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Distributions of organic carbon and related parameters in a Louisiana sugarcane soil

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ABSTRACT

Soil organic carbon (SOC) is an important component of the global carbon budget. The aim of this study was to assess the spatial variability of SOC and nitrogen (N) in a long-term study of continuous sugarcane cropping in Louisiana. Soil core sampling along two transects of different residue management practices (1.8 m spacing and 1 m depth) was carried out; one where the residue was burned after harvest, and the other where the residue was left. The soil cores were sectioned in 10 cm increments and analyzed for SOC and N, pH, bulk density and cation exchange capacity (CEC). Significant correlations were observed between CEC and SOC. For individual soil depths, semivariogram analysis indicated that there was a lack of spatial variation for all properties measured. Semivariograms for the entire data set indicated extensive spatial structure for SOC, N and CEC. For the burned area, greatest spatial structure was observed for SOC and CEC. Vertical distribution results indicated that the no-burn area stored significantly more SOC and N than the burned. This finding was inconsistent with measurements made one year later (2013) where SOC and N results indicated no significant differences between the burn and no-burn areas. Results from a control area under bermudagrass indicated higher SOC and N near the soil surface compared to both the burn and no-burn. Based on two years of data, the influence of no-burn management of sugarcane residue on carbon stock in the soil profile is inconclusive.

1. Introduction

The stock of carbon in the soil plays a significant role in the carbon budget. It has been argued that soil organic carbon (SOC) may be increased appreciably when management practices of no-till are implemented (Lal, 2004; West and Post, 2002). In fact, for several decades no-tillage agricultural practices in agro-ecosystems have been commonly adopted as means for soil conservation and increasing SOC. However, results obtained by several scientists, for example, Vanden Bygaart and Angers (2006), Baker et al. (2007), Yang et al. (2008), and Blanco-Canqui and Lal (2008) suggest that the effectiveness of no-till depends strongly on the depth of sampling to monitor changes in SOC. A review by Luo et al. (2010), found that where samples extended below the traditional 30 or 40 cm, there was no signifcant difference in carbon stock between conventional and no-tillage.

In sugarcane (*Saccharum Spp. Hyb.*) cropping systems, burning prior to or following harvest is a common practice in Louisiana. Burning of the harvest residue reduces the amount of surface organic matter available for incorporation into the soil, so a cessation of burning typically results in increased SOC. However, several years may be required before changes are evident. Galdos et al. (2009) found that in an Oxisol, the total soil carbon in the surface 10 cm was 30% higher in a no-burn compared to a burn treatment. On the other hand, Ball-Coelho et al. (1993) reported that in a Spodosol, no difference was detected in soil carbon after the first ratoon in the surface 7.5 cm.

The spatial distribution of SOC is an important consideration when estimating carbon stock. Although studies of SOC typically focus on the upper 10–20 cm of soil, appreciable amounts of soil carbon can exist in deeper soil layers (Franzluebbers, 2010; Jobbagy and Jackson, 2000). There is evidence that SOC can accumulate in the subsoil. For example, a study of a sugarcane cropping system in Australia found that older, more established sites had higher levels of organic carbon at the 50–80 cm depth relative to new sites (Skjemstad et al., 1999). This suggests that carbon accumulation may occur below shallow soil depths. Mechanisms of subsoil accumulation of new carbon include integration of plant roots and root exudates, vertical transport of dissolved organic matter (David and Zech, 1990), and

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bioturbation (Rumpel and Koegel-Knabner, 2011). Subsoil carbon may be particularly relevant to carbon sequestration, because deeper soil carbon tends to have a longer residence time (Rumpel et al., 2002; Schöning and Kögel-Knabner, 2006).

The objectives of this study were to: (1) assess the lateral and vertical variability and (2) profile stocks of SOC and N under long-term sugarcane management in Louisiana. Examples of sugarcane where residue from the combine harvester was burned after harvest (burn), and where residue remained on the soil surface after harvest (no-burn) were included. Sites were intensively sampled to 1 m in 2012 to 1 m and re-sampled to 2 m in 2013. Variability in cation exchange capacity (CEC) and pH was also determined. Together with N, these parameters affect strongly affect fertility in surface and near-surface soil, therefore biomass productivity and input of OC to the soil.

2. Materials and methods

2.1. Field studies

This study was carried out at the St. Gabriel Sugar Research Station of the LSU AgCenter located some 16 km south of Baton Rouge, Louisiana and 500 m east of the Mississippi River. The experimental site was described earlier by Selim (2003), and covered approximately 1.5 ha of a Commerce silt loam soil (fine-silty, mixed, nonacid, thermic, Aeric Fluvaquent) and was in sugarcane for over 50 years. Sugarcane, a ratoon crop, is typically planted in the fall followed by three or four ratoons. The land was rowed where six plots (3 treatments × 2 replications) running east to west were established. Each plot consisted of 9 rows 150-m long with 1.82-m row spacing. The three treatments were: (i) burning the mulch after harvest, (ii) leaving the mulch on the field after harvest (no-burn), and (iii) sweeping the mulch off the top of the row after harvest. These management treatments were implemented on sugarcane grown on this site since 2001.

Two sets of soil samples were collected on transacts of the burn and no-burn plots on April 30, 2012, and August 1, 2013 (see Fig. 1). In 2012, core sampling was carried out at a spacing of 1.8 m to a depth of 1 m. Each of thirty soil cores per transect were divided into 10 cm sections for a total of 300 samples per plot. Each sample was oven-dried, ground, and analyzed for soil moisture content and bulk density. Each sample was further analyzed for percent total C and percent total N using a dry combustion method as per instrument manufacturer (Elementar Americas Inc., Mount Laurel, NJ). Select soil samples were tested for inorganic C according to the pressure calcimeter method (Loeppert and Suarez, 1996). Half of the samples (every other core along each transect) were analyzed for cation exchange capacity (CEC) using the ammonium acetate replacement method (Sparks et al., 1996). Half of those samples were analyzed for soil pH using a 1:1 ratio of deionized water to soil. Percentages of total C and N were converted to mass of total C and N per hectare for each 10 cm segment using mean bulk density of each treatment, and mean total C and N per depth (Mg ha^{-1}) was used to determine total C and N per treatment for the entire 1 m depth.

In 2013, core sampling was carried such that for the burn and no-burn treatments, three cores were sampled. The cores were at 5 m spacing to a depth up to 2.7 m depending on the soil wetness. The purpose of this sampling was to examine the changes of C and N distribution versus depth at different times. These cores were divided into 10 cm increments, dried, ground, and analyzed for total carbon and nitrogen content, initial moisture content, and pH according to the methods described above.

2.2. Statistics

Paired *t*-tests were used to determine if differences between areas where residue was burned and not burned were significant. Assumptions for the paired *t*-test include data that are normally distributed and have equal variance of the two populations. Assumptions were tested with the Shapiro–Wilk test for normality and the *f*-test for equal variance. The *t*-tests were completed for the complete dataset for each treatment and also for each soil depth and area. The primary objective of this work, however, was description of lateral and vertical spatial variability.

Semivariograms and kriging were used to assess the spatial variability of measured parameters. These methods are widely used to model spatial variability of environmental data (e.g.

Fig. 1. Arial photograph of the experimental site indicating sampling locations for the burn and no-burn plots.