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Spatial distribution of carbon over an eroded landscape in southwest Wisconsin☆

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Abstract

Spatial distribution of carbon (C) within a soil profile and across a landscape is influenced by many factors including vegetation, soil erosion, water infiltration, and drainage. For this reason, we attempted to determine the soil C distribution of an eroded soil. A three-dimensional (3D) map of a 0.72 ha field with a Dubuque silt loam soil which has three levels of erosion (slight, moderate, and severe) was developed using soil distribution and profile data collected using a profile cone penetrometer (PCP). This map displays the distribution of the total depth of the Ap and Bt1 horizons and the upper part of the 2Bt2 horizon. A map of soil C distribution was created for this landscape using C content information obtained from soil samples. Based on the C distribution in the upper two horizons, a 3D viewing was developed of soil C distribution for this eroded landscape. The 3D assessment of C distribution provides a better means of assessing the impact of soil erosion on C fate. It was estimated that there were 52 Mg ha^{-1} of total C in the surface (Ap) horizon and 61 Mg ha^{-1} in the Bt1 horizon for the 0.72 ha area. This increase in C with depth in the soil can be attributed to an increase in clay content and C leaching resulting in stable carbon–clay complexes. The C content was 16.0, 17.5, and 19.0 g kg^{-1} for the Ap horizon in the slight, moderate, and severe erosion levels, respectively. However, it was estimated that the total C amount in the respective Ap horizons was 28, 14, and 10 Mg ha^{-1} for the slight, moderate, and severe areas. The Bt1 horizon had 31, 19, and 11 Mg ha^{-1} of C in the slight, moderate, and severe areas, respectively. For the 0.72 ha area, 25% was severely eroded with 31 and 44% being moderate and slight, respectively. Soil C distribution information, such as that presented here, can be very valuable for soil management and could be used to determine possible C storage credits.

Keywords: Erosion; Soil carbon; Spatial variability; 3D soil map; Carbon sequestration

1. Introduction

Erosion can change the biological, chemical, and physical properties of a soil. Frequently these changes in soil properties can be attributed to changes in C content of the eroded soil. It is difficult to determine a priori the impact of erosion on a given soil. For

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example, Lowery et al. (1995) found that in most cases erosion resulted in a decrease in soil C, but in a Dubuque silt loam soil, the C content in the surface increased with soil erosion. It has been reported that organic C compounds interact more readily with clay than silt or sand particles (Mortland, 1970; Greenland, 1971; Bohn et al., 1985; Stevenson, 1994; Sparks, 1995).

Variability in C with erosion is related to soil profile characteristics. Three classes, or levels, of erosion have been established by the Soil Survey Staff of the formerly known Soil Conservation Service (currently Natural Resources Conservation Service) of the United States Department of Agriculture (Soil Survey Division Staff, 1993). Class 1, or slight erosion severity, is defined as a loss of less than 25% of the original A horizon or of the uppermost 20 cm if the original A horizon was less than 20 cm thick. Moderate erosion severity, Class 2, is described as a loss of 25–75% of the original A horizon or of the uppermost 20 cm if the original A horizon was less than 20 cm thick. A loss greater than 75% of the original A horizon or of the uppermost 20 cm if the original A horizon was less than 20 cm thick is considered as severe erosion, or Class 3. The reasoning behind these guidelines is that as soil erosion progresses, surface soil layers are removed exposing underlaying layers. It should be noted that we are referring to past erosion and not present or ongoing erosional process. In the Dubuque silt loam case described by Lowery et al. (1995), the topsoil was removed by erosion in a soil where C was leached to the subsoil and formed clay complexes.

Increases in clay content have been reported in the Ap horizon of some eroded soils. Olson and Nizeyimana (1988) observed an increase in clay content in eight eroded soils throughout Illinois, while Chengere and Lal (1995) also reported an increase in clay content after removal of the surface 20 cm of a silty clay loam soil to simulate severe erosion. This increase in clay content in the Ap horizon is attributed to the exposure and subsequent mixing by tillage operations of lower soil horizons (B) rich in clay. It appears that under certain conditions, as the clay content of the surface horizon increases as a result of erosion, the carbon content of the surface soil is also increased.

The erosional process can change important soil properties, such as organic matter content and particle size distribution, which in turn can affect soil bulk density, hydraulic conductivity, water retention, and other important soil properties including overall crop productivity. Therefore, the objective of this study was to determine soil C distribution of an eroded soil, including the development of a 3D map of soil to allow the calculation of total C distribution.

2. Materials and methods

The study was conducted in the driftless-region of southwestern Wisconsin, at the University of Wisconsin–Madison Lancaster Agricultural Research Station (42°52′N, 90°42′W). Soil at the research site is a Dubuque silt loam (fine-silty, mixed, mesic, Typic Hapludalfs). This soil was formed in loess underlain by a red clay residuum with a sub-angular blocky structure (Glocker, 1966). Depth to the red clay residuum ranges from 0.45 to 0.95 m. The site was 120 m × 60 m and it was located on a southwest facing slope (10–14%). In 1985, three levels of past erosion (slight, moderate, and severe) were identified using the depth to the red clay residuum (2Bt2 horizon) as a baseline (Fig. 1) (Andraski and Lowery, 1992). Three 7.3 m × 13.7 m plots were established for each of the three erosion levels in 1985 in the 0.72 ha field. This area has been cropped in continuous corn (*Zea mays* L.) for the last 16 years.

Soil profile penetration data were collected with a PCP in a 10 m × 10 m grid. The PCP consisted of a 30° cone with a 2.0 cm base diameter, threaded to a 1.25 cm diameter × 1.5 m long stainless steel rod (ASAE, 1999). Penetration force was measured with a 1360 kg load cell, while depth was measured using a string potentiometer (Rooney and Lowery, 2000). The PCP was pushed into the soil profile at a rate of 5 cm s^{-1} with a hydraulic soil probe mounted on a truck. An electronic data logger was used to collect load cell and string potentiometer data every 0.05 s. A digital elevation model (DEM) was created from data collected with a differentially corrected Global Positioning System (GPS) attached to an all-terrain vehicle. Profile cone penetrometer sampling points were also geo-referenced with a GPS.