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Effects of agricultural management systems on soil organic carbon in aggregates of Ustolls and Usterts

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Abstract

Soil erosion contributes to the removal and redistribution of soil organic C from cultivated fields. The soil organic C content of wind erodible and water unstable aggregates is an important factor in determining the amount of carbon loss occurring in erosion processes. The relative distribution of organic carbon among aggregate size fractions may also affect the response of soils to erosion. Soil organic C distribution is dependent on the chosen management system. The effects of no-till, till, and grassland management systems on organic C content of erodible and non-erodible aggregates were examined in six Ustolls and two Usterts of central South Dakota. Organic C contents were related to dry- and wet-sieving to represent the potential influence of wind and water erosion on C loss in the absence of vegetative cover. Loss of aggregate stability in cultivated soils was associated with organic C loss. Most structural characteristics developed under tilled systems persisted after 6–16 years of no-till. Changes in distribution of organic C due to management systems were most evident in Ustolls where cultivation resulted in net soil C losses. Soil organic C was not significantly increased by the no-tillage practices applied in this on-farm study (in Ustolls 49 Mg ha^{-1} in no-till versus 41 Mg ha^{-1} in till, for 0–0.20 m depth). Soil properties of Usterts were less affected by land use and management practices due to the high shrink swell action and self-mixing. In both soil orders the greater concentration of organic C in the wind erodible (<1 mm) dry aggregate size fraction implies a high potential for organic C loss by erosion in addition to organic C loss from mineralization after tillage. Grassland when compared to cultivated topsoil showed the largest amounts of organic carbon stored and the minimal potential for erosion loss of soil organic C.

Keywords: Soil organic C; Water erosion; Wind erosion; Soil management; No-till

1. Introduction

Organic C is a major component of the soil organic fraction and a variation of organic C content and location causes clear soil structural modifications. In general, soil organic C content declines with intensive management systems (Sparrow et al., 1999) and tends to decrease with increasing soil depth in relation to

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reductions in biological activity and root growth. Differences in depth distribution can be induced by different management systems. Organic C tends to be uniformly distributed within the tilled depth of moldboard plowed soils, and stratified in no-till soils with the highest concentration at the surface, where the first changes are usually observed after conversion from intensive tillage (Beare et al., 1997). Organic C content was found to be significantly different between management systems only in the top 0–0.05 m (Six et al., 1999, 2000).

There are few published data about organic C distribution in dry aggregate size fractions. Sometimes inferences have been made based on pre-moistened wet-sieved aggregates with discordant results (Angers and Carter, 1996). Puget et al. (1995, 2000) reported a reduction of organic C with decreasing aggregate sizes of dry-sieved aggregates. de Jonge et al. (1999) found a reduction of organic C with increasing aggregate size. Lado et al. (2004) did not find significant differences in organic matter content for different dry aggregate size fractions in a Humic Dystrudept containing >3% organic matter. In contrast, the organic matter was significantly greater in the 4–6 mm aggregate size fraction when the organic matter was <3% in a similar soil.

Wind erosion can result in considerable amounts of soil loss and deposition. Redistribution of soil implies redistribution of soil C. Soil C losses and gains from wind erosion depend on the C content of erodible particles and aggregates. Aggregates less than 1 mm in diameter are potentially erodible by wind (Woodruff and Siddoway, 1965). Particles and aggregates less than 0.1 mm in diameter are considered to be the most erodible (Skidmore and Powers, 1982). Su et al. (2004) attributed the major reduction in soil organic C found in the topsoil of a cultivated Entisol to the loss of particles and aggregates <0.1 mm in diameter by wind erosion. Potential losses of C from wind erosion are dependent on the proportion of erodible aggregates in the topsoil and in the C content of these aggregates.

Soil aggregate stability has been related to organic C content and localization in the architecture of the soil. Decreasing organic C contents are linked to decreasing wet aggregate stability and size of water stable aggregates (Puget et al., 2000). Less organic C in finer wet stable aggregate sizes was measured both in till and no-till soils (Beare et al., 1997). A linear relationship between macroaggregation and macroaggregate organic C content ($R^2 = 0.89$) was found by Shaver et al. (2003). A linear correlation was observed between organic C and wet stable aggregate size ($r = 0.90$) in soils of southeastern Scotland (Ball et al., 1996). The correlation coefficient was also significant ($r = 0.58$) in samples of an Inceptisol from New Zealand (Haynes and Swift, 1990). A significant linear relationship between C content and wet aggregate stability with $R^2 = 0.62$–0.67 ($n = 12$) was reported for Oxisols (Kouakoua et al., 1999). When air-dried aggregates are wet-sieved, stabilization by organic C may be more evident than in the case of pre-moistened aggregates not subjected to slaking stresses because stability to slaking is apparently a function of organic C (Chenu et al., 2000).

Organic components can stabilize soil structure protecting the soil from erosion. At the same time the organic fraction can be stabilized by physical protection of mineral soil constituents and by chemical interactions with soil mineral surfaces. In particular, soil constituents with a large specific surface area are involved in these processes. Consequently, clay mineralogy and organic composition of the clay-size fraction can be factors determining soil structural characteristics. The ≥35% smectitic clay content of Vertisols produces soil cracking and self-mixing. Therefore, a uniform distribution of organic C is expected and horizons tend to be less differentiated in Vertisols than in other soil orders (Soil Survey Staff, 1999). Organic C concentration in wet stable macroaggregates appeared 1.65 times greater in macroaggregates than in microaggregates in soils with dominant 2:1 clay minerals consisting of illite and chlorite (Six et al., 2000). In these soils the concentration of organic C was similar in macroaggregates from all management systems, whereas it decreased from grasslands to no-till fields to tilled fields in microaggregates. Other soils with mixed clay mineralogy did not show any significant trend (Six et al., 2000). In a kaolinitic Ultisol organic C was higher in water stable microaggregates of 0.106–0.250 mm size than in smaller or larger aggregate size fractions in no-till soils, whereas similar concentrations of organic C among aggregate size fractions were measured in tilled soils (Beare et al., 1994).

The objective of this study was to examine the effect of management systems on organic C content of