0.0005), again despite differences in antecedent water content of the 0-1 in soil layer. Soil loss values given translate into 1367 lbs/A soil loss for the CT treatment and 120 lbs/A soil loss for the NT treatment.

Differences occurred for overall sediment yields (Table 1) and soil loss rates (Fig. 2) within each event. For CT plots, soil loss rates steadily increased throughout the first 35-40 min of simulated rainfall before reaching quasi-steady-state conditions (1.9-2.0 lb/A/h). Conversely, soil loss rates for NT plots increased ever so slightly never exceeding a soil loss rate of 0.22 lb/A/h. Maximum soil loss rate for CT plots (2.08 lb/A/h) was 9.4 X greater than corresponding values for NT plots (0.22 lb/A/h).

Differences in infiltration, runoff, and soil loss between CT and NT treatments can be explained, in part, by differences in the rate of surface seal development and/or soil surface protection from raindrop impact by residue. For example, difference between INF_{max} and INF_{min} (d INF) was 4.5 X greater for CT plots (1.8) than for NT plots (0.4). Values for d INF relate to degree of surface seal formation with larger values of d INF being proportional to or indicative of greater alterations or changes in each soil's surface due to surface sealing. Furthermore, surface residue accumulation in NT systems generally limits soil detachment by raindrop impact, expressed as splash sediment. CT plots had 4.5 X more splash sediment (S_s) during the first 10 min of each simulated rainfall event than NT plots (P=0.0001) (Table 1). Results support the concept that NT with surface residue management is effective in reducing raindrop impact, descreasing surface sealing and its negative impact, and soil detachment. Note that r values for runoff (R) vs. soil loss (E) from CT, NT, and both CT and NT combined were 0.96, 0.94, and 0.97, respectively.

From a practical standpoint, producers want to know how a particular tillage system will affect how much rainfall and/or irrigation will infiltrate into the soil surface, thus potentially becoming available for plant uptake. Crop production in Georgia and the Southeast is water limited; thus, supplemental irrigation is needed to sustain profitable crop production. Reduced tillage systems that retain more irrigation and/or rainfall, lose less water as runoff, use water more efficiently, and conserve soil and water resources will reduce supplemental irrigation amounts and other input costs and improve producer's proft margin. Over the 60 min of simulated rainfall, significant infiltration differences (2 X) occurred between NT and CT plots (Table 1). Therefore, given the rainfall intensity (2.2 in/h), and assuming that evapotranspiration (ET) was 0.2 in/day and all infiltration was available to plants, the 0.9 inches of infiltration during the 60 min simulated rainfall event for CT plots would result in 4.9 days of water for crop use; whereas the 2.0 inches of infiltration during the 60 min simulated rainfall event for NT plots would result in 10.2 days of water for crop use. This difference (5.3 days of water for crop use or 2.1 X) is extremely important for low water holding capacity Ultisols that experience extended periods of drought annually. For example, a producer utilizing a CT system would get 4.9 days of water for crop use for the 2 inch rainfall event before needing to consider supplemental irrigation, while the producer utilizing a NT system would get 10.2 days of water for crop use for the same rainfall event before needing to irrigate. To further illustrate water savings with NT, if we assume that 16 irrigations (1 in/irrigation/A) is needed to produce a given crop under CT conditions as described herein, then ~8 irrigations would be needed to produce the same crop under NT conditions. If the cost to apply each irrigation was $20/A-inch of water, then the 8 irrigations saved would also save ~$160/A in irrigation cost.

Table 1. Hydrology and erosion parameters for treatments studied.

Tillage	w	INF	INF	R	R	R_{max}	E	S_s	PAW
	%	in/h	%	in/h	%	in/h	oz	oz	days
CT	6 (29)	0.9 (37)	45 (38)	1.2 (31)	55 (31)	1.9 (15)	32.3 (40)	0.9	4.9
NT	16 (38)	2.0 (07)	90 (04)	0.2 (40)	10 (40)	0.5 (57)	2.9 (53)	0.2	10.2
Diff	2.5 X	2.2 X	2.0 X	6.0 X	5.5 X	3.8 X	11.1 X	4.5 X	2.1 X
P(T</=t)	0.0074	0.0001	0.0001	0.0001	0.0001	0.0001	0.0005	0.0001	0.0001

x (CV), n=6; w=antecedent (gravimetric) water content in the 0-1 in soil layer; INF=infiltration; R=runoff; Rmax=maximum 5 min runoff rate; E=total soil loss; Ss=soil splash during 0-10 min time period; PAW=estimated plant available water (assumed ET=0.2 in/d).

CONCLUSIONS

We quantified infiltration, runoff, and sediment yields from a Cecil sandy loam (slope=2%) managed under CT and NT systems. Treatments included tillage (CT, NT) and fertilizer source (commercial, CF; poultry litter, PL), each replicated three times (CT-PL, CT-CF, NT-PL, NT-CF), for a total of 12 field plots or simulations. Each 60-ft^2 field plot received simulated rainfall at a constant rate (target rate=2 in/h; 12-run ave.=2.2 in/h; CV=4%) for 60 min.

1. Fertilizer source sub-treatment did not significantly affect hydrology and erosion parameters at the 0.05 level. Data from these sub-treatments were combined into overall CT and NT main treatments (n=6).

2. CT plots had 2.2 X less infiltration and 6.0 X more runoff than NT plots, eventhough NT plots had 2.5 X higher soil water contents in the 0-1 inch soil layer. NT and CT plots had 90% and 45% (2 X difference) of the simulated rainfall infiltrated; whereas NT and CT plots had 10% and 55% (5.5 X difference) of the simulated rainfall runoff. CT plots (1367 lbs/A) had 11.1 X more soil loss than NT plots (120 lbs/A). Maximum runoff rate for CT plots (1.9 in/h) was 3.8 X greater than that for NT plots (0.5 in/h); maximum soil loss rate for CT plots (2.08 lb/A/h) was 9.4 X greater than that for NT plots (0.22 lb/A/h).

3. Compared to NT plots, CT plots had 4.5 X more splash sediment and were 4.5 X more susceptible to surface sealing. NT with surface residue is effective in reducing raindrop impact, descreasing surface sealing and its negative impact, and soil detachment.

4. Assuming that evapotranspiration was 0.2 in/day and all infiltration was available to plants, CT plots had 4.9 days of water for crop use; whereas NT plots had 10.2 days of water for crop use. This difference (5.3 days of water for crop use) would result in a producer utilizing a NT system to irrigate ~ 2.1 X less than a producer utilizing a CT system to produce the same crop, a 50% water and energy savings in irrigation cost.

REFERENCES

Frauenfeld, B., and C.C. Truman. 2004. Variable rainfall intensity effects on runoff and interrill erosion from two Coastal Plain Ultisols in Georgia. Soil Sci. 169:143-154.

Gardner, W.H., 1986. Water content. P. 493-594. In A. Klute (ed.) Methods of Soil Analysis, Part 1, Physical and Mineralogical Methods, Agronomy Monograph No. 9 (2nd Edition). ASA-SSSA, 677 S. Segoe Rd., Madison, WI 53771, USA.

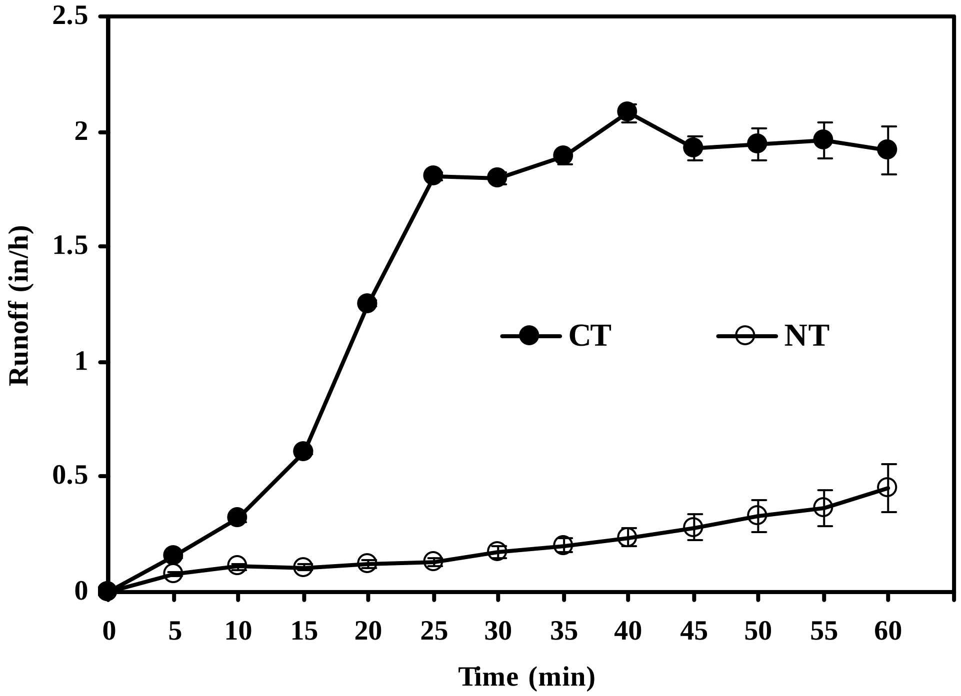

Fig. 1. Runoff rates for the combined CT and NT treatments from the Cecil sandy loam (bars=standard error).

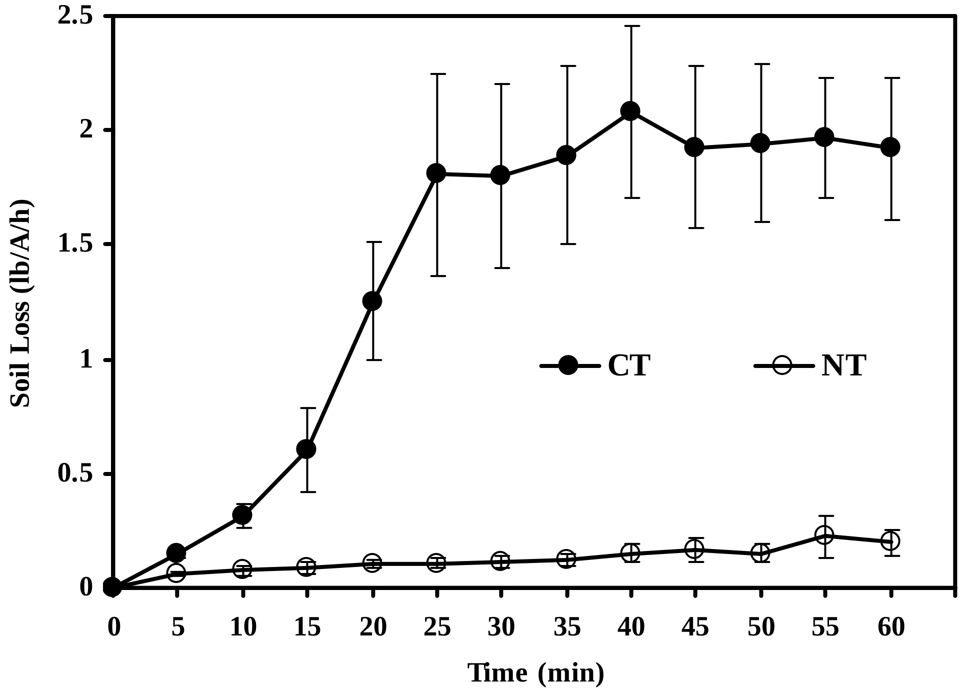

Fig. 2. Soil loss rates for the combined CT and NT treatments from the Cecil sandy loam (bars=standard error).