SOIL MANAGEMENT EFFECTS ON INTERRILL ERODIBILITY OF TWO ALABAMA SOILS

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ABSTRACT

Many Southeastern soils have been managed with conventional tillage practices in past, and most are considered highly erodible. Conservation tillage is effective in reducing soil loss. The objective of this study was to quantify soil loss and calculate interrill erodibilities (K_i) for a loamy sand (Typic Hapludult, E.V. Smith Research Center) and a silt loam soil (Rhodic Paleudult, TN Valley Substation) in the Coastal Plain and Limestone Valley, respectively, managed under conventional- (CT) and no-till (NT) systems. We also evaluated NT with and without fall paratilling (+P, -P), as well as with and without surface cover from a small grain winter cover crop (C, NC). Therefore, four tillage/residue treatments evaluated were: 1) conventional tillage without paratilling and without a winter cover crop (CT-PT, NC), 2) no-tillage without paratilling and without a cover crop (NT-P, NC), 3) no-tillage without paratilling but with a winter cover crop (NT-P, C), and 4) no-tillage with paratilling and a cover crop (NT+P, C). Tillage treatments were replicated four times. Duplicate 10 ft^2 (1 m^2) plots established on each tillage treatment were exposed to simulated rainfall (2 in h^{-1} or 50 mm h^{-1} for 2 h). Runoff and soil loss were continuously measured from each flat, level-sloping plot. Slopes for rainfall simulation plots on each soil were about 1%. At E.V. Smith, runoff and soil loss were controlled by residue cover. Interrill erodibilities ranged from 0.14-4.34. Runoff, soil loss, and interrill erodibility (0.29-5.12) values at TN Valley were controlled by fall paratilling. At both sites, runoff, soil loss, and erodibility values were greatest and infiltration was lowest for CT-P, NC plots (worst-case scenario). Runoff, soil loss, and erodibility values were lowest and infiltration was highest for NT+P, C plots (best-case scenario). Interrill erodibility values for CT-P, NC plots were 18-20 times and 10-14 times greater than corresponding values for NT+P, C plots at E.V. Smith and TN Valley, respectively. The CT-P, NC treatment in the Coastal Plain and Tennessee Valley regions of Alabama represents the greatest potential for runoff and soil loss. Surface residue management through conservation tillage coupled with non-inversion deep tillage like paratilling is the best system to promote infiltration and reduced runoff, soil loss, and interrill erodibility for soils in the Coastal Plain and Tennessee Valley regions of Alabama.

KEYWORDS

Coventional till, no-till, non-inversion deep tillage, paratill

INTRODUCTION

Alabama soils are traditionally managed under conventional tillage, tend to be drought-prone, and are susceptible to erosion. Conservation tillage is effective in reducing soil loss, yet some farmers are still reluctant to adopt these practices, despite potential benefits.

Conservation tillage reduces runoff and soil loss by increasing residue, organic matter, aggregate stability, and decreasing water dispersible clay (Shaw *et al*., 2002; Truman *et al*., 2002 a,b). In the Southeast, equipment traffic, implement action, and consolidation compact weakly-structured surface soils, and deep tillage is needed to disrupt compacted zones (Raper *et al*., 1994; Reeves and Mullins, 1995). Paratilling, a noninversion deep tillage technique, reduces bulk density and soil strength in the soil profile (Pierce and Burpee, 1995; Schwab *et al*., 2002; Truman *et al*., 2002 a), which affects infiltration and erosion (Rawitz *et al*., 1994; Truman *et al*., 2002 a,b). We quantified soil loss and calculated interrill erodibilities for two Alabama soils managed under conventional- (CT) and no-till (NT) systems.

MATERIALS AND METHODS

Site 1 was at the Alabama Agricultural Experiment Station's (AAES) E.V. Smith Research center near Shorter, AL. The soil was a loamy sand (Typic Hapludult). The surface horizon (0-9.5 in, 0-24 cm) had a sand content of

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81% and a clay content of 5%. Historical details regarding this site are given in Reeves *et al*. (2000) and Truman *et al*. (2002a). The site was managed under conventional- (CT) and no-till (NT) systems since 1989. Each tillage treatment (four reps) was established on field plots 10 ft wide and 70 ft long. Conventional tillage consisted of disking, chisel plowing, in-row subsoiling, disking, and field cultivating. Paratilling was conducted in the spring with a four-shank Paratill· (Bigham Brothers, Inc., Lubbock, TX), equipped with a smooth roller that disrupted soil to about 16 in (40 cm).

Site 2 was at the AAES Research & Extension Center at Belle Mina, AL. The soil was a silt loam (Rhodic Paleudult). The surface horizon (0-7.5 in, 0-19 cm) had a sand content of 15% and a clay content of 31%. Historical details regarding this site are given in Schwab *et al*. (2002) and Truman *et al*. (2002b). The silt loam was managed under CT and NT systems. Each tillage treatment (four reps) was established on field plots 26 ft wide and 50 ft long. Conventional tillage consisted of fall chisel plowing followed by spring disking and cultivator leveling. Paratilling was done in fall following cotton (*Gossypium hirsutum* L.) harvest each year since 1994.

At both sites, tillage/residue treatments included: 1) conventional tillage without paratilling (P) and without residue cover (CT-P, NC), 2) no-tillage without paratilling and without cover (NT-P, NC), 3) no-tillage without paratilling and with cover (NT-P, C), and 4) no-tillage with paratill and cover (NT+P, C). Winter cover crops in residue cover treatments were planted each fall since 1994 at Belle Mina and since 1989 at E.V. Smith. The fall prior to rainfall simulations, cover crops used were black oat (*Avena strigosa* Schreb.) and rye (*Secale cereale* L.) at E.V. Smith and Belle Mina, respectively.

Soil samples were taken from within each tillage treatment at each site. When possible, samples were collected in the immediate vicinity of areas designated for simulated rainfall. Soil properties were determined with the following methods: particle size distributions (PSDs) by the pipette method (Kilmer and Alexander, 1949), soil organic carbon (SOC) by the combustion method (Yeomans and Bremmer, 1991), aggregate stability by the water stable aggregate method (Kemper and Rosenau, 1986), and bulk density by the core method (Blake and Hartge, 1986).

For PSDs, samples were air-dried, crushed, and coarse fragments removed. PSDs were measured by the pipette method, with sands separated into size fractions by sieving.

SOC was determined from samples taken from 10 composite core samples (1 in diameter) taken adjacent to rainfall simulation plots. Samples were divided into five depth increment from 0-7 in. (0-1, 1-3, 3-6, 6-12, and 12-18 cm) depths. Recognizable debris was removed from the samples, and subsamples were finely ground in a roller mill (Kelly, 1994). Subsamples were analyzed for carbon by automated combustion using an NA 1500 NCS analyzer (Fisons Instruments Inc., Beverly, MA 01915). Each ground subsample was subjected to four carbon analyses.

Percent water-stable aggregates (WSA) from the 0-1.2 in (0-3 cm) soil depth were determined from composite samples taken from five locations adjacent to areas designated for rainfall simulations. Mean WSAs (%) were determined from eight lab determinations from each composite sample per plot.

Bulk density was determined from core samples (2 in diameter) taken from three locations and three depths ranging from 0-17 in for both sites (0-6, 6-12, 12-18 cm for E.V. Smith; 0-15, 15-30, 30-45 cm depths for TN Valley) adjacent to areas designated for rainfall simulation.

Duplicate 10 ft^2 (1 m^2) plots were established on one replicate of each tillage treatment (13-17 July, 1999 for site 1; 8-10 Nov., 1999 and 26-27 Jun., 2000 for site 2), and were considered replicates. Simulated rainfall was applied to each 10 ft^2 (1 m^2) plot at an intensity of 2 in h^{-1} (50 mm h^{-1}) for 1 h. One hour after the end of the first simulated rainfall event, each plot received an additional simulated rainfall event (2 in h^{-1} for 1 h). Rainfall was applied with an oscillating nozzle rainfall simulator (Foster *et al*., 1982) that used 80100 VeejetÆ nozzles. The simulator was placed 10 ft (3 m) above each subplot. Well water was used in all simulations at all sites.

Runoff (R) and soil loss (E) from each plot were measured continuously at 5-min intervals during each simulated rainfall event. Runoff and E were determined gravimetrically, and infiltration (INF) was calculated by difference (rainfall–runoff).

At the conclusion of each simulated rainfall event, all identifiable non-decomposed residue cover from each plot was collected, dried at 80°C for 72 h, cleared of soil particles, and weighed.

Interrill erodibility was first calculated from the equation: $E=K_{ii} \text{ x } I^2$, where E is the interrill erosion rate, K_{ii} is the interrill erodibility parameter, and I is the rainfall intensity (Truman and Bradford, 1995). Interrill soil erodibility was then calculated from the equation $E=K_{ii}I \text{ x } q$, where K_{ii} is the interrill erodibility parameter and q is the flow discharge (Truman and Bradford, 1995).

Regression analysis was used to determine relationships between dependent and independent variables. Means and coefficients of variation (cv, %) are given for measured data.

RESULTS AND DISCUSSION

Bulk density (BD), soil organic carbon (SOC), and residue cover for each tillage treatment are given in Table 1.

Table 1. Mean values and coefficient of variation (CV) for elected soil properties for tillage treatments studied.

Tillage		Residue	Bulk density†		S0C-1‡		SOC-3§		Residue¶	
Surface	Paratill	Cover	Mean	CV	Mean	CV	Mean	CV	Mean	CV
			g cm^{-3}		-- % --		-- % --		lbs acre^{-1}	
E.V. Smith										
NT	Yes	Yes	1.52	14	0.82	9	0.52	3	7591	5
NT	No	Yes	1.71	5	1.46	3	1.09	2	9630	9
NT	No	No	1.71	14	1.09	1	0.69	1	2910	25
CT	No	No	1.54	8	0.62	9	0.53	10	110	13
Tennessee Valley										
NT	Yes	Yes	1.31	10	1.37	3	1.25	1	3999	25
NT	No	Yes	1.44	4	2.58	3	1.25	6	4438	14
NT	No	No	1.43	8	1.71	1	1.05	1	2393	16
CT	No	No	1.54	5	0.94	3	0.9	1	927	5

† Bulk density for 0-6 inch depth

‡ SOC-1 soil organic carbon values for the 0 - 0.4 inch depth

§ SOC-3 soil organic carbon for the 0.4 - 1.2 in depths. Residue

¶ Amount of residue cover from a 10 ft2 area after rainfall simulation.

At E.V. Smith, BD values were 6% greater for no-till plots compared to those of conventional-till plots for this sandy soil. Conversely, for the silt loam at the TN Valley, BD values were 10% greater for conventional-till plots compared to those of no-till plots. In no-till plots, paratilling reduced BD values by 10-12% at both sites compared to non-paratilled no-till plots.

At both sites, no-till plots had about 65% more SOC than conventional-till plots, and SOC values for the 0-0.4 in (0-1 cm) soil layer of no-till plots were 80-100% greater than those for conventional-till plots (Table 1). Also, SOC values decreased with depth with no differences occurring below 1.2 in (3 cm). At both sites, no-till plots had at least 4 times more surface residue than conventional-till plots. Also, no-till plots with cover had 1.8-2.9 times more surface cover than no-till plots without cover.

At E.V. Smith, runoff and infiltration were controlled by surface cover (Table 2). No-till plots with cover had the lowest runoff (highest infiltration), whereas conventional-till plots with no cover had the highest runoff (lowest infiltration). Among no-till plots, those without cover had 5 times more runoff than those with cover.

At TN Valley, runoff and infiltration were controlled by fall paratilling (Table 2). The no-tillage paratilled plots with cover (NT+P, C) had the lowest runoff (highest infiltration), whereas CT-P, NC plots had the highest runoff (lowest infiltration). Runoff losses differed slightly for NT-P, C and NT-P, NC plots.

For both sites, runoff rates increased through the first simulated rainfall event (0-60 min), then reached steady-state rates during the second (60-120 min) simulated rainfall event. Removing residue caused runoff rates to increase at a faster rate than those from plots where residue remained in place, and increased steady-state runoff rates for all plots. Conventional tillage plots had the highest runoff rates, while NT+P plots had the lowest runoff rates.

At E.V. Smith, soil loss, like runoff and infiltration, was controlled by residue cover (Table 3, Fig. 1), despite this site having a well-developed hardpan. Soil loss values were greatest for conventional-till plots, and lowest for NT-P, C and NT+P, C plots. Removing residue from no-till plots increased soil loss by at least 6 times. Overall, no-till plots had at least 5 times less soil loss than conventional-till plots. Soil loss rates during both simulated rainfall events increased rapidly during the first 20 min of simulated rainfall, then reached steady-state values. Conventional tillage plots had the greatest steady-state soil loss rates, whereas NT+P, C plots had the lowest steady-state rates (20-fold differ-

Table 2. Runoff and infiltration values for the first (0-60 min) and second (60-120 min) simulated rainfall events. Target rainfall intensities were 2 in h^{-1}.

			0 - 60 minutes				60 - 120 minutes			
Tillage		Residue	Runoff		Infiltration		Runoff		Infiltration	
Surface	Paratill	Cover	Mean	CV	Mean	CV	Mean	CV	Mean	CV
			%							
E.V. Smith										
NT	Yes	Yes	3.5	8	96.5	0	3.3	8	95.7	1
NT	No	Yes	3.3	19	96.7	1	6.7	33	92.8	3
NT	No	No	19.1	16	80.9	4	44.6	6	55.2	5
CT	No	No	60.8	8	39.1	12	72.1	4	27.7	10
Tennessee Valley										
NT	Yes	Yes	5.2	39	94.8	4	7.1	36	92.8	4
NT	No	Yes	18.6	19	81.4	17	65.7	1	34.3	30
NT	No	No	16.8	41	83.2	9	54.1	15	45.9	17
CT	No	No	36.5	3	63.5	9	74.1	0	25.9	0

ence). Surface residue protects the soil surface from raindrop impact, thus limiting surface seal development and maintaining infiltration and reducing runoff and soil loss. As a result, removing residue from no-till plots increased runoff and soil loss, and decreased infiltration. Soil loss was correlated with surface residue cover ($R^2 = 0.77$). The R^2 value for soil loss vs. surface residue cover for no-till plots was 0.97.

Interrill erodibility (K_i) is a calculated parameter that represents the combined processes of soil detachment and sediment transport. Equations for calculating K_i (Table 3; Fig. 1) use measured values of soil loss, rainfall intensity, and/or runoff. The equation, $E=K_{ii}*I^2$, has been used to calculate K_i values because soil loss from interrill areas is generally thought to be detachment-limiting, and soil detachment has been related to rainfall parameters (I). However, soil loss and K_i values at E.V. Smith were dependent upon the transportability of soil particles, which are dominated by cohesionless sand-sized particles and thus were transport-limiting. Soil loss was related to runoff (transport capacity) for all plots (R^2=0.76), with CT-P, NC plots having a R^2 value of 0.98. Therefore, the equation, $E=K_{iq}*I*q$, was used to calculate erodibilities. Conventional tillage nonparatilled plots without cover (CT-P, NC) had the highest K_{ii} value and NT+P, C plots had the lowest K_{ii} value (18-fold difference). Again, surface residue controlled soil loss and K_{iq} values as no-till plots with cover were at least 5 and 12 times less erodible (based on K_{iq}) than no-till plots without cover and conventional-till plots.

At Belle Mina (TN Valley), soil loss, like runoff and infiltration, was controlled by fall paratilling (Table 3; Fig. 1). Soil loss values were greatest for conventional-till plots, and lowest for NT+P, C plots. Paratilling no-till plots decreased soil loss by 2.3 times. Overall, no-till plots had 4.7 times less soil loss than conventional-till plots. Soil loss rates during both simulated rainfall events increased rapidly during the first part of simulated rainfall, then reached steady-state values. Conventional tillage plots had the greatest steady-state soil loss rates, whereas NT+P, C plots had the lowest steady-state rates (14-fold difference). Paratilling reduces compaction, breaks up dense subsurface layers, thus maintains infiltration and reduces runoff.

Soil loss and K_i values at TN Valley were dependent on both the detachment of soil particles and the transport of sediment. This silt loam soil is more cohesive than the loamy sand soil at E.V. Smith, therefore, calculated K_i values need to represent detachment and transport processes. For our experimental conditions, both equations, $E=K_{ii}*I^2$ and $E=K_{iq}*I*q$, were adequate in quantifying K_i, including differences in K_{ii} (0.29-4.03) and K_{iq} (0.48-5.12) values between no-till paratilled and non-paratilled plots, which had a 14-fold difference in runoff. CT-P, NC plots had the greatest K_{ii} and K_{iq} values and NT+P, C plots had the lowest K_{ii} and K_{iq} values (13-fold difference for K_{ii} and

Table 3. Total soil loss for the first (0-60 min = E_{60}) and second (60-120 min = E_{120}) simulated rainfall events, steady-state soil loss ($E_{s/s}$), and interrill erodibility (K_i) values for each tillage.

			Soil loss					Interill Erodibility	
Tillage		Residue	0 - 60 min.		60 - 120 min.		Steady	without	with
Surface	Paratill	Cover	Mean	CV	Mean	CV	state	flow	flow
			------------- g m^{-2} -------------				kg m^{-2} h^{-1}	----- kg s m^{-4} -------	
E.V. Smith									
NT	Yes	Yes	11	32	13	1	0.01	0.14	0.24
NT	No	Yes	8	6	14	56	0.02	0.29	0.47
NT	No	No	78	17	70	43	0.07	1.00	1.87
CT	No	No	193	20	180	9	0.20	2.87	4.34
Tennessee Valley									
NT	Yes	Yes	24	26	21	15	0.02	0.29	0.48
NT	No	Yes	38	67	58	49	0.07	1.00	1.18
NT	No	No	45	34	65	10	0.07	1.00	1.59
CT	No	No	136	40	261	0	0.28	4.03	5.12

10-fold difference for K_{iq}). Among no-till plots, paratilled plots (NT+P, C) were 3 times less erodible than non-paratilled (NT-P, C and NT-P, NC) plots.

At both sites, runoff, soil loss, and K_i values were greatest and infiltration was lowest for CT-P, NC plots, while runoff, soil loss, and K_i values were lowest and infiltration was highest for NT+P, C plots. The CT-P, NC treatment has historically been the "standard practice" for farmers in the Coastal Plain region and Tennessee Valley region of Alabama, yet represents the greatest potential for runoff and soil loss. Therefore, from our data, we concluded that NT+P, C plots represented the best-case scenario and CT-P, NC plots represented the worst-case scenario.

CONCLUSIONS

We evaluated soil loss and interrill erodibilities (K_i) from two Alabama soils managed under conventional- (CT) and no-till (NT) systems. Four tillage/residue treatments evaluated were conventional tillage without paratilling and without a small grain cover crop (CT-PT, NC), no-tillage without paratilling and without cover (NT-P, NC), no-tillage without paratilling but with a cover crop (NT-P, C), and no-tillage with fall paratilling and a cover crop (NT+P, C). Each 10 ft^2 (1 m^2) plot was exposed to 2 h of simulated rainfall (I=2 in h^{-1}, 50 mm h^{-1}), and runoff and soil loss were measured continuously. The following conclusions can be made:

1. At both sites, no-till plots had 65% more SOC than conventional-till plots, and SOC values for the 0-0.4 in (0-1 cm) soil layer of no-till plots were 80-100% greater than those for conventional-till plots. Soil C values decreased with depth with no differences occurring below 1.2 in (3 cm). No-tillage resulted in at least 4 times more surface residue than conventional-till plots, and no-till plots with a winter cover crop had 1.8-2.9 times more surface cover than no-till plots without cover.

2. At E.V. Smith, runoff, infiltration, soil loss, and K_i values were controlled by surface cover. No-tillage plots with a winter cover crop had the lowest runoff (highest infiltration), whereas conventional-till plots (without cover) had the highest runoff (lowest infiltration). No-tillage plots without cover had 5 times more runoff than no-till plots with cover. Soil loss and K_i values depended on the transportability of soil particles. Removing residue from no-till plots increased soil loss by at least 6 times. Conventional tillage resulted in the greatest soil loss and K_{ii} values, whereas NT+P, C plots had the lowest corresponding values (18-20 fold difference). Surface residue protects the soil surface from raindrop impact, thus limiting surface sealing, maintaining

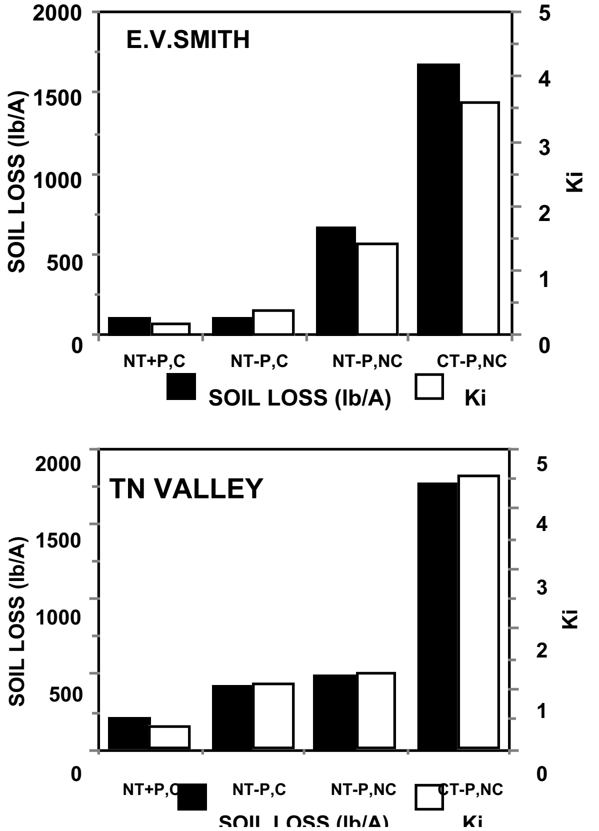

Fig. 1. Soil loss and interrill erodibility (K_i) at E.V. Smith and TN Valley for the four tillage treat-ments studied (NT=no-till; CT=conventional-till; P=paratill; C=residue cover; NC=no residue cover).

infiltration and reducing runoff and soil loss. As a result, no-till plots with cover were at least 5 and 12 times less erodible than no-till plots without cover and conventional-till plots.

3. For the silt loam soil in the TN Valley; runoff, infiltration, soil loss and K_i values were controlled by fall paratilling. No-tillage with fall paratilling and a rye cover crop resulted in the lowest runoff (highest infiltration), whereas CT-P, NC plots had the highest runoff (lowest infiltration). Soil loss and K_i values depended on both detachment of soil particles and transport of sediment. For this heavier soil, fall paratilling prevents compaction, breaks up dense subsurface layers, and thus increases infiltration and reduces runoff and erosion. As a result, NT+P, C plots were 3 times less erodible than NT-P, C and NT-P, NC plots. Conventional tillage plots had the greatest soil loss, K_{ii}, and K_{iq} values, whereas NT+P, C plots had the lowest corresponding values (10-14 fold difference).

4. At both sites, runoff, soil loss, and K_i values were greatest and infiltration was lowest for CT-P, NC plots (worst-case scenario), while runoff, soil loss, and K_i values were lowest and infiltration was highest for NT+P, C plots (best-case scenario). The CT-P, NC treatment has historically been the "standard practice" for farmers in the Coastal Plain and Tennessee Valley regions of Alabama, yet represents the greatest potential for runoff and soil loss. We conclude that surface residue management through conservation tillage systems coupled with noninversion deep tillage like in-row subsoiling or paratilling is the best system to promote infiltration and reduce runoff, soil loss, and K_i for soils in the Coastal Plain and Tennessee Valley regions of Alabama. Our findings support the rapid rate of adoption of these soil management systems in recent years by Alabama farmers.

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