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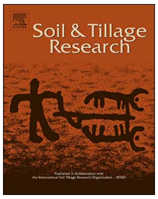

Sediment-bound total organic carbon and total organic nitrogen losses from conventional and strip tillage cropping systems

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ABSTRACT

Global carbon (C) and nitrogen (N) cycles are closely linked to erosion and hydrologic processes. By reducing tillage erosion and runoff, sediment-bound C and N losses can be reduced. Published studies represent only a few soil types and regions and rarely directly compare tillage practices. The objective of this study was to quantify concentrations and sediment-bound total organic carbon (TOC) and nitrogen (TON) loads and enrichment ratios in runoff from 0.2-ha fields in rotational cotton (*Gossypium hirsutum L.*)-peanut (*Arachis hypogea L.*) production during a 7-yr study within a southeastern USA coastal plain landscape. The Ultisoils at the study site have loamy sand to sandy loam texture surface horizons. The fields were in either continuous conventional tillage (CT) or strip tillage (ST) and were at upper, middle, and lower landscape positions. Sediment-bound TON and TOC concentrations were significantly greater from ST than CT fields as were the TOC and TON enrichment ratios. However, due to greater surface runoff and sediment loss, TON and TOC loads were significantly greater from CT than ST fields. The CT and ST loads were significantly different at the upper and middle but not at the lower landscape position. Enrichment ratios, 14 to 19 for TON and 8 to 12 for TOC, were several-fold greater than reported in the limited available literature, where studies focused on finer textured surface soils. Our findings have highlighted the site-specific nature of erosion processes, how they affect sediment-bound C and N loss in agricultural landscapes, and how reducing tillage may impact sediment C and N dynamics. The observed enrichment ratios can be used to modify or adjust values used in current erosion models and improve their suitability for use in the region and elsewhere where surface soils have sandy texture and when practices like ST are implemented.

1. Introduction

There is increasing global recognition that soil should be considered as an ecosystem component that plays a critical role in the understanding of earth systems, global sustainable development goals, control of the carbon and nitrogen cycles, environmental protection, and climate mitigation, etc. (Drohan et al., 2010; Megonigal et al., 2010; Richter and Yaalon, 2012; Brevik et al., 2015; Soil Science Society of America, 2015; Keesstra et al., 2016). Understanding soil organic matter (SOM), and by extension soil organic carbon (SOC) and nitrogen (SON) dynamics, is essential for efficient and environmentally sustainable agricultural production (Doran and Parkin, 1994; Robinson et al., 1994). There is also a direct link to climate change assessments since SOM can serve as both a source and sink of atmospheric carbon dioxide and other greenhouse gases (Lal, 2014).

Soil degradation due to certain types of land use and intensity compromises ecosystem services derived from soils, such as SOC accumulation, with the degree depending on soil and climate characteristics (Bruun et al., 2015; De Oliveira et al., 2015; Sá et al., 2015; García-Díaz et al., 2016; Hu et al., 2016; Montiel-Rozas et al., 2016). Depletion of SOC due to deforestation, biomass burning, conversion of natural to agricultural ecosystems, drainage of wetlands and soil cultivation has contributed substantial quantities of carbon to the atmosphere (Lal, 2003). In turn, there is evidence that the process can be reversed through improved soil management including use of conservation tillage, cover crops, and crop rotations, etc. (Jarecki and Lal, 2003; De Oliveira et al., 2015; Sá et al., 2015; Gao et al., 2016; García-Díaz et al., 2016; Montiel-Rozas et al., 2016).

A primary uncertainty in estimates of how these practices impact SOC sequestration or release is the impact of soil erosion on SOC losses and the fate of the eroded sediment within terrestrial and aquatic ecosystems (Polyakov and Lal, 2004; Kirkels et al., 2014; Lal, 2014;

Abbreviations: C, carbon; N, nitrogen; CT, conservation tillage; ST, strip tillage; ER, enrichment ratio; TON, total organic nitrogen; TOC, total organic carbon; ln, natural logarithm

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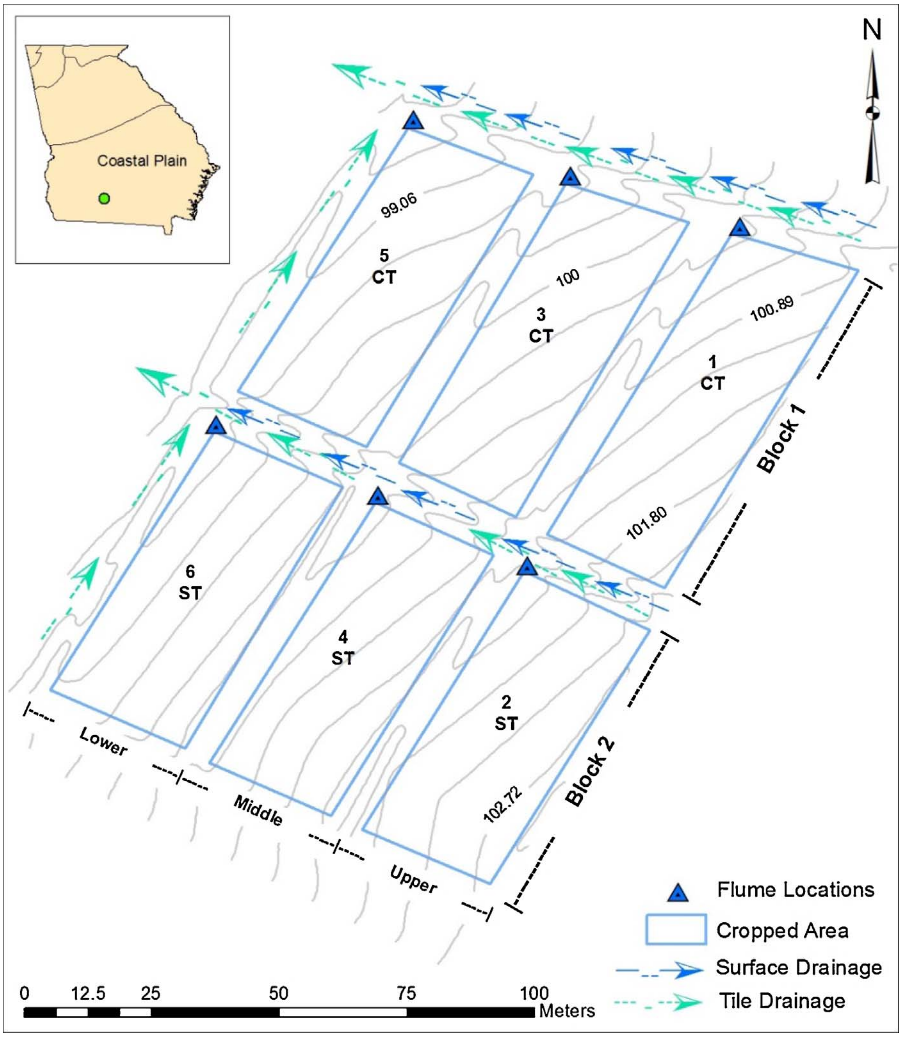

Fig. 1. Experimental field layout showing blocks, landscape position, and tillage treatments as conventional tillage (CT) and strip tillage (ST), as well as locations of flumes for runoff measurement and sample collection. The inset map shows the location of the study site (dot) and extent of the Coastal Plain within the state of Georgia. Contour elevations are in meters and intervals are approximately 0.30 m.

Amundson et al., 2015). Dialynas et al. (2016) noted the close linkage between soil erosion, especially from agriculture, and the global carbon cycle, and pointed out how the knowledge gap about the fate of eroded SOC is a key factor in the wide margin in estimates (from source to sink) of the net effect of soil erosion on the carbon cycle.

Typically, sediment resulting from soil erosion is enriched in carbon and nitrogen when compared to the source surface soil because of selective erosion of fine soil particles and organic residues (Massey and Jackson, 1952; Menzel, 1980). Enrichment ratios are calculated as the concentration in sediment divided by the equivalent concentration in the surface soil. Various depths of interaction have been used ranging from 1.5 to 10 cm. Cogle et al. (2002) reported average enrichment ratios of 1.3 to 4.1 for organic carbon and 3.0 to 6.3 for nitrogen (Kjeldahl method) for an Indian Alfisol, with surface texture of sandy loam merging to sandy clay loam or light clay. Fifteen management practices were evaluated. The soil depth of interaction did not significantly change computed values. Strickland et al. (2012) reported a similar range of enrichment ratios for total carbon and nitrogen (dry combustion) from a Georgia Ultisol loamy sand from two rainfall simulation studies and further noted that enrichment ratios for nitrogen for soils under conservation tillage were higher than soils under conventional tillage. These values also spanned the normal range reported in other studies (Lowrance and Williams, 1988; Smith et al., 1993; Gregorich et al., 1998; Schiettecatte et al., 2008a,b).

Although a decrease in enrichment ratio with increasing sediment load, sediment delivery ratio (SDR), and storm intensity has often been observed, it is becoming clear that soil erosion, re-deposition, and enrichment ratios for carbon and nitrogen characteristics are region-specific. Factors include the confluence of soil type, texture, macro-aggregation at the soil surface, landscape position and slope, antecedent soil water content, rainfall intensity patterns, watershed geomorphic characteristics, and land use and management (Barthes et al., 1993; Cogle et al., 2002; Silburn and Glanville, 2002; Schiettecatte et al., 2008a; Rimal and Lal, 2009; Berhe et al., 2012; Strickland et al., 2012; Li et al., 2016). For example, some experiments showed that enrichment of organic carbon during rill erosion was unselective (Li et al., 2016) or that interill erosion contributed to a decreased organic carbon enrichment ratio as erosion rates increased (Schiettecatte et al., 2008a), while others showed that diffusive erosion (sheet flow) increased sediment enrichment of organic carbon delivered to rills which then transport the C-enriched sediment downslope (Silburn and Glanville, 2002; Polyakov et al., 2004). Another factor to consider is tillage where reported trends are also mixed. Regarding carbon enrichment, some studies have reported that the ratio increased as SDR increased with soil in no-till tillage management (Jacinthe et al., 2002), that slope, rainfall intensity and soil type had almost no effect in conventional tillage systems (Li et al., 2016), that conservation tillage systems had no effect (Owens et al., 2002), or that the ratio was higher from conventional