Mineralogy of eroded sediments derived from highly weathered Ultisols of central Alabama

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Abstract

Coarse-textured surface horizons are common in highly weathered southeastern US coastal plain soils. These soils have historically been managed under conventional tillage practices, but conservation tillage management practices are increasing. Although clay ($<2\,\mu m$) contents are low in these surface horizons (typically $<100\,g\,kg^{-1}$), the reactive nature of this fraction tends to play a dominant role in colloidal facilitated pollutant transport. Studies have suggested that enrichment of certain minerals occurs in transported sediments, thus, we evaluated sediment size and the mineralogical partitioning of clay minerals of soil versus runoff sediment under simulated rainfall. In addition, because water dispersible clay (WDC) has been shown to be correlated with soil erodibility, we evaluated WDC differences as a function of tillage practices. Plots were established at a site in the upper coastal plain of central Alabama, where soils classified as coarse-loamy, siliceous, subactive, thermic Plinthic Paleudults and Typic Hapludults (FAO-Acrisols). Surface tillage treatments were established in 1988, and included conventional tillage (CT) versus no surface tillage (NT) treatments, with crop residue remaining or removed, and with or without paratilling (non-inversion subsoiling). Within these plots, simulated rainfall (target intensity $= 50\,mm\,h^{-1}$ for 2 h) was applied to replicated $1\,m \times 1\,m$ areas, and runoff and sediment were collected. Mineralogical analyses of soils and sediment were conducted using thermogravimetric analysis (TGA) and X-ray diffraction (XRD) techniques. WDC quantities were highly correlated with percent soil organic carbon (SOC) ($r^2 = 0.76$), which was a function of tillage treatment. Although no differences in the mineralogy of the $<2\,\mu m$ sediment were observed between tillage treatments, runoff sediments ($<2\,\mu m$) were enriched in quartz (qtz) and relatively depleted with kaolinite compared to in situ soils. These findings will facilitate development of mechanistic models that predict sediment attached losses of nutrients and pesticides.
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Keywords: Water dispersible clay (WDC); Conservation tillage; Clay mineralogy; Erodibility; Ultisols; Alabama

1. Introduction

Ultisols with coarse-textured surface horizons and highly weathered mineralogical suites are common in the southeastern US coastal plain. Many of these soils are intensively cropped to cotton (*Gossypium hirsutum* L.), and have historically been under conventional tillage practices. This often results in accelerated erosion and loss of productive topsoil, sedimentation of waterways, and the transport of pollutants into water sources through colloidal facilitated transport of nutrients and pesticides.

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Soils possessing water dispersible particles, particularly water dispersible clay (WDC), are susceptible to surface sealing and crusting, which decreases infiltration and increases erosion (Chiang et al., 1994). Soil erodibility, or the susceptibility of a soil to release sediment under erosive forces, has been correlated with water stable aggregate quantities and the ratio of WDC to total clay (Bajracharya et al., 1992). Although many properties have been correlated with WDC quantities, total clay content of the soil has been shown to be the most significant (Brubaker et al., 1992). Soil organic matter (SOM) content, exchangeable cation and sodium absorption ratios (SARs), pH, and the soil solution ionic strength also affect soil dispersibility (Goldberg et al., 1990; Miller et al., 1990; Heil and Sposito, 1993). Other soil properties correlated with WDC include dithionite–citrate–bicarbonate extractable Fe and Al, the coefficient of linear extensibility (COLE), cation exchange capacity (CEC), and the water content at 1.5 MPa (Brubaker et al., 1992). Some of these near-surface properties important for WDC amounts are strongly affected by soil management. For example, Curtin et al. (1994) showed crop management practices (mainly crop rotation) affected WDC quantities for some Canadian soils.

Highly weathered soils dominated by kaolinite, gibbsite, Fe oxides, and hydroxy-interlayered vermiculite (HIV) can have relatively high amounts of WDC (Miller and Baharuddin, 1986; Miller and Radcliffe, 1992; Chiang et al., 1994). Miller et al. (1990) examined the dispersibility of Georgia soils and found that for Ap horizons, kaolinitic soils were more dispersive than soils which contained both smectite and kaolinite. Dispersibility of highly weathered soils may be due to the low electrolyte concentrations commonly found in these soil environments (Miller and Radcliffe, 1992). Kaplan et al. (1996) found that the dispersibility of highly weathered soils was in part due to resident low electrolyte concentrations as well as the presence of organic coatings, and their data suggested that even slight increases in SAR can enhance dispersion. Kretzschmar et al. (1993) found that fine grained ($<0.2\,\mu m$) WDC collected from highly weathered soils was enriched with kaolinite, gibbsite, and Fe oxides, and was depleted in HIV and quartz (qtz). Mobile colloids leached through reconstructed columns have been shown to be enriched in kaolinite, Fe oxides, and gibbsite as compared to the total clay

fraction, and depleted with regard to HIV and qtz (Kaplan et al., 1997). These authors concluded that the relatively coarser size of HIV and qtz (concentrated in the coarse clay fraction) may constrain their movement through the soil matrix as compared to other minerals. Relatively few studies have evaluated the mineralogy of overland eroded sediments.

However, much work has been done examining the preferential erodibility of particular particle sizes. Wan and El-Swaify (1998) found that processes associated with splash (soil detachment) and wash (sediment delivery) caused preferential transport of particles $<63\,\mu m$. Splash sediment size tended to be similar to in situ soil, while wash sediment tended to be finer. Due to aggregation effects, eroded sediment from agricultural fields is often coarser than the fundamental particle size of the residual soil (Meyer et al., 1992). Aggregated sediments derived from clay-rich soils are sometimes coarser than sediments derived from coarser-textured soils (Gabriels and Moldenhauer, 1978; Meyer et al., 1992). Meyer et al. (1992) examined midwestern and southern soils, and showed that soils with higher clay dominantly erode as aggregates, whereas coarser soils (silty and sandier-textured) erode as primary particles. They also suggest that once-dispersed, sediment derived from soils is similar in texture to the fundamental particle size. Because of the reactive nature (charged surfaces) and relatively higher surface area of clay particles, runoff enriched in clay has an increased ability to facilitate off-site transport of sorbed nutrients and pesticides.

Conservation tillage systems are becoming more common in the southeastern US. Decreased erosion is one of the main benefits of conservation tillage and residue management (Seta et al., 1993; Gaynor and Findlay, 1995; Potter et al., 1995). This is partly due to increases in SOM that often result with adoption of conservation tillage practices (Edwards et al., 1992; Langdale et al., 1992; Reeves, 1997). Increases in SOM often lead to improved aggregation, increased infiltration, and subsequently, decreased erodibility (Castro and Logan, 1991; Reeves, 1997; Truman et al., 2002). Differences in dynamic near-surface soil properties (including SOM) may also result in differences in dispersed particle amounts and the preferential dispersion of certain clay minerals. Because mechanistic models developed to predict sediment attached

losses of pollutants need data on the reactive nature of the sediment, mineralogical enrichment studies are fundamental to model development. This study was conducted to evaluate the effect of long-term tillage systems in coarse-textured surface horizons of highly weathered soils on (1) WDC quantities and (2) clay mineralogical partitioning between eroded sediments and in situ soil.

2. Materials and methods

2.1. Research site

The research site was located in the upper coastal plain province of central Alabama at the E.V. Smith Research Center of the Alabama Agricultural Experiment Station. Soils were classified as coarse-loamy, siliceous, subactive, thermic Plinthic Paleudults and Typic Hapludults (Table 1). As common for this region, surface horizons (Ap horizons) were coarse-textured (loamy sand and sandy loam), and clay contents were low (Table 1).

2.2. Treatments

Soils of the region are intensively cropped, and an experiment with treatments (plots are 3.0 m × 21.3 m) consisting of tillage-residue management practices was evaluated. A further explanation of treatments can be found in Truman et al. (2002), and a brief summary follows. Historical information on trafficking at this site can be found in Reeves et al. (1992). From 1988 to 1995, the site was in a traffic and tillage study using a corn (*Zea mays* L.)–soybean (*Glycine max* L. (Merr.)) rotation, along with a winter cover crop of crimson clover (*Trifolium incarnatum* L.). During that period (1988–1995), conventional tillage (CT) (all conducted in spring) consisted of disking, chisel plowing, in-row subsoiling, disking, field cultivation; the conservation tillage system consisted of no surface tillage (NT) with in-row subsoiling using a narrow-shanked subsoiler (strip tillage). In the fall of 1995, all plots were subsoiled (with a bent-leg subsoiler) to the 40 cm depth to remove existing traffic and subsoiling treatment effects, and subsequently cropped to ultra-narrow row cotton (19 cm rows) in 1996–1997. Surface tillage treatments remained unchanged, thus the integrity

of the CT versus the NT treatments and residue management has remained intact since 1988. Winter cover crops of lupin (*Lupinus albus* L.) and black oat (*Avena strigosa* Schreb.) were planted in 1996 and 1997, respectively. In the summer of 1998, the plots were planted to sorghum–sudangrass (*Sorghum drummondii* (Nees ex Steud.) Millsp. and Chase), with black oat (*A. strigosa* Schreb.) being planted for seed in November and harvested in June 1999.

Black oat residue was mowed and evenly distributed, and was removed from four treatments prior to rainfall simulations (discussed below). CT treatments were applied on 7 July 1999, and half of the plots were subsequently paratilled (P). This resulted in a factorial arrangement of two long-term surface tillage treatments (CT and NT), with two residue management treatments (residue removed (RR) or left in place before rainfall simulation experiments (RT)), and two non-inversion deep tillage treatments (paratilled (P) or non-paratilled (NP)). For rainfall simulation experiments, duplicate 1 m × 1 m plots were established on one replicate of each tillage–residue–paratill treatment. Each tillage treatment (CT versus NT) was replicated four times. The treatments are shown in Table 2.

2.3. Analyses

Bulk samples were collected from the horizons of two pedons (pedon samples) and the near-surface (0–1 cm depth) of each plot (plot samples). For the two pedons, soils were described and sampled as per standard soil survey practices (Table 1). The plot samples were composite sampled (20 samples) at the 0–1 cm depth for comparison with sediment samples in runoff collected during rainfall simulation experiments (discussed below). All samples were air-dried, crushed, and coarse fragments (>2 mm) were removed. Particle size determination (PSD) was conducted on all samples by the pipette method, and sand grains were separated into size fractions by sieving (Kilmer and Alexander, 1949). For pedon samples, base cations (Ca, Mg, K, and Na) were extracted with 1 M NH_4OAC (pH 7), Al was extracted with 1 M KCl, and both were measured with atomic absorption spectroscopy (AAS) (Soil Survey Investigation Staff, 1996). CEC was measured with the NH_4OAC (pH 7) method (Soil Survey Investigation Staff, 1996). For

Table 1
Soil characterization data for two sampled pedons for the E.V. Smith sites[a]

Horizon	Depth (cm)	Sand (g kg^{-1})	Silt (g kg^{-1})	Clay (g kg^{-1})	Ca (cmol$_c$ kg^{-1})	Mg (cmol$_c$ kg^{-1})	K (cmol$_c$ kg^{-1})	Na (cmol$_c$ kg^{-1})	Al (cmol$_c$ kg^{-1})	CEC (cmol$_c$ kg^{-1})	ECEC (cmol$_c$ kg^{-1})	BS (%)
Pedon 1: coarse-loamy, siliceous, subactive, thermic Plinthic Paleudult												
Ap	0–17	804	159	38	1.17	0.54	0.17	0.02	0.00	2.28	1.89	83.1
BE	17–42	732	196	72	0.67	0.45	0.13	0.02	0.00	1.86	1.27	68.6
Bt1	42–80	720	207	73	0.20	0.32	0.12	0.03	0.11	1.41	0.77	47.4
Bt2	80–99	720	201	79	0.09	0.16	0.10	0.01	0.86	1.58	1.22	22.8
Btv	99–122	740	176	84	0.10	0.20	0.11	0.03	0.97	1.59	1.42	27.9
BC	122–140	729	152	118	0.14	0.21	0.10	0.01	1.48	2.28	1.95	20.5
C	140–150	714	149	138	0.19	0.27	0.11	0.02	1.74	2.94	2.32	19.9
Pedon 2: coarse-loamy, siliceous, subactive, thermic Typic Hapludult												
Ap	0–24	806	148	46	1.40	0.26	0.02	0.14	2.28	2.30	94.8	
Bt1	24–51	698	177	124	0.36	0.53	0.18	0.02	0.90	2.73	1.99	39.9
Bt2	51–84	725	161	115	0.16	0.31	0.15	0.02	1.74	2.62	2.37	24.0
BC	84–110	792	150	58	0.07	0.14	0.08	0.02	0.70	1.18	1.01	26.2
C	110–150	761	148	92	0.13	0.16	0.08	0.01	0.83	1.64	1.21	23.0

[a] CEC: cation exchange capacity; ECEC: effective cation exchange capacity; BS: base saturation.

Table 2
Averaged physical and chemical data at the 0–1 cm depth for in situ soil samples

Treatment[a]	Sand (g kg^{-1})					Silt (g kg^{-1})	Clay (g kg^{-1})	Fe$_d$[b] (%)	Fe$_o$ (%)	Fe$_p$ (%)	SOC[c] (%)	WDC[d] (%)	WDC:clay[e] (%)
	Very coarse	Coarse	Medium	Fine	Very fine								
NT, RT, NP	91	241	257	161	77	146	27	0.25	0.05	0.02	1.47	0.11	4.10
NT, RT, P	46	185	259	211	114	155	31	0.29	0.05	0.03	0.82	0.48	15.60
NT, RR, NP	82	217	250	181	91	148	30	0.28	0.04	0.02	1.09	0.53	17.69
NT, RR, P	88	205	242	162	86	182	35	0.28	0.05	0.03	1.00	0.33	9.58
CT, RT, NP	75	188	240	200	116	145	36	0.33	0.04	0.03	0.52	1.05	29.19
CT, RT, P	79	221	248	181	102	142	27	0.28	0.04	0.02	0.50	0.51	19.14
CT, RR, NP	83	218	233	161	101	175	30	0.31	0.05	0.02	0.62	0.58	19.46
CT, RR, P	68	190	249	199	108	153	33	0.33	0.05	0.03	0.65	0.66	19.81

[a] NT: no surface tillage; CT: conventional tillage; RR: residue removed; RT: residue remain in place; P: paratill; NP: no paratill.

[b] Fe$_d$, Fe$_o$, and Fe$_p$ are sodium dithionite, ammonium oxalate, and sodium pyrophosphate extractable Fe, respectively.

[c] Soil organic carbon.

[d] Water dispersible clay.

[e] Ratio of WDC to total clay.

plot samples, organically bound Fe was extracted with sodium pyrophosphate (Fe$_p$), non-crystalline (poorly crystalline and organically bound) Fe was extracted with acid ammonium oxalate (Fe$_o$), and total Fe oxides and organically bound Fe were extracted with dithionite–citrate–bicarbonate (Fe$_d$) (Jackson et al., 1986). Soil organic carbon (SOC) was evaluated on all samples using dry combustion (Yeomans and Bremner, 1991).

The WDC of plot samples (0–1 cm depth) was analyzed (20 laboratory replications, except 10 replications for plots 409 and 410) using a modification of the method of Miller and Miller (1987). Forty milliliter of H$_2$O were added to 5.0 g of soil in 50 ml tubes, and were mechanically shaken on a flatbed-reciprocal shaker (120 oscillations min^{-1}) for 12 h. The H$_2$O was the same as used in the rainfall simulation experiments (collected from a nearby well), and for all experiments had an average pH $= 7.7 \pm 0.1$, and an electrical conductivity $= (0.0018 \pm 2.5) \times 10^{-5}$ S m^{-1}. 2.5 ml samples were taken from the tube at a 2.5 cm depth after solutions had settled for 1 h and 50 min. The clay concentration was then calculated.

2.4. Rainfall simulations

On one replicate of each tillage–residue–paratill treatment, duplicate 1 m × 1 m plots were established for rainfall simulations. Plots were constructed by inserting 1 m × 1 m metal frames (15 cm in height) approximately 10 cm into the soil. Runoff was collected continuously throughout 2 h of simulated rainfall (target intensity ~ 50 mm h^{-1}). Each plot had similar slopes ($\sim$1%). Details of these rainfall simulation experiments are covered in Truman et al. (2002). In summary, rainfall simulations were conducted by raining for 1 h, breaking for 1 h, then raining again for an additional 1 h. Samples for this study were collected at an outlet every 20 min during rainfall periods. Sediment samples were composted into one sample for each plot so sufficient clay could be obtained for analyses. Thus, sediments analyzed represented a composite for the rainfall simulation event.

2.5. Mineralogy

Plot soil samples (0–1 cm) and runoff sediment samples were fractionated into sand (50–2000 μm), silt (2–50 μm), and clay (<2 μm) using standard centrifugation and sieving techniques following SOM removal (Jackson, 1975). Fine clay (<0.2 μm) was not separated from samples because of insufficient clay amounts in the runoff sediment. Silt and clay amounts in the runoff samples were calculated from suspension densities, and sand amounts were measured after sieving and drying. Clay mineralogical (<2 μm) constituents were evaluated using a combination of X-ray diffraction (XRD) and thermogravimetric analysis

(TGA). Very fine sand (50–100 μm) and silt fractions were crushed and analyzed as powder mounts with XRD.

Clay fractions were orientated using the method of Drever (1973), and examined by XRD using these treatments: Mg-saturation/ethylene glycol solvation at 25 °C, Mg-saturation at 25 °C, K-saturation at 25, 300, and 550 °C (Whittig and Allardice, 1986). Magnesium-saturated clay fractions were analyzed with TGA. Analyses were conducted from 25 to 625 °C in an argon atmosphere, and gibbsite (using the theoretical water loss of 31.2%) and kaolinite (theoretical water loss of 14.0%) were quantified. HIV and qtz amounts were estimated using the techniques of Karathanasis and Hajek (1982). This method uses the proportional XRD intensity of HIV and qtz peaks to an internal kaolinite standard (peaks used with corresponding d-spacings of 1.40 nm for HIV, 0.72 nm for kaolinite, and 0.425 nm for qtz). Although reporting exact quantities on clay mineral amounts is open to some interpretation, the above mentioned techniques provide a sound approach for relative comparisons.

3. Results and discussion

3.1. Water dispersible clay

Surface horizons were coarse-textured, which is common for soils of this region (Tables 1 and 2). Although clay amounts were low in these surface horizons, reactive surfaces important for colloidal facilitated transport are concentrated in this fraction (and to a lesser extent in the silt), while coarser fractions are typically dominated by relatively inert qtz. Therefore, our analyses concentrated on the clay fraction of these soils.

Overall, <30% of the total clay was dispersible by our methods (Table 2). Brubaker et al. (1992) analyzed soils collected from eight orders (65 samples) and found an average of 34% of the clay fraction was water dispersible. Kaplan et al. (1996) found relatively higher amounts of WDC for two southeastern sandy surface horizons than WDC amounts in our study, but SOM levels in their study were relatively low, which might affect dispersion amounts. Our numbers are intermediate of values Miller and Baharuddin (1987) found for 15 southeastern soils. These authors found

that higher amounts of WDC can be obtained with increased shaking time (0.5 h versus 36 h). Because our shaking time (12 h) was in between these, it is not surprising our percentages lie intermediate of theirs.

Differences in WDC were evident between tillage–residue management treatments (Table 2). The straight conventional tillage treatment (CT, RT, NP) had higher amounts of WDC (as both actual totals and the percentage of total clay) than other treatments, whereas the NT treatment had the lowest amounts of WDC (Table 2). Also, when all treatments are grouped as either conservation tillage (NT) or conventional tillage, the ratio of WDC and total clay was lower for the conservation tillage ($11.7 \pm 6.2\%$) versus the conventional tillage ($21.9 \pm 4.9\%$) treatments. Differences in SOC were a function of treatment, with NT treatments possessing higher percentage of SOC than conventional tillage treatments (see Truman et al., 2002, for details). High correlation ($p = 0.008$) between the ratio of WDC and total clay versus the percentage of SOC existed for these soils (Fig. 1). Levy et al. (1993) found micro-aggregates were most stable for kaolinitic soils with higher SOM levels. Castro and Logan (1991) found decreasing erodibility with increasing organic C content for tropical soils. Soil erodibility has been shown to be correlated with the ratio of WDC to total clay (Bajracharya et al., 1992), and our data suggests a similar relationship for these soils managed under given tillage–residue management practices.

3.2. Mineralogy

Sand and silt fractions for soil samples taken from the 0 to 1 cm depth were dominated by qtz (Fig. 2). As expected, small quantities of phyllosilicates were also evident in the total silt and very fine sand fractions (Fig. 2). These soils possessed clay mineralogical suites typical of highly weathered soils (Table 3 and Fig. 3). For all plots examined, HIV and kaolinite dominated the clay fractions, with lesser amounts of gibbsite and qtz (Fig. 3). The absence of XRD peaks indicative of goethite or hematite and the low amount of Fe_o and Fe_d in the total soil suggests Fe oxide quantities were minimal.

Runoff sediment size was similar to particle size of the in situ soil (Table 3), which is similar to findings by other workers (Meyer et al., 1992). No difference in clay mineralogy of sediments existed between
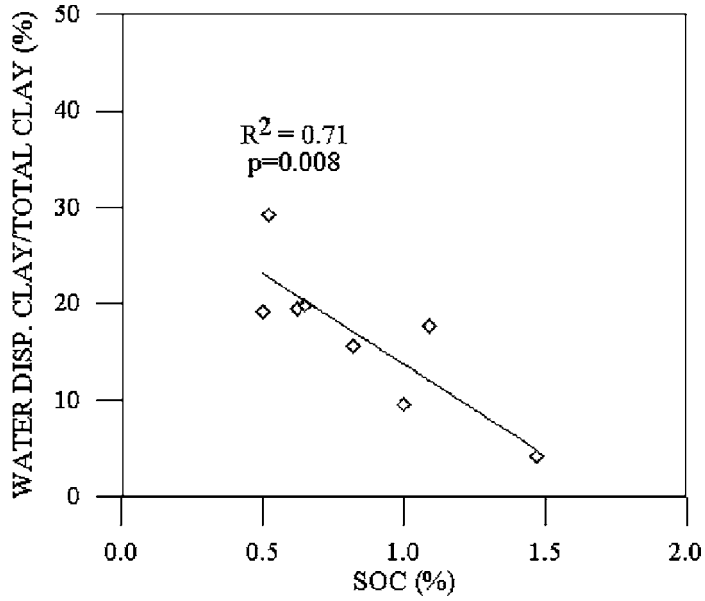
Fig. 1. The ratio of WDC to total clay versus the percentage SOC for the 0–1 cm depth sampled from the tillage system treatment plots.
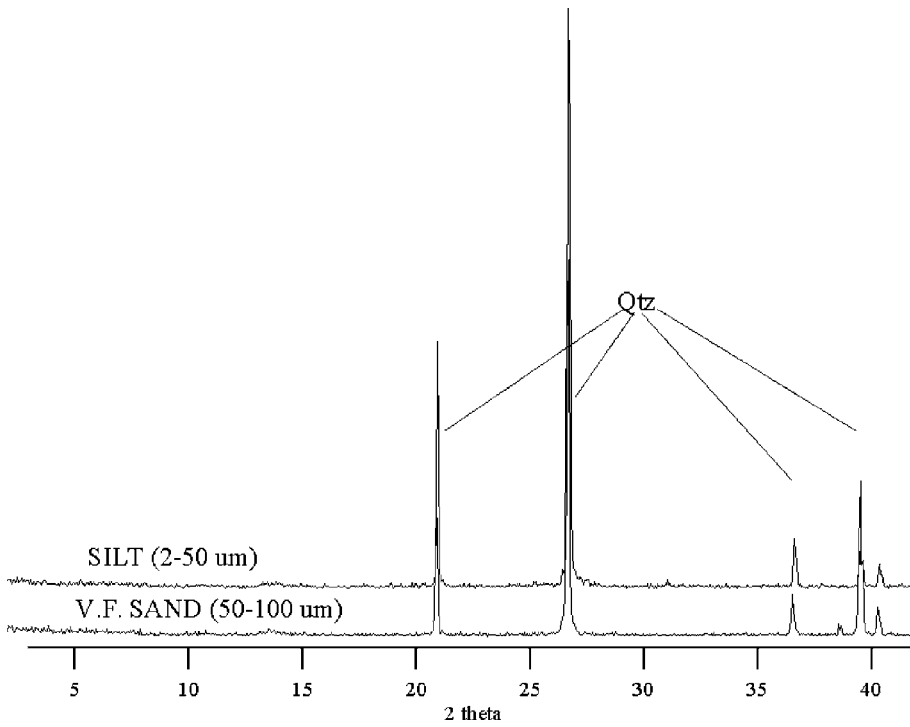

Fig. 2. X-ray diffractograms (powder mounts) for silt (2–50 μm) and very fine sand (50–100 μm) fractions for 0–1 cm depth for the NT, residue removed, paratill treatment.

Table 3
Comparison of mineralogical composition of clay ($<2\,\mu$m) fraction between in situ soil and runoff sediment[a]

Treatment[b]	In situ soil samples (0–1 cm)					Sediments in runoff[c]							
	Kao (%)	HIV (%)	Gibb (%)	Qtz (%)	Total (%)	Kao (%)	HIV (%)	Gibb (%)	Qtz (%)	Total (%)	Sand (g kg^{-1})	Silt (g kg^{-1})	Clay (g kg^{-1})
NT, RR	33.9	45.0	0.8	5.3	85.0	24.6 (1.7)	44.5 (12.6)	0.5 (0.2)	10.5 (0.5)	80.1 (14.9)	911 (31)	65 (13)	24 (33)
NT, RR, P	37.6	62.1	0.7	6.4	106.8	24.5 (1.8)	45.9 (1.0)	0.7 (0.1)	15.6 (1.7)	86.7 (4.4)	899 (81)	82 (70)	19 (12)
CT	40.9	65.9	0.8	6.3	113.9	28.3 (1.7)	42.8 (8.5)	0.8 (0.0)	16.1 (11.4)	88.1 (4.7)	848 (95)	125 (74)	27 (22)
CT, P	39.6	55.8	0.9	6.3	102.6	24.9 (2.0)	51.5 (3.9)	0.6 (0.6)	14.7 (1.1)	91.7 (5.5)	949 (37)	36 (20)	15 (17)
CT, RR	36.1	50.3	1.2	6.4	94.0	27.4 (1.3)	48.2 (2.2)	0.5 (0.0)	13.9 (1.9)	90.0 (2.8)	818 (19)	149 (10)	32 (11)
CT, RR, P	37.7	59.5	0.8	4.9	102.9	26.1 (2.4)	53.1 (3.2)	0.6 (0.1)	11.8 (0.6)	91.6 (5.1)	881 (29)	98 (22)	21 (8)

[a] Kao: kaolinite; HIV: hydroxy-interlayered vermiculite; gibb: gibbsite; qtz: quartz.

[b] NT: no surface tillage; CT: conventional tillage; RR: residue removed; P: paratill.

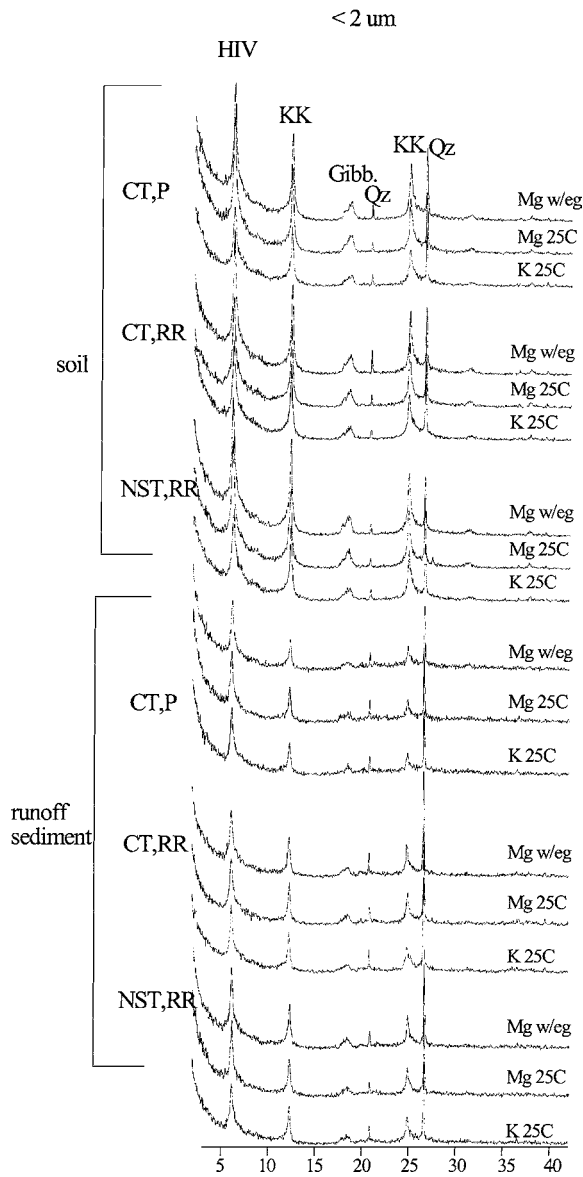[c] Numbers in parentheses are standard deviations of means.

Fig. 3. X-ray diffractograms of clay fractions for soil and sediment for three plots (CT–P, CT–RR, and NST–RR). KK: kaolinite, gibb: gibbsite and qz: quartz. Mg w/eg is Mg-saturated with ethylene glycol solvation, and Mg and K 25 °C are Mg- and K-saturated analyzed at 25 °C.

Table 4
Comparison of average mineral quantities for in situ soil and runoff sediment averaged for all plots (normalized to a 100% basis)[a,b]

	n	Fraction ($<2\,\mu m$)			
		Kao (%)	HIV (%)	Gibb (%)	Qtz (%)
In situ soil	6	37.5 (1.9)	55.7 (2.6)	0.9 (0.2)	5.9 (0.7)
Sediment	12	29.6 (2.3)	54.1 (5.0)	0.8 (0.2)	15.6 (4.3)

[a] Kao: kaolinite; HIV: hydroxy-interlayered vermiculite; gibb: gibbsite; qtz: quartz.
[b] Numbers in parentheses are standard deviations of means.

soils (Table 3). Reasons for this were unclear, but may be due to increased amounts of relatively amorphous material in the sediments.

Because mineral recovery amounts were different between soil and sediment samples, quantities of mineral recovery were normalized to 100% for relative comparison purposes (Table 4). When mineral quantities in the clay fraction of sediments were compared to soil samples for all plots, differences in mineral quantities existed (Fig. 3 and Table 4). More specifically, our data suggests clay fractions of sediments were enriched with qtz (9.7% higher for sediment), and slightly depleted with respect to kaolinite (7.9% lower for sediment) (Table 4). This is evidenced by the TGA data (for kaolinite), as well as the higher relative intensity of the XRD qtz peak and the lower relative intensity of kaolinite peaks of sediment compared to in situ soil (Fig. 3). We hypothesize these differences might be due to a relatively increased aggregation and aggregate stability of kaolinite particles, possibly reducing the amount of transported kaolinite compared to qtz. The clay-sized qtz might be more easily dispersed and/or less likely to exist in larger aggregates, and thus more readily available for transport. No differences were evident for HIV and gibbsite. Kaplan et al. (1997) found relative enrichment of kaolinite and gibbsite in leached colloids from reconstructed columns, and relative depletion of the coarser-sized HIV and qtz, which was hypothesized to be due to size constraints. In runoff, however, size constraints would not be as restrictive, which might explain these differences. Kretzschmar et al. (1993) found that water-dispersed fine clay ($<0.2\,\mu m$) was enriched with kaolinite and depleted with respect to qtz. This may have been due to a general overall absence of qtz in the fine clay fraction, which tends

tillage–residue management practices (Table 3), and no particular enrichment or depletion of a particular clay mineral occurred as a function of tillage. It was, however, evident that our percent recovery for clay minerals in the sediments was less than that for in situ

to predominantly exist in the coarse clay (0.2–2 μm). We did not separate the fine clay from the total clay in these analyses, thus we cannot address this issue.

4. Conclusions

Differences in WDC for these soils appeared to be related to SOC amounts. Overall, decreases in WDC were found with increasing SOC. This provides more evidence that conservation tillage practices generally enhance soil quality for these coastal plain soils. We have collected data (Truman et al., 2002) which show differences in infiltration exists for tillage–residue management practices for these soils. The differences in WDC quantities, along with other established findings (porosity differences, residue effects, etc.), might help explain differences in infiltration rates between tillage systems in this region.

The fundamental particle size between soils and runoff sediment was similar. We did not detect differences in the clay mineralogy of sediments as affected by tillage–residue management systems. However, slight enrichment in qtz and slight depletion in kaolinite were found in the clay fraction of the runoff sediment versus the in situ soils for these sandy soils. Thus, from an overall reactive surface perspective, our data suggests the runoff sediment derived from these highly weathered soil systems may be slightly less reactive than in situ soil. However, differences in organic matter between soil and runoff sediment would also need to be evaluated to fully address the activity. Because soil mineralogical constituents can be broadly ascertained by soil survey maps, mechanistic models can incorporate these mineralogical enrichment data with soil survey data to improve estimates of field-scale losses of sediment attached contaminants (such as P).

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