SOIL CARBON CONTENT WITHIN
A RED CEDAR-SCOTCH PINE SHELTERBELT

Thomas J. Sauer and Cynthia A. Cambardella
USDA-ARS, National Soil Tilth Laboratory, Ames, IA
and
James R. Brandle, School of Natural Resources,
University of Nebraska-Lincoln, Lincoln, NE

ABSTRACT

Carbon (C) sequestration in woody biomass is promoted as a practice to offset increasing atmospheric carbon dioxide (CO₂) concentrations. Less attention has been devoted to C sequestration in soil under reforestation or afforestation scenarios. The objective of this study was to quantify soil organic C (SOC) in surface layers within and adjacent to a 35 yr-old shelterbelt in eastern Nebraska. The 2-row, north-south shelterbelt was composed of eastern red cedar (Juniperus virginiana) and scotch pine (Pinus sylvestris). The shelterbelt was planted in 1968 and initially included eastern cottonwood (Populus deltoides), which were removed after ~15 years. Adjacent fields were cropped primarily to wheat (Triticum aestivum L.), grain sorghum [Sorghum bicolor (L.) Moench], corn (Zea mays, L.), and soybean [Glycine max (L.) Merr.]. In November 2003, a 7 x 17 sampling grid at 1.8 m spacing was established across a section of the shelterbelt on Tomek silt loam (fine, smectitic, mesic Pachic Argiudolls). Four soil cores were collected within 0.25 m of each grid point, divided into 0-0.075 and 0.075-0.15 m depth increments, and composited by depth. Under the shelterbelt, all surface litter in a 0.5 x 0.5 m square at each grid point was collected before soil sampling. SOC in uncultivated areas within the shelterbelt averaged 23.1 and 16.8 Mg ha⁻¹ for the 0-0.075 and 0.075-0.15 m layers and 18.6 and 17.7 Mg ha⁻¹ for the same layers in the cropped fields. Significantly greater SOC in the shelterbelt is attributed to decomposition of tree litter, absence of tillage, erosion reduction, and deposition of wind-blown dust.

Keywords: afforestation, red cedar, scotch pine, shelterbelt, soil organic carbon

INTRODUCTION

Carbon (C) sequestration in woody biomass is promoted as a practice to offset increasing atmospheric carbon dioxide (CO₂) concentrations. Extensive analyses of forest productivity for numerous forest types and management practices have recently been completed to quantify their potential for C sequestration (Vitousek et al. 1991; Kirschbaum 2003). Shelterbelts or field windbreaks consist of one to several rows of trees planted across or on the borders of crop fields and grazing lands to reduce wind speed and improve the local microclimate for crop and animal production. This agroforestry practice is most common in semiarid areas where it also protects the soil from wind erosion. Brandle et al. (1992), Schroeder (1994), and Kort and Turnock (1999) estimated C sequestration in aboveground biomass for different shelterbelt species in the US and Canada. These estimates ranged from < 1 Mg C km⁻¹ for single-row shrubs to > 100 Mg km⁻¹.
C km$^{-1}$ of hybrid poplar (*Populus x deltoides*). The belowground biomass or soil C sequestration potential of shelterbelts was not considered. To fully assess the C sequestration potential for agroforestry systems, C stock estimates should include forest products, detritus, and soil components (Nair and Nair 2003). The objective of this study was to quantify soil C in surface layers within and adjacent to a 35 yr-old shelterbelt in eastern Nebraska.

**MATERIALS AND METHODS**

The study site was located at the University of Nebraska-Lincoln Agricultural Research and Development Center near Mead, NE (41° 9’ N, 96° 29’ W, 356 m asl). Soil samples were collected within and adjacent to a 2-row, north-south shelterbelt planted with three tree species (eastern red cedar (*Juniperus virginiana*), scotch pine (*Pinus sylvestris*), and eastern cottonwood (*Populus deltoides*)) in 1968. The tree rows were 400 m long, spaced 3.65 m apart, and tree spacing within rows was 1.8 m. The cottonwood trees were removed after ~ 15 years (i.e., early 1980s). Red mulberry (*Morus rubra*), honeylocust (*Gleditsia triacanthos*) and various grasses and forbs were present at the margins of the shelterbelt. Adjacent fields were cropped primarily to wheat (*Triticum aestivum*), grain sorghum [*Sorghum bicolor* (L.) Moench], corn (*Zea mays*, L.), and soybean [*Glycine max* (L.) Merr.].

The topography at Mead is nearly level with soils formed on a loess-mantle over an ancient terrace of the Platte River. In the fall of 2003, a section of the shelterbelt located on Tomek silt loam (fine, smectitic, mesic Pachic Argiudolls) was selected for soil sampling. Sampling points were located on a 7 x 17 (parallel-to x perpendicular-to shelterbelt) sampling grid at 1.8 m-spacing except for the two columns of sample points in the grid between the tree rows, which were only 1.2 m apart to allow these sample points to be equidistant from the tree rows. Four 3.2 cm-diam. soil cores were collected within 0.25 m of each grid point, divided into 0-0.075 and 0.075-0.15 m depth increments, and composited by depth. In the uncultivated area, all nonwoody vegetation and surface litter in a 0.5 x 0.5 m square at each grid point was collected prior to soil sampling. The field east of the shelterbelt had been cropped with soybean, which had been harvested and tilled before planting of winter wheat. The field west of the shelterbelt had been cropped with corn (*Zea mays* L.) and the stubble remained on the surface. Surface crop residue was brushed aside before soil cores were collected from the field grid points.

All soil samples were weighed and a subsample removed and dried for 24 hrs at 105°C to determine soil water content and bulk density. All remaining field-moist sample was passed through a 8 mm sieve, visible roots removed, and a ~100 g subsample of the sieved soil was in turn passed through a 2 mm sieve. All soil samples were then air-dried. A ~ 15 g subsample of the air dry 2 mm fraction was placed on a roller mill (Bailey Mfg., Inc., Norwalk, IA) for 12 hrs to create a fine powder for total C and N analysis. Total soil C (TOC) and total N were measured using dry combustion (Fison NA 15000 Elemental Analyzer, ThermoQuest Corp., Austin, TX) and soil carbonates (SIC) were quantified using the pressure calcimeter method of Sherrod et al. (2002). Soil organic C (SOC) was calculated as the difference between TOC and SIC. Single-Factor ANOVA at $P = 0.05$ was used to test for differences in SOC between samples from cultivated (n=56) and uncultivated soil (n=62). Maps of SOC distribution were prepared using Surfer© surface mapping system (ver. 7.04, Golden Software, Inc., Golden, CO).
RESULTS AND DISCUSSION

SOC in uncultivated areas within the shelterbelt averaged 23.1 and 16.8 Mg ha\(^{-1}\) for the 0-0.075 and 0.075-0.15 m layers as compared to 18.6 and 17.7 Mg ha\(^{-1}\) for the same layers in the cropped fields. Thus, over the total sample depth (0-0.15 m), SOC averaged 39.9 and 36.3 Mg ha\(^{-1}\) for the shelterbelt and cultivated areas, respectively. For both soil layers and for their sum, SOC was significantly greater \((P < 0.05)\) in the shelterbelt by an average 24.2, 5.4, and 10.2\% for the 0-0.075, 0.075-0.15, and total 0-0.15 m layers.

Spatial patterns of SOC exhibited distinct areas with greater levels of SOC within the shelterbelt and especially between the tree rows (Figures 1-3). Greater SOC within the shelterbelt is attributed to decomposition of tree litter, absence of tillage, erosion reduction, and deposition of wind-blown dust. The area between the tree rows would have been uncultivated the longest, had some of the thickest litter layers, and had no understory. By comparison, the areas between the tree rows and the shelterbelt margins were cultivated for several years after tree planting, had generally thinner litter layers, and had a cover of perennial grasses, small trees, and shrubs. Further investigation is necessary to ascertain whether soil disturbance, litter and wind-blown dust deposition patterns, or vegetation differences affected the observed spatial patterns in SOC.

The 3.7 Mg ha\(^{-1}\) greater SOC measured within the shelterbelt compared to the cultivated fields is equivalent to an increase of SOC of 5.4 Mg km\(^{-1}\) of shelterbelt. While the greatest increase in SOC likely occurred in the surface 0.15 m of soil, additional accumulation may have occurred in deeper layers. Also, there was no accounting for C contained in roots. The 5.4 Mg of SOC km\(^{-1}\) of shelterbelt represents a significant C stock that would increase with the inclusion of SOC from deeper soil layers and C from roots. Quantification and inclusion of these C pools would greatly enhance the accuracy of C sequestration estimates for shelterbelt systems.

Figure 1. Map of SOC in Mg ha\(^{-1}\) for the 0-0.075 m soil layer. Small triangles are tree locations and shading delineates uncultivated area.
CONCLUSIONS

Analysis of surface soil layers within and adjacent to a 35 yr-old shelterbelt indicated greater SOC within the shelterbelt. Inclusion of data on changes in SOC and C in tree roots is essential to develop an accurate assessment of C sequestration potential of agroforestry systems. Further research is necessary to identify the mechanism(s) responsible for the observed spatial patterns of SOC within and adjacent to the shelterbelt and to evaluate other tree species/soil combinations.
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