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Crop management effects on soil carbon sequestration on selected farmers' fields in northeastern Ohio

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Abstract

Soil organic carbon (SOC) pool is the largest among terrestrial pools. The restoration of SOC pool in arable lands represents a potential sink for atmospheric CO_2. Restorative management of SOC includes using organic manures, adopting legume-based crop rotations, and converting plow till to a conservation till system. A field study was conducted to analyze soil properties on two farms located in Geauga and Stark Counties in northeastern Ohio, USA. Soil bulk density decreased with increase in SOC pool for a wide range of management systems. In comparison with wooded control, agricultural fields had a lower SOC pool in the 0–30 cm depth. In Geauga County, the SOC pool decreased by 34% in alfalfa (*Medicago sativa* L.) grown in a complex rotation with manuring and 51% in unmanured continuous corn (*Zea mays* L.). In Stark County, the SOC pool decreased by 32% in a field systematically amended with poultry manure and 40% in the field receiving only chemical fertilizers. In comparison with continuous corn, the rate of SOC sequestration in Geauga County was 379 kg C ha^{-1} $year^{-1}$ in no-till corn (2 years) previously in hay (12 years), 760 kg C ha^{-1} $year^{-1}$ in a complex crop rotation receiving manure and chemical fertilizers, and 355 kg C ha^{-1} $year^{-1}$ without manuring. The rate of SOC sequestration was 392 kg C ha^{-1} $year^{-1}$ on manured field in Stark County.

Keywords: Carbon sequestration; CN pools; Soil fertility; Crop management; Crop rotation; Conservation tillage; Manure addition; Soil pH

1. Introduction

Restoration of soil organic carbon (SOC) in arable lands represents a potential sink for atmospheric CO_2 (Lal and Kimble, 1997). Strategies for SOC restoration by adoption of recommended management practices (RMPs) include conversion from conventional tillage to no-till, increasing cropping intensity by eliminating summer fallows, using highly diverse rotation, introducing forage legumes and grass mixtures in the rotation cycle, increasing crop production, and increasing carbon (C) input into the soil (Lal et al., 1998; Lal, 1999; Desjardins et al., 2001; Hao et al., 2002). In the US, cropland under no-till increased from 14.7% in 1995 to 19.6% in 2002 (Fawcett and Towery, 2003). There is a strong

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interaction among RMPs with regards to their effect on SOC concentration and soil quality (Jarecki and Lal, 2003). Adopting no-till in combination with other management practices can enhance SOC sequestration. In combination with minimum or no-till management, crop rotations can reduce soil erosion, enhance SOC concentration and sequester soil C (Lal, 2001). West and Post (2002) observed that changing plow till to no-till increased SOC pool at the rate of 57 g C m^{-2} $year^{-1}$ (or 570 kg ha^{-1} $year^{-1}$). Relatively lower rates (14 g C m^2 $year^{-1}$) of increase in SOC pool were associated with adoption of complex crop rotations. The efficiency of a no-till system for SOC sequestration is enhanced when used in combination with high intensity crop rotations and elimination of summer fallow (Potter et al., 1997; Campbell et al., 1998). Converting a monoculture to a crop rotation also leads to SOC sequestration, which increases residue inputs to the soil (Robinson et al., 1996; Drury et al., 1998; Halvorson et al., 2002). Increase in SOC may not occur in crop rotations, which include high frequency of low residue producing crops, such as soybean (*Glycine max* L.) (Omay et al., 1997; Dick et al., 1998; Studdert and Echeverria, 2000). Buried residues and roots decay faster than above ground or surface applied residues as is the case in a no-till system (Ghidey and Alberts, 1993). A strong interaction between C, water and N cycles impacts the SOC pool and soil erosion risks (Reicosky, 1994).

The data on SOC sequestration rate under on-farm conditions are scanty, but needed for assessing the C credits and evaluating the impact of management system on soil quality. Therefore, the objectives of this study were to compare SOC and N pools, and other soil properties under different crop management systems under on-farm conditions on selected farms in northeastern Ohio, USA.

2. Materials and methods

2.1. Sites and soil description

Two farms, one each in Geauga and Stark Counties in northeastern Ohio, were selected for the study. The long-term mean precipitation is 1112 mm per annum in Geauga County and 915 mm in Stark County. The precipitation distributed evenly throughout the year, and is adequate for crop production in most soils. The average annual temperature is 9.0 °C in Geauga and 10.2 °C in Stark County (USDA, 1971, 1982). The farms are located near Burton in Geauga County (41.29N, 81.07W) hereafter called ‘‘Geauga Farm’’, and near Louisville in Stark County (40.57N, 81.15W) hereafter called ‘‘Stark Farm’’. In both Counties dairy farming is the principal enterprise. However, the soils which are more suited for grasses than for row crops have been used in agriculture since the beginning of the 19th century. Soils of the Geauga Farm are classified as a Canfield silt loam (fine-loamy, mixed, mesic Aquic Fragiudalfs) and those of the Stark Farm as a Ravenna Canfield silt loam (fine-loamy, mixed, mesic Aeric Fragiudalfs). These are deep, gently sloping (2–4%), moderately well drained soils formed on glacial till (Wisconsin age) on uplands. They contain fragipan that restricts rooting depth and the movement of water. Permeability is moderate above the fragipan and slow in the fragipan and substratum (USDA, 1971, 1982). The mean texture particle size distribution for the surface layer comprises 30% sand, 38% clay and 32% silt in the Geauga Farm; and 29% sand, 33% clay and 38% silt in the Stark Farm.

The land use and management system chosen for the Geauga Farm included: a wooded control (wooded), continuous corn (CC), continuous corn with no-till management (CCNT), alfalfa in crop rotation with cattle manure (ARM) and grass meadow in an unmanured crop rotation (GRUM) (Table 1). All fields and wooded area in the Geauga Farm were located within a 2.5 km radius and have the same loamy texture. Land use and management systems chosen for the Stark Farm included: a wooded control (wooded), corn in poultry manured corn/soybean rotation (manured) and soybean with chemical fertilizer (mineral) in corn/soybean rotation (Table 1). Both fields in the Stark Farm are adjacent to each other and bordered with a wooded area. In both farms, all fields were managed with a minimum till system with the exception of CCNT in the Geauga Farm where a no-till system was practiced. Minimum till system refers to minimum cultivation required to grow a crop successfully, and in the Geauga Farm and Stark Farm, the soil cultivation was restricted to chisel and disc. The no-till corn was planted directly into the seedbed, which was not tilled since the previous corn crop.