This paper was peer-reviewed for scientific content.
Pages 499-502. In: D.E. Stott, R.H. Mohtar and G.C. Steinhardt (eds). 2001. Sustaining the Global Farm. Selected papers from the 10th International Soil Conservation Organization Meeting held May 24-29, 1999 at Purdue University and the USDA-ARS National Soil Erosion Research Laboratory.

Land Use Effects on Soil Carbon Pools in Two Major Land Resource Areas of Ohio, USA

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ABSTRACT

Conversion from natural to agricultural ecosystems decreases soil organic carbon (SOC) pools and the magnitude of the decrease depends on land use, management, and ecological factors. Quantification of the loss of SOC by conversion to agricultural land uses provides a reference point with regards to the potential of resequestration of SOC through improved management. In March of l998 a study was initiated to evaluate the differences in SOC pool in cropped, pastured, and forested (native) sites in Ohio. Out of a total of 24 Land Resource Regions (LRRs) in the United States, this study covered two Lake States Fruit, Truck, and Dairy Region and Central Feed Grains and Livestock Region located in the central section of the United States. In these two LRRs two Major Land Resource Areas (MLRAs) were part of the study. These MLRAs represent climate, water, soil types, elevation, topography, natural vegetation and land use for large areas in Ohio and adjacent states. The SOC pool was quantified by evaluating two predominant soil types to a depth of 30 cm. Cultivation resulted in an overall decrease of 37% in SOC pool for the soils analyzed. Established pasture had the capacity to sequester more SOC than the forest ecosystem. The data show that changes in SOC pool due to land use change depends on soil type, drainage, management practices and duration of current land use.

INTRODUCTION

Change in land use impacts soil organic carbon (SOC) pools and fluxes. Houghton (1995) estimated that 120 Pg C has been released to the atmosphere due to change in land use throughout the world since 1850. Change in land use typically results in differing rates of erosion, aggregate formation, biological activity, and drainage, which all have a significant impact on SOC accumulation and CO_2 evolution. Losses of SOC result in the decrease of water, atmospheric and soil quality. Differing land uses have variable impact on SOC pool and dynamics. Agricultura1 forested, and pastured land make up the most land area and have a potential to sequester large amounts of carbon. About 77.3% of all land use change is due to removal of forests and conversion of grasslands for arable land use (Lal et al., 1997). The conversion of natural ecosystem to cropland in the United States has led to the release of 5,000 Tg (million metric tons) C to the atmosphere (Lal et al., 1998). Understanding the impacts of agriculture, forest, and pasture on soil carbon pools and fluxes will allow for a better understanding of the potential of soil to sequester and release carbon.

Comparative efficiency of forest versus pasture on C dynamics is not very well understood. Most studies have shown that due to large amounts of biomass and high rate of biomass turnover, pasture or grassed areas sequester more SOC than forested areas (Neill et al., 1997; Yakimenko, 1997). In contrast, Guggenberger (1994) found that pasture sequestered carbon only at a slightly faster rate than forest. Studies that compare SOC losses or gains due to land use change have been limited to a single soil type, comparing land use change over different soils, and to change in SOC content in the plow layer with or without accompanying data on soil bulk density. Furthermore, most SOC studies have not comprehensively analyzed the relevant ecoregional factors, which are essential to understanding the effects of land use on SOC pools and dynamics. A better understanding of how ecoregions are affected by land use change will allow for effective land use policy that can be implemented to curtail the rate of CO_2 emission from soil to the atmosphere. Therefore the objective of this study was to determine the effects of land use change on SOC pool in two regions of Ohio. The SOC pool in these regions were evaluated for three land uses (forest, pasture, and cropland) on three different soil types.

MATERIALS AND METHODS

Site Descriptions

The study covered two Land Resource Regions (LRRs) consisting of two Major Land Resource Areas (MLRAs) in Ohio. One LRR was the Lake States Fruit, Truck, and Dairy Region, which contains the MLRA (99) Erie-Huron Lake Plain (Fig. 1). This MLRA was represented by two soil types, the Hoytville soil series and the Nappanee soil series (Table 1). Both soils are poorly drained. The other LRR was the Central Feed Grains and Livestock region, which contains the MLRA (111) Indiana and Ohio Till Plain (Fig. 1). This MLRA was represented by the Miamian soil series, which is a well-drained soil (Table 1). All sites were chosen carefully to be representative and typical of the soil series. The Hoytville and Miamian soils were chosen at the locations where they were originally mapped. All sites had a

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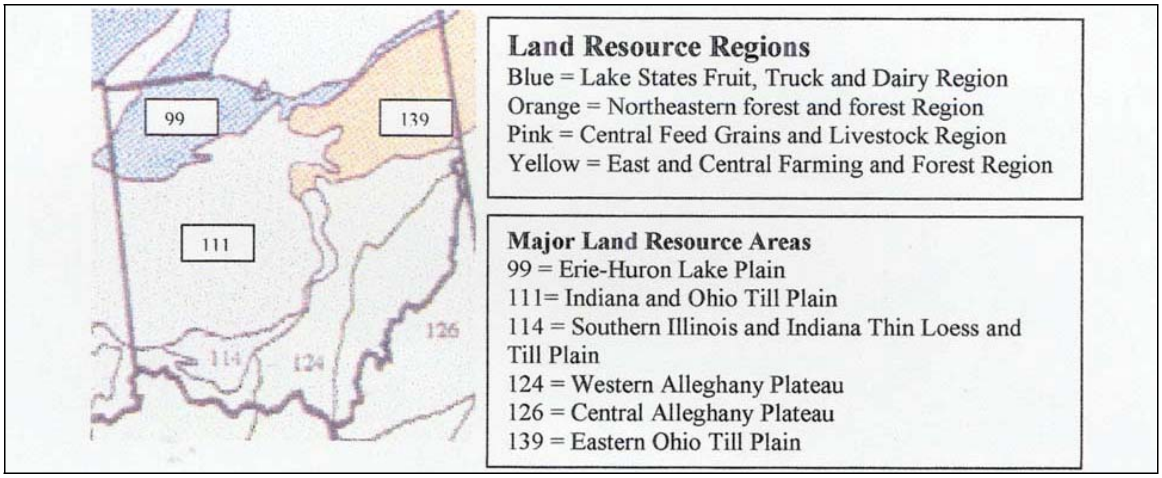

Figure 1. Locations of Land Resource Regions and Major Land Resource Areas

Table 1. Site locations and classifications.

Site	Series	Classification	Coordinates
Englewood	Miamian	fine mixed mesic Oxyaquic Hapludalf	Lat. 39˚ 52΄ Long. 83˚ 46΄
Hoytville	Hoytville	fine illitic mesic Mollic Epiaqualf	Lat. 41˚ 31΄ Long. 83˚ 46΄
Cygnet	Nappanee	fine illitic mesic Aeric Epiaqualf	Lat. 41˚ 14΄ Long. 83˚ 38΄

Table 2. Site characteristics.

Soil series	Land use	Drainage	% slope	Duration of land use (years)
Miamian	Forest	Well drained	4	Native
Miamian	Pasture	Well drained	4	15
Miamian	Crop	Well drained	4	100
Nappanee	Forest	Somewhat poorly drained	1	Native
Nappanee	Pasture	Somewhat poorly drained	1	45
Nappanee	Crop	Somewhat poorly drained	1	75
Hoytville	Forest	Very poorly drained	1	Native
Hoytville	Pasture	Very poorly drained	1	45
Hoytville	Crop	Very poorly drained	1	40

predominant slope of 0 to 4 % (Table 2).

Three sites were chosen for each soil series to represent three land uses (forest, pasture, and cropland). Forested sites chosen had never been totally cleared although they all showed some signs of partial logging in the past. The pasture and cultivated sites ranged in approximate age from 15-100 years since conversion to these land uses (Table 2). Subsurface drainage was installed for the cropped sites of the Hoytville and Nappanee soils. A drainage ditch was in close proximity of the pasture site for the Hoytville soil.

Sampling and analysis

Soil profiles were dug on all sites, using a backhoe. Three separate soil samples were taken from each depths of 0-5 cm, 5-10 cm and then by horizon to a depth of 30-cm. Soil samples were composited and analyzed for total carbon by dry combustion method (Soil Survey Laboratory Methods Manual, 1996). Before dry combustion, samples were ground to pass through a 0.5-mm sieve. Samples were also analyzed for calcium carbonates (Soil Survey Laboratory Methods Manua, 1996). Soil bulk density measurements were made by the core method for every 10-cm layer to a depth of 30-cm (Blake and Hartage, 1986). Data were analyzed for mean and standard deviation for each property within a land use system. Although Duncan's range test would be more indicative of the significant differences, profile samples taken for different land use treatments were not replicated as per a standard statistical design. For a similar reason, the scale of the y-axis for 0-5 cm layer is different from that of others to accommodate large changes in SOC pool of this vis-à-vis other layers.

RESULTS AND DISCUSSION

The highest SOC pool was measured in the forest ecosystems for both the Miamian and the Hoytville soil series (Fig. 2.). In the Nappanee soil, however, the highest SOC pool was measured in the pastureland use. This difference may be attributed to differences in land use history and management of the pasture. The Nappanee site had been intensively used for grazing for approximately 45 years. Intensive grazing involves the use of chemical

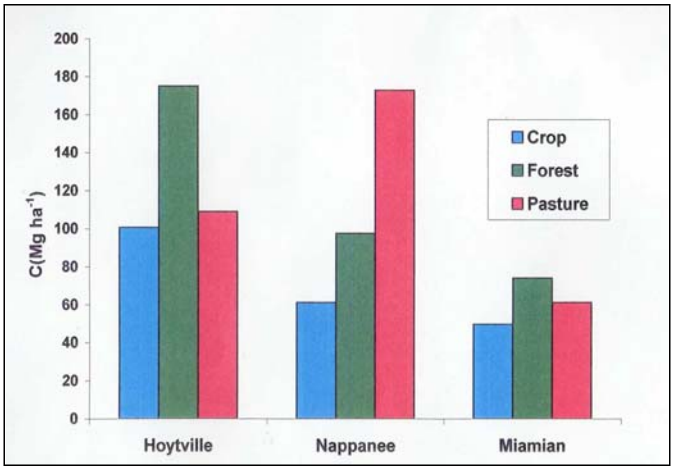

Figure 2. Soil organic carbon (SOC) at a 0-30 cm depth.

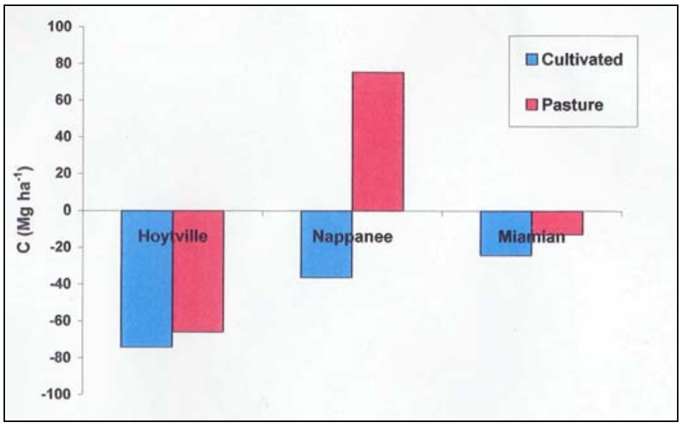

Figure 3. Soil organic carbon losses and gains from long term pastures and cropped fields at a 0-30 cm depth. Native forest was used as a baseline.

fertilizer. Also, the manure incorporation into the soil increases with grazing intensity. The Miamian site had only been under pasture for 15 years and had only been used sporadically for grazing. The Hoytville pasture site has rarely been grazed, which probably resulted in minimal inputs of fertilizer. Several experiments have demonstrated that fertilizer application increases SOC content (Janzen et al., 1992; Gregorich et al., 1996; Nyborg et al., 1997). The least SOC pool in all soils was observed for the cultivated sites (Fig. 3), which may be attributed to removal of biomass, degradation of soil structure, and the exposure of organic matter to mineralization and decomposition processes.

The Hoytville forest site had the largest SOC pool among the forest sites, and thus experienced the largest losses of SOC with change of land use to pasture and cropland (Fig. 3). The Hoytville site also had the highest standard deviation of the mean SOC pool for all land uses (Table 3). The large SOC pool in the forestland use may be attributed to both the drainage class of the soil and the past management practices. Hoytville soil is a very poorly drained soil in contrast to the somewhat poorly drained Nappanee soil and the well-drained Miamian soil. Soils with long periods of anaerobic conditions typically have high SOC contents. The large

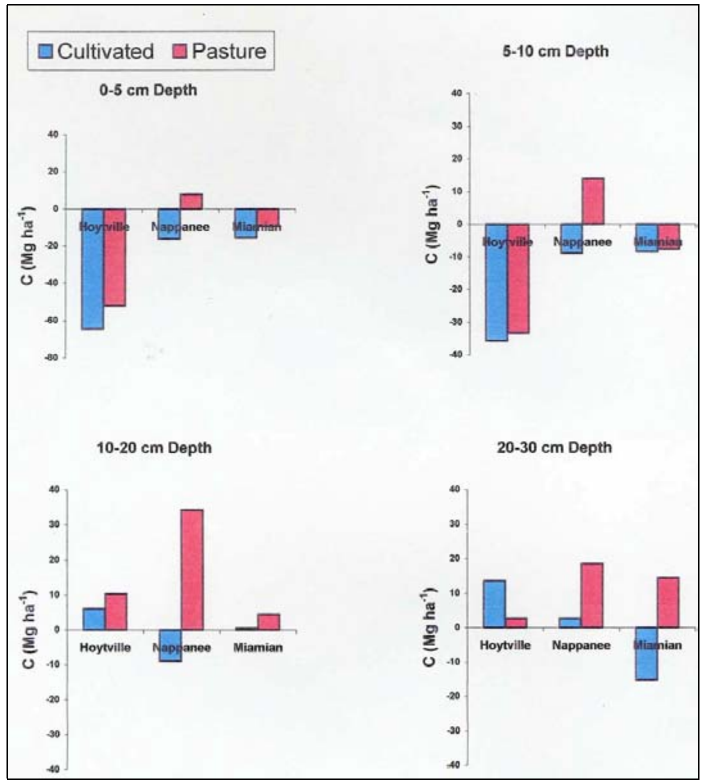

Figure 4. Losses and gains of SOC due to change land use at different depths. Native forest was used as the baseline.

difference in SOC pool between the forested and pasture site of the Hoytville soil may be due to the close vicinity of a drainage ditch at the pasture site. Artificial drainage has been shown to decrease SOC content (Sullivan et al., 1997). Logging practices may also have contributed to the differences between the forest sites. Not only does interval but the intensity of logging also impacts SOC (Olson et al., 1996; Jurgensen et al., 1997; Knoep and Swank, 1997). The SOC pool of the Miamian soil was least affected by change in land use, which may have also been in part due to soil drainage. Being a well-drained soil, its SOC pool is less impacted by change in drainage and land use. Both pasture and cropland uses resulted in decrease in SOC pool in the 0-5 cm and the 5-10 cm depths, except in the Nappanee pasture site (Fig. 4). In the 10-20 cm and the 20-30 cm depths the crop and pasture sites typically showed an increase in SOC pool in comparison to the forested sites due to plowing and to the deeper root systems in the pastures. Root biomass is the main reason for increases in SOC pool in pastoral land use (Balesdent and Balbane, 1996). There was no increase in the SOC pool in the Nappanee and Miamian cropland sites for the two lower depths, which may be attributed to differences in tillage practices. SOC contents decreased consistently with depths (Table 4). The Hoytville soil had the highest standard deviations from the mean for the 0-5 cm and 5-10 cm depths and the Nappanee soil had the lowest. The arable sites consistently had higher bulk densities for different depths (Table 5). The bulk (density at 0-10 cm in the forest site was high for the Hoytville soil. Comparatively low bulk density of the pasture site may be due to little or no grazing pressure.

CONCLUSIONS

Most agricultural soils in Ohio are below their potential level because of the historic C loss. Conversion to an appropriate land use and adoption of recommended agricultural practices can lead to C sequestration in soil over a 25 to 50 year period. Establishing the rate of C sequestration through a range of management options is a priority for principal soils and agroecosystems. In addition to conversion of highly erodible land to Conservation Reserve Program, recommended management practices to enhance SOC pool include conservation tillage in combination with cover crops and integrated nutrient management for agricultural soils, and controlled grazing and fertilizer use for pastures. The SOC sequestration research needs to be done at a regional level for site-specific conditions reflecting soil type, drainage, management practices, and land use options.

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