Available online at www.sciencedirect.com
SCIENCE DIRECT®
ELSEVIER
Soil & Tillage Research 80 (2005) 201–213
Soil & Tillage Research
www.elsevier.com/locate/still

Soil organic carbon and nitrogen in a Mollisol in central Ohio as affected by tillage and land use

P. Puget, R. Lal*

The Ohio State University, School of Natural Resources, Kottman Hall, 2021 Coffey Road, Columbus, OH 43212, USA

Received 23 December 2002; received in revised form 19 March 2004; accepted 25 March 2004

Abstract

Minimum tillage practices are known for increasing soil organic carbon (SOC). However, not all environmental situations may manifest this potential change. The SOC and N stocks were assessed on a Mollisol in central Ohio in an 8-year-old tillage experiment as well as under two relatively undisturbed land uses; a secondary forest and a pasture on the same soil type. Cropped systems had 51 ± 4 (equiv. mass) Mg ha^{-1} lower SOC and lower 3.5 ± 0.3 (equiv. mass) Mg ha^{-1} N in the top 30 cm soil layer than under forest. Being a secondary forest, the loss in SOC and N stocks by cultivation may have been even more than these reported herein. No differences among systems were detected below this depth. The SOC stock in the pasture treatment was 29 ± 3 Mg ha^{-1} greater in the top 10 cm layer than in cultivated soils, but was similar to those under forest and no-till (NT). Among tillage practices (plow, chisel and NT) only the 0–5 cm soil layer under NT exhibited higher SOC and N concentrations. An analysis of the literature of NT effect on SOC stocks, using meta-analysis, suggested that NT would have an overall positive effect on SOC sequestration rate but with a greater variability of what was previously reported. The average sequestration rate of NT was 330 kg SOC ha^{-1} $year^{-1}$ with a 95% confidence interval ranging from 47 to 620 kg SOC ha^{-1} $year^{-1}$. There was no effect of soil texture or crop rotation on the SOC sequestration rate that could explain this variability. The conversion factor for SOC stock changes from plow to NT was equal to 1.04. This suggests that the complex mechanisms and pathways of SOC accrual warrant a cautious approach when generalizing the beneficial changes of NT on SOC stocks.

Keywords: Soil carbon sequestration; Nitrogen stock; No till; Pasture; Forest; Meta-analysis; Soil quality; Conservation tillage

1. Introduction

Conversion of natural ecosystems to agriculture as well as increasing intensity of tillage are known to decrease soil organic matter (SOM) levels and contribute significantly to the increase in atmospheric CO_2 concentration (Lal et al., 1998). Between 1850 and 1995, SOM mineralization emitted $136 \pm 55 \times 10^{15}$ g of C to the atmosphere (Houghton, 1995; Watson et al., 2001). Changes in SOM by different agricultural land uses and practices have been extensively reviewed by Mann (1986), Davidson and Ackerman (1993), Guo and Gifford (2002), and Murty et al. (2002). Guo and Gifford (2002) reported that soils lost 42 and 59% of their soil organic carbon (SOC) stock upon conversion from forest to crop and from grassland to crop, respectively. In contrast, Mann (1986) calculated losses <20% of the initial stock, which was corroborated by Kern and Johnson (1993) and Murty et al. (2002) who evaluated the decrease of SOC stock in the major

* Corresponding author. Tel.: +1-614-292-9069; fax: +1-614-292-7932.
E-mail address: lal.l@osu.edu (R. Lal).

0167-1987/$ – see front matter
doi:10.1016/j.still.2004.03.018

US cropland soils at ca. 16 and 22–25%, respectively. However, Davidson and Ackerman (1993) argued that calculations made on a fixed soil depth instead of an equivalent mass of soil underestimated the changes in SOC stock. With the objective of reducing net emission of CO_2 and other greenhouse gases (GHGs), soil C sink capacity has been debated (Swift, 2001; West and Marland, 2002), i.e., can the "lost C" be re-sequestered in soils and if so, how and to what extent?

Three main strategies for SOC sequestration in the biosphere are: (i) enhancing the re-growth of perennial vegetation through conversion of cropland to grassland or forestland, (ii) increasing the net primary productivity and therefore the amount of residue returned to the soil, mainly through intensification of agricultural inputs: fertilizer, irrigation, manuring, and (iii) adopting conservation tillage especially no tillage (NT). Post and Kwon (2000) reported that changes in land use to perennial vegetation may potentially sequester C at a rate of 300–350 kg C ha^{-1} $year^{-1}$. However, they acknowledged that this increase was too small to counteract the "anthropogenically released" C in the global C cycle. Several studies have shown that intensification of farming systems augments SOC levels mainly by increasing the amount of biomass produced and the amount of residues returned (Larson et al., 1972; Zielke and Christenson, 1986; Havlin et al., 1990; Campbell and Zetner, 1993; Follett, 2001). However, some researchers have pointed out that these approaches may not be as efficient as perceived when fluxes of all GHGs, especially the hidden C costs of agricultural intensification, are taken into account (Robertson et al., 2000; Schlesinger, 2000a,b).

Conservation tillage practices, especially NT, can improve SOC and other soil nutrient stocks. Conservation tillage was developed primarily to combat soil erosion by developing a protective mulch layer of crop residues at the soil surface. Consequently, the repetitive use of this technique profoundly affects the incorporation and depth distribution of SOC, as well as the whole ecology and functioning of soil (Kladivko, 2001). No tillage impacts SOC stock in two ways: (i) by reducing disturbance which favors the formation of soil aggregates and protects SOC encapsulated inside these stable aggregates from rapid oxidation (Chaney et al., 1985; Elliott, 1986; Beare et al., 1994; Six et al., 2000) and (ii) by modifying the local edaphic environment: bulk density, pore size distribution, temperature, water and air regime that might also restrict SOC biodegradation (Mielke et al., 1986; Kay and VandenBygaart, 2002). The literature is replete with studies that show an increase in SOC stock with conversion to NT, at least in the surface soil (e.g. Blevins et al., 1983; Dick, 1983; Dick et al., 1986, 1991; Doran, 1980; Lal et al., 1990). Paustian et al. (1997) and Lal et al. (1998) summarized the rate of accumulation of SOC stock under NT at 300–800 kg SOC ha^{-1} $year^{-1}$. However, under some conditions, especially in fine-textured soils, there may be little or no increase in SOC stock, especially at a depth greater than the plow layer (Mielke et al., 1986; Dalal, 1988; Angers et al., 1995,1997; Wander et al., 1998).

The present study was undertaken to determine how contrasting agricultural land uses and tillage practices might affect SOC sequestration in a fine-textured Mollisol in central Ohio. We determined the distribution and stocks of SOC and N through the soil profile and compared our data with those reported in the literature in which studies were carried out on paired experiments of NT versus plow till.

2. Materials and methods

A tillage experiment was initiated in Autumn 1993 to determine the effect of three tillage practices [chisel till (CT), moldboard plow till (PT) and NT] on corn (*Zea mays*) yield and plant nutrients. The experiment was located at the Don Scott Experimental Farm, Columbus, OH (40°04′30′′N; 83°04′W) on a Kokomo silty clay loam (somewhat poorly drained, fine, mixed, mesic, Typic Argiaquolls) (McLoda and Parkinson, 1980). The experimental plot was divided in two blocks (west and east) on which corn and soybean (*Gtycine max*) were cropped in alternate years. The above-ground crop residue returned was 8–10 Mg ha^{-1} $year^{-1}$ during the corn cycle and 2–3 Mg ha^{-1} during the soybean cycle. Each block was divided into 12 subplots of 17.5 m × 22.5 m corresponding to three tillage treatments replicated four times. Soil samples were collected in December 2001 in the west block after corn harvest following 8 years of consecutive tillage treatment. A soil core (7.6 cm in diameter) was taken from the center of each subplot, using a truck-mounted hydraulic probe