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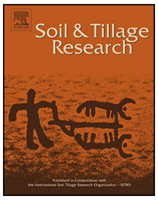

Soil biological properties, soil losses and corn yield in long-term organic and conventional farming systems

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ABSTRACT

Topsoil losses through surface runoff have severe implications for farmers, as well as surrounding ecosystems and waterbodies. However, integrating management systems that enhance soil organic matter (SOM) can stabilize the soil surface from erosion. Little is known about how differences in both tillage and cropping system management affect carbon and subsequent sediment losses in horticultural fields, particularly in the humid climate of the southeast. Research was conducted in the Appalachian Mountains in Mills River, NC on a fine-sandy loam Acrisol from 2010 to 2012 on long-term plots established in 1994. Project objectives included to: (1) quantify labile and total organic matter based on tillage and cropping system practices, (2) determine if relationships exist between SOC ad sediment losses, and (3) determine long-term management and tillage impacts on total organic matter lost via runoff. We hypothesized that organic management and reduced tillage would lead to increased soil carbon, which subsequently reduce losses as soil is stabilized. Organic no tillage and conventional till treatments contained on average 14.34 and 6.80 g kg^{-1} total carbon (TC) respectively, with the organic no till treatments containing twice the quantity of TC and light fraction particulate organic matter (LPOM) in the upper 15 cm as compared with the conventionally tilled treatments, and four times the quantity of microbial biomass carbon (MBC). LPOM and HPOM, the heavier fraction of POM, did not differ in the organic till and conventional no till treatments.Data support our hypothesis that organic production in combination with no tillage increases C pools (both total and labile) as compared with tilled conventional plots. However, organic no till treatments produced sweet corn (*Zea mays* var. *saccharata*) yields less than 50% of that of conventional treatments, attributed to weed competition and lack of available N. No tillage treatments lost two to four times less soil C via surface runoff than tilled systems. Additionally, we found that as total soil C increased, suspended solids lost through surface runoff decreased. Overall, our results indicate tillage to be an important factor in enhancing soil C and decreasing soil loss through surface runoff.

1. Introduction

Corn (*Zea mays*) cropping systems in the Southeastern U.S. lose an estimated 3.5 tons of topsoil ha^{-1} year^{-1}, with a total of 4.2×10^6 tons of topsoil lost annually (Natural Resource Conservation Service, 2006). Agricultural soil and nutrient runoff are the leading pollutants to our surveyed rivers and lakes (United States Environmental Protection Agency, 2010), with an estimated one third of the soil and associated nutrients carried by runoff and discharged into streams and water bodies (Kok et al., 2009). This loss of surface soil and associated nutrients depletes soil and nutrient stocks, while also degrading water quality in associated watersheds.

Soil organic matter additions help stabilize soil from runoff losses and protect the soil surface from erosion by increasing infiltration and water holding capacity, ultimately leading to decreased nutrient and sediment pollution, defined here as soil and associated soil-bound nutrients lost via surface runoff (Apezteguía et al., 2009; Bollag et al., 1992; Lal, 2004). Additionally, the resulting increase in soil organic matter can lead to greater soil aggregation, which increases pore space and further promotes

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infiltration (Shepherd et al., 2002; Williams and Petticrew, 2009). Soil organic carbon is the largest single component of SOM (Dungait et al., 2012) and is often measured to assess soil organic matter concentration.

Tillage facilitates rapid decomposition of SOM due to the disruption of aggregate-embedded organic matter, and exposure of microorganisms to increased oxygen (Bot and Benites, 2005; Tisdall and Oades, 1982). Intensive tillage can be a leading cause of erosion due to disruption of the soil surface and removal of protective residue that would otherwise be effective in slowing runoff and soil loss (Kok et al., 2009). Conservation tillage, however, by definition leaves residue on the fields, covering at least 30% of the soil surface and has been shown to significantly reduce soil erosion potential (Kasper et al., 2009). Organic systems utilize organic inputs and can increase SOC in agricultural soils (Lal, 2004; Wander and Traina, 1996) however, these systems rely heavily on tillage to control weeds, which promotes soil degradation and leads to increased runoff (Bot and Benites, 2005).

Microbial biomass and labile fractions of organic matter undergoing decomposition are two indicators of microbial activity. Microbial biomass is the biological fraction of soil actively involved in the transformation of organic residues (Merino et al., 2004) and is defined as the total mass of living microorganisms in a given volume or mass of soil (Franzlubbers and Haney, 2006). Particulate Organic Matter (POM) can also be a reliable measurement of labile organic matter (Marriott and Wander, 2006; Wander, 2004; Wander et al., 2007). To assess POM, density fractionation can be used to separate light fractions (LPOM) from more decomposed heavy fraction POM (HPOM) (Wander and Traina, 1996). The LPOM is strongly influenced by plant litter additions and is considered to be young recently decomposed C, or C in the early stages of decomposition (Gregorich and Janzen, 1996). HPOM, the heavier fraction of organic matter, is slightly more stable and is characterized by a continuum of organic materials that have already undergone varying degrees of decomposition (Marriott and Wander, 2006; Gregorich and Janzen, 1996).

In this experiment we sought to determine how long-term organic and conventional management under different tillage practices impact soil C pools, and if pool size affects sediment and C losses. Our three objectives include to: (1) quantify labile and total organic matter based on tillage and cropping system practices, (2) determine if relationships exist between SOC and sediment losses, and (3) determine long-term management and tillage impacts on total organic matter lost via runoff. For this study, we hypothesized that organic management in combination with no tillage would increase C pools (both total and labile) as compared with conventionally tilled plots, and that organic management and reduced tillage practices are associated with reduced sediment losses.

2. Materials and methods

2.1. Study site

The field site is located at the Mountain Horticultural Crops Research Station in Mills River, NC (35°25′50″ North, 82°30′5″West). Land is gently sloped at 2–7% and is situated on a stream terrace of the French Broad River, with soil type a Delanco fine-sandy loam (fine-loamy, mixed, mesic, Aquic Hapludult or Acrisol). Physical properties of the site are provided in Table 1.

2.2. Experimental design

Five production treatments were tested in this experiment: (1) organic management + no tillage (ONT), (2) organic management + conventional tillage (OT), (3) conventional management + no tillage (CNT), (4) conventional management + conventional tillage (CT), and (5) CO (control-tilled, disked and no inputs of fertilizers or pesticides [control]). The five treatments were replicated four times each in a completely randomized design and a buffer (15.24 m) of grass surrounded each plot (9.14 m × 18.29 m) to eliminate potential drift of fertilizers and pesticides. A description of treatment management is presented in Table 2. Plots have been under these treatments since 1994 with the organic plots certified organic by International Certification Services, Inc. (Medina, ND).

2.3. Field preparation

The long-term sequence of vegetables grown in the field plots is described by Wang et al. (2011). Table 1 outlines all field practices for the 2011 and 2012 growing seasons. "Sunrise" variety crimson clover (*Trifolium incarnatum*) at a rate of 33.6 kg ha^{-1} and "Arthur" variety wheat (*Triticum*) at 80.6 kg ha^{-1} 1 were planted in all treatment plots except the control. In 2012, Banvel II herbicide [sodium salt of dicamba (3,6-dichloro-o-anisic acid)] was applied in February at 0.29 l ha^{-1} to kill clover in conventional plots. Winter cover crops were terminated chemically (conventional treatments) or mechanically (organic treatments) at flowering in the spring. Sweet corn (*Zea mays* var. *saccharata*) was planted at a rate of 65,235 seeds ha^{-1} in all plots in May or June and harvested approximately 80 days after planting. Fertilizer N was applied to treatment plots at a rate of 201.6 kg total N ha^{-1} in different forms for organic and conventional treatments (Table 2). A chisel plow, which plowed to a depth of 9 inches, was used in 2009–2013 for both the OT and CT treatments.

At the down slope end of each plot a collection trough was installed to funnel surface runoff to a central outlet point. Wooden boards were installed around the outside perimeter of field plots by partially burying them in the soil to prevent lateral flow of surface water and to ensure rainfall water was collected at the central outlet. An Isco automated sampler and weir was installed at the outlet point of each plot, designed by the Department of Biological and Agricultural Engineering fabrication shop at NCSU, with integrated flow meter and a flume to measure flow volume and collect water/sediment samples flowing through a flume (Virtual Polymer Compounds, Medina, NY). An annual irrigation event of an equal quantity of water was applied to all plots once in the summer of each year.

2.4. Soil sampling

Soil samples were collected from all plots in October 2010, April 2011, July 2011, May 2012, and July 2012 for microbial biomass and December 2009, April 2011 and May 2012 for particulate and total organic matter. Ten subsamples were taken to a 15 cm (6 inch) depth from each plot with a 2.54 cm (one-inch) diameter soil probe, homogenized, and stored according to procedures outlined below.

2.5. Soil carbon pools

Fresh, moist soil samples for the microbial biomass measurements were sieved to 2 mm and stored at 4 °C for up to 10 days before analysis. Chloroform fumigation was used to measure microbial biomass and obtain soil microorganism C and N as an indicator of biological activity among treatments (Iyyemperumal et al., 2007; Vance et al., 1987). This approach compares total microbial N and C from two sets of soils, with one set killed via fumigation compared with a set of unfumigated samples. Microbial biomass C and N (MBC/MBN) were calculated using the following equations: