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Letter to the Editor

Effects of Tillage Practices and Land Use Management on Soil Aggregates and Soil Organic Carbon in the North Appalachian Region, USA

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ABSTRACT

Promoting soil carbon sequestration in agricultural land is one of the viable strategies to decelerate the observed climate changes. However, soil physical disturbances have aggravated the soil degradation process by accelerating erosion. Thus, reducing the magnitude and intensity of soil physical disturbance through appropriate farming/agricultural systems is essential to management of soil carbon sink capacity of agricultural lands. Four sites of different land use types/tillage practices, i) no-till (NT) corn *(Zea mays* L.) (NTC), ii) conventional till (CT) corn (CTC), iii) pastureland (PL), and iv) native forest (NF), were selected at the North Appalachian Experimental Watershed Station, Ohio, USA to assess the impact of NT farming on soil aggregate indices including water-stable aggregation, mean weight diameter (MWD) and geometric mean diameter (GMD), and soil organic carbon and total nitrogen contents. The NTC plots received cow manure additions (about 15 t ha^{-1}) every other year. The CTC plots involved disking and chisel ploughing and liquid fertilizer application (110 L ha^{-1}). The results showed that both water-stable aggregation and MWD were greater in soil for NTC than for CTC. In the 0–10 cm soil layer, the > 4.75-mm size fraction dominated NTC and was 46% more than that for CTC, whereas the < 0.25-mm size fraction was 380% more for CTC than for NTC. The values of both MWD and GMD in soil for NTC (2.17 mm and 1.19 mm, respectively) were higher than those for CTC (1.47 and 0.72 mm, respectively) in the 0–10 cm soil layer. Macroaggregates contained 6%–42% and 13%–43% higher organic carbon and total nitrogen contents, respectively, than microaggregates in soil for all sites. Macroaggregates in soil for NTC contained 40% more organic carbon and total nitrogen over microaggregates in soil for CTC. Therefore, a higher proportion of microaggregates with lower organic carbon contents created a carbon-depleted environment for CTC. In contrast, soil for NTC had more aggregation and contained higher organic carbon content within water-stable aggregates. The soil organic carbon and total nitrogen stocks (Mg ha^{-1}) among the different sites followed the trend of NF > PL > NTC > CTC, being 35%–46% more for NTC over CTC. The NT practice enhanced soil organic carbon content over the CT practice and thus was an important strategy of carbon sequestration in cropland soils.

Key Words: aggregate stability, macroaggregates, microaggregates, no-till, water-stable aggregation

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More than 50% of the global annual carbon (C) emission (about 11 Gt) is absorbed by natural sinks (land and ocean); therefore, the annual uptake by the atmosphere ranges between 4 and 5 Gt C year^{-1} for the decade ending in 2015 (Le Quéré *et al*., 2015). Hence, it is important to develop strategies that increase the C sink capacity of the natural sinks, especially those in the terrestrial biosphere so as to reduce the net uptake of CO_2 by the atmosphere (Lal, 2008). Soil organic C (SOC) as well as its potential to become a "managed" sink for atmospheric CO_2 has been a priority research area since the beginning of the 21st century (Lal, 2004; Sainju, 2006; Saha *et al*., 2011) because of its multiple benefits including the positive effects on soil physical, chemical, and biological properties (Carter, 1996; Lal, 2004). Therefore, *in-situ* SOC conservation should be prioritized in any management system to harness the soil C sink capacity. Conservation tillage, comprising a wide range of practices, is widely promoted as the best agricultural management practice to reduce soil erosion and maintain high SOC content (Lenka and Lal, 2013). The no-till (NT) practices have the potential to sequester SOC ranging from 0.3 to 0.4 Mg C ha^{-1} year^{-1} in European agricultural land (Freibauer *et al*., 2004). Similar values (0.2–0.4 and 0.3–0.4 Mg C ha^{-1} year^{-1}) have also been reported from USA and Cana-

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da (Watson *et al.*, 2000). Long-term use of NT practices can strongly affect surface hydrologic properties, increasing water infiltration rate and decreasing the runoff (Lal, 2004; Lenka and Lal, 2013). Furthermore, improvement in stability of soil aggregates reduces risks of soil erosion and the attendant degradation (Tisdall and Oades, 1982; Sheehy *et al.*, 2015). Therefore, knowledge of soil aggregate stability and its dynamics in relation to land use management is important in managing soil functionality, reducing risks of soil degradation, and identifying restorative management options (Kahlon *et al.*, 2013). Therefore, the present study was conducted to compare the effects of tillage practices on soil aggregation by selecting four sites of different land use types/tillage practices in the North Appalachian region of Ohio, USA. Furthermore, distribution of total organic C (TOC) within microaggregates (< 0.25 mm) and macroaggregates (> 0.25 mm) was assessed for each site to understand the role of aggregation in SOC and total nitrogen (TN). Therefore, the specific aim of this study was to investigate the tillage-induced differences in soil aggregation and SOC and TN contents.

A field study was conducted on a slope with an average gradient of about 10% in sub-watersheds at the North Appalachian Experimental Watershed Station formerly operated by the United States Department of Agriculture (USDA) Agricultural Research Services (ARS) in Coshocton County, Ohio, USA (40°21′36″ N, 81°47′45″ W). The long-term mean annual temperature and precipitation in the region are 10.3 °C and 950 mm, respectively. Soil of the region is a Rayne silt loam (fine-loamy, mixed, active, mesic Typic Hapludult).

Four sites of different land use types/tillage practices were selected for the study: i) no-till (NT) corn (*Zea mays* L.) (NTC), ii) conventional-till (CT) corn (CTC), iii) pastureland (PL), and iv) native forest (NF). The NTC plots had been under continuous corn since 1965 with cow manure additions (about 15 t ha^{-1}) approximately every other year. The CTC plots had been under continuous corn since 1985. The CTC involved disking and chisel ploughing and the depth of the tillage ranged from 18 to 20 cm from the surface layer. Liquid fertilizer (10:34:0 (weight:weight:weight), N:P:K) was applied at the pre-plant stage (110 L ha^{-1}) and two applications of urea-ammonium nitrate solution (URAN) at the crop growth stage (110 L ha^{-1}). The PL plots had been under meadow for at least 50 years though the exact date was unknown. The NF plots were logged for timber in the 1930's and thus NF is a secondary forest of approximately 80 years old. These plots were not replicated. Thus, soil samples were obtained on sub-plots, and were considered as pseudo-replicates.

Soil samples in triplicate from the 0–10 and 10–20 cm layers were collected from each site in November 2014. During the soil sample collection under CTC and NTC, residues were observed from previous crop and the areas were unploughed. The nitrogen (N) and C contents of crop residues were 27 and 390 g kg^{-1}, respectively. Soil bulk density was determined by the core (core diameter 8 cm and length 10 cm) method from duplicate soil samples after oven drying at 105 °C (Gee and Bauder, 1986). For aggregate analysis, soil samples from each layer and each site were pre-sieved using 8- and 4.75-mm sieves. Soil aggregates retained on the 4.75-mm sieve were separated by wet sieving (John and Kim, 2002). Aggregates were then sieved in water using 4.75, 2, 1, 0.5, 0.25, and 0.105-mm sieves for 30 min (30 r min^{-1}) (Yoder, 1936). Soil particles retained on each sieve were collected and oven dried at 45 °C. The dry weight of all these water-stable aggregates was measured for each size fraction and for each soil sample. Along with the bulk soil, a portion of the aggregates were finely ground and separated into micro- and macroaggregates for measurement of TOC and TN with a CN analyzer (Model-FLASH 2000, Organic Elemental Analyzer, Thermo Scientific, USA). The C and N were determined for bulk soils (Mg ha^{-1}) and in micro- and macroaggregates (g kg^{-1}) for each soil layer for all sites studied.

The aggregate indices, mean weight diameter (MWD) and geometric mean diameter (GMD), were calculated following Nimmo and Perkins (2002):

$$\mathrm{MWD} = \Sigma x_i y_i \tag{1}$$

where y_i is the proportion of each size class i with respect to the total sample and x_i is the mean diameter of size class i (mm);

$$\mathrm{GMD} = \exp[\Sigma(w_i \ln x_i)/\Sigma w_i] \tag{2}$$

where w_i is the weight of the aggregates of size class i (g).

One-way analysis of variance (ANOVA) was performed to study the significant effects of land use types and tillage practices on variables including aggregate size distribution, MWD, GMD, SOC, TOC, and TN, followed by Tukey's honestly significant difference (HSD) analysis. Statistical analyses were performed using MS-Excel 10 and SPSS 15.

Distribution of the water-stable aggregates in the 0–10 and 10–20 cm layers was as shown in Fig. 1. In