Geoderma 281 (2016) 119–126

Contents lists available at ScienceDirect

Geoderma

journal homepage: www.elsevier.com/locate/geoderma

Comparing soil carbon estimates in glaciated soils at a farm scale using geospatial analysis of field and SSURGO data

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ARTICLE INFO

Article history:
Received 12 April 2016
Received in revised form 20 June 2016
Accepted 26 June 2016
Available online xxxx

Keywords:
Ecosystem services
Functions
GIS
Mapping
Pedons
Pool
Soil inorganic carbon (SIC)
Soil organic carbon (SOC)
Stock
Storage
Total carbon (TC)

ABSTRACT

Soil carbon is a key soil property related to ecosystem services and it is often used in soil carbon content estimates at various scales. Uncertainties in soil carbon estimates often arise from variability in field, laboratory, and/or geospatial data at a farm scale. The objectives of this study were to quantify and compare levels of soil organic carbon (SOC), soil inorganic carbon (SIC), and total soil carbon (TC) for a 147-hectare field site in upstate New York based on three alternative analysis procedures: a) using carbon concentrations reported by the Soil Survey Geographic (SSURGO) spatial databases for each soil map unit (SMU) present at the field site and applying that value across each SMU; b) averaging the carbon contents of soil cores collected within a specific SMU boundary and applying the averaged value across each SMU; and c) interpolating carbon contents across the field site based on the individual soil cores. Maps of SOC, SIC, and TC contents based on the interpolated core samples were different from maps created by applying averaged core results or SSURGO values across the SMUs. Differences in the magnitudes and spatial distributions of carbon can be attributed to several factors. For example, SSURGO soil carbon values are frequently measured for a selected pedon(s) from a "type location" and not from the actual study location. These "type locations" can be located far from study sites and even in different states. Also, SSURGO soil carbon values may overestimate the actual contents when compared to systematic field measurements because the SSURGO values at lower depths are often extrapolated from upper soil horizons. Such extrapolations affect inorganic carbon to a much greater extent than organic carbon, therefore better agreement is observed in the present study between SOC estimates from the SSURGO database and field measurements. Because regional and/or global carbon estimates are rarely made with detailed field data due to the high costs of field and laboratory measurements, additional field sampling is needed to constrain and improve these estimates and also to assess the potential variability present.

1. Introduction

Terrestrial soil carbon stocks and cycling are poorly understood because of a lack of detailed field data on soil organic carbon (SOC), soil inorganic carbon (SIC), and total soil carbon (TC) for specific areas and the world in general (Dawson and Smith, 2007). Even when data are available, there is uncertainty in estimates from variability in measurements and analyses (Dawson and Smith, 2007; Schwager and Mikhailova, 2002). Soil organic carbon has been identified as a key soil property linked to ecosystem services such as provisional services (e.g., food, fuel, fiber), regulating services (e.g., climate and greenhouse gas regulation), cultural services (e.g., recreation, ecotourism), and supporting services (e.g., weathering, soil formation, nutrient cycling) (Adhikari and Hartemink, 2016).

The most common technique for estimating carbon stocks is the "measure-and-multiply" approach, which has been used for national (Cambule et al., 2014; Kern, 1994; Guo et al., 2006), regional (Tan et al., 2009; Thompson and Kolka, 2005) and global carbon estimates (Batjes, 1996). In the U.S., midpoint soil carbon values from the State Soil Geographic (STATSGO) and the Soil Survey Geographic (SSURGO) databases have been used to estimate soil carbon contents at a variety of spatial scales. The STATSGO database (map scale of 1:250,000) is generalized from the more detailed SSURGO (map scale of 1:12,000) database and both share soil pedon information. Several studies have compared soil carbon estimated using STATSGO and SSURGO with the common conclusion that estimates of soil carbon vary from these databases (Davidson and Lefebvre, 1993; Wu et al., 2001; Rasmussen, 2006). In contrast, few studies have compared SSURGO soil carbon estimates

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http://dx.doi.org/10.1016/j.geoderma.2016.06.029
0016-7061/

against actual field measurements (Zhong and Xu, 2011). For example, Zhong and Xu (2011) compared SOC estimates in Louisiana using STATSGO, SSURGO and field measurements and concluded that SSURGO and field SOC estimates showed a closer match.

The SSURGO database contains soil information collected by the National Cooperative Soil Survey based on field and laboratory analyses (Soil Survey Staff, 2015). The information is displayed by soil map unit (SMU) and is available for most areas in the U.S. and the Territories, Commonwealths and Island Nations served by the USDA-NRCS (Soil Survey Staff, 2015). The map units describe soils with unique properties, interpretations, and productivity (Soil Survey Staff, 2015). Each map unit may contain one to three major components and some minor components (Soil Survey Staff, 2015). The map units are typically named for the major components (Soil Survey Staff, 2015). Soil information is reported for scales ranging from 1:12,000 (more detailed) to 1:63,360 (Soil Survey Staff, 2015).

Previous research efforts have focused primarily on estimating SOC from STATSGO and SSURGO databases, but only rarely making comparisons against actual field measurements within the soil map units. This study was aimed at conducting a more comprehensive assessment – not only of SOC but also SIC and TC – and comparing the "measure-and-multiply" approach using SSURGO and field measurements at a farm scale. The specific objectives of the study were to: 1) quantify contents and storage of soil organic carbon (SOC), soil inorganic carbon (SIC), and total soil carbon (TC) from averaged and interpolated soil core measurements using SSURGO soils boundaries, 2) compare these field carbon estimates with estimates of SOC, SIC and TC based on existing SSURGO database information, and 3) discuss implications for relying on SSURGO database estimates for soil carbon at a farm scale, particularly for the types of glaciated soils existing at the present study site.

2. Materials and methods

2.1. Study area

The Cornell University Willsboro Research Farm (44° 22′ N, 73° 26′ W; Fig. 1) is located near Willsboro in Essex County in northeastern New York State (Sogbedji et al., 2000). The research farm has an area of approximately 150 ha and is situated on the gently rolling lacustrine plain adjacent to Lake Champlain (Mikhailova et al., 1996). The climate in the area is temperate with a 150-day growing season (Mikhailova et al., 1996). Soils (Table 1) are highly variable as a result of glacial deposits (e.g., glacial till, deltaic or glacial like sands and clays) and include the soil orders Entisols, Inceptisols and Alfisols (Mikhailova et al., 1996).

2.2. Sampling

Fifty-four soil cores were collected on the Willsboro Research Farm in the summer of 1995 based on a regular square grid sampling pattern (Fig. 1), with each grid being 137.16 m by 137.16 m. Coordinates (NAD27 State Plane Coordinate System's New York East Zone, using Station ESSEX2 and Poke-A-Moonshine L.O.T. and Bench Mark H 395) and elevation values for the sample locations were obtained from a professional land survey team that used an Intelligent Total Station, Set 2C SOKKISHA (Standard deviation: ±3 mm + 2 ppmD) (Mikhailova et al., 1996). Undisturbed soil cores of variable depth (sample depth varied due to the actual possibility of obtaining the sample) were extracted

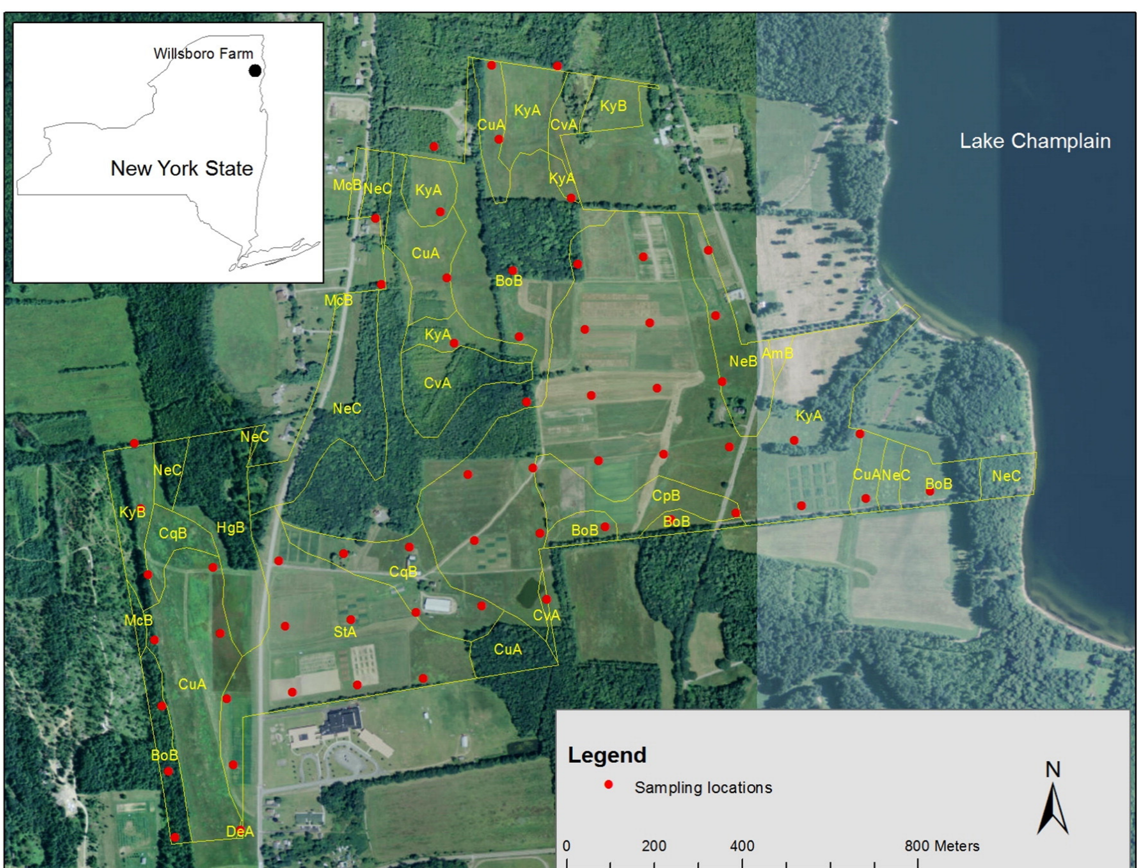

Fig. 1. Map of Willsboro Farm, NY with the following soil types: Howard gravelly loam, 2 to 8% slopes (HgB); Bombay gravelly loam, 3 to 8% slopes (BoB); Kingsbury silty clay loam, 0 to 3% slopes (KyA); Kingsbury silty clay loam, 3 to 8% slopes (KyB); Covington clay, 0 to 3% slopes (CvA); Churchville loam, 2 to 8% slopes (CpB); Cosad loamy fine sand, 0 to 3% slopes (CuA); Claverack loamy fine sand, 3 to 8% slopes (CqB); Deerfield loamy sand, 0 to 3% slopes (DeA); Stafford fine sandy loam, 0 to 3% slopes (StA); Amenia fine sandy loam, 2 to 8% slopes (AmB); Massena gravelly silt loam, 3 to 8% slopes (McB); Nellis fine sandy loam, 3 to 8% slopes (NeB); Nellis fine sandy loam, 8 to 15% slopes (NeC).