CARBON SEQUESTRATION: THE LACK OF INITIAL MEASUREMENT COULD BIAS INTERPRETATIONS OF MANAGEMENT EFFECT ON SOIL CARBON

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Abstract

Much research has been done in the last decades to determine the effect of management practices on the rate of soil carbon (C) sequestration over time. Generally paired fields are sampled and soil organic carbon (SOC) content under each management system is determined. Conclusions about the effectiveness of different management systems in sequestering soil C are established based on the SOC difference and length of the experiment. However, properly archived historic samples are often unavailable. In this study, a split plot experiment was established in 1997 at Mead, NE with crop rotation as the main factor – continuous maize (CC) and maize/soybean (CB) – and nitrogen applied to maize as the sub factor – 0 kg/ha (0 lbs/acre), 100 kg/ha (90 lbs/acre), 300 kg/ha (270 lbs/acre). Soil samples were taken to a depth of 120 cm (4 ft) in 1998 and in 2009 and SOC was determined. Two analyses were conducted; one based solely on treatment differences among samples obtained in 2009. A second analysis was made based on SOC trend over time using samples from 1998 as a benchmark. Results obtained from analyzing only 2009 samples show greater carbon content under CB rotation than under CC when the 3 ft soil profile was considered. When carbon trends were analyzed over time, less SOC is lost under CC than CB. These findings suggest that conclusions based solely on one sampling date in paired experiments do not account for possible initial differences. Analyzing trends of carbon change over time allow for a better understanding of the effect of management practices on SOC.

Introduction

Atmospheric enrichment of carbon dioxide (CO_2) from anthropogenic activity is considered to be the main cause of the climate change and soils are considered to be an important source and sink of atmospheric CO_2 (Lal, 2004). To properly determine SOC changes over time it's been argued that long-term experiments, deep soil sampling and equivalent soil mass comparisons are required (Baker et. al, 2007). There has been extensive research on the impact of different management practices on the SOC but in many cases paired field are sampled and the effectiveness of any different management systems in sequestering SOC are established based on the SOC difference and length of the experiment. Given that SOC changes are relatively small compared to the SOC content, initial measurement could help in distinguishing effective changes due to management practices by taking into account natural soil variability.

Materials and Methods

A split-plot experiment was established in 1997 at Mead, NE under irrigation and disk tillage with crop rotation as the main block – continuous corn (CC) and corn/soybean (CB) – and nitrogen applied to corn as the subplots – 0 kg ha^{-1} (0 lbs $acre^{-1}$), 100 kg ha^{-1} (90 lbs $acre^{-1}$), 300 kg ha^{-1} (270 lbs $acre^{-1}$). In spring of 2009 each experimental unit was sampled at 6 depths (0-2, 2-6, 6-12, 12-24, 24-36, and 36-48 in) and analyzed for total soil carbon. Three soil cores for the 0-12 in, divided in 0-2, 2-6 and 6-12 in intervals and two additional 0-2 in cores were taken with a hand probe and mixed for a complex sample. Visible root segments were handpicked from the samples. Additional replicate samples for the 12-48 in, two per plot, were obtained with and hydraulic probe (21.5 mm diameter). The cores were divided into 3 depths (12-24 cm, 24-36 cm and 36-48 in) and mixed for complex samples at each depth. Soil samples in 1998 were taken to a depth of 4 ft (1 foot increments). The whole field had been under CB rotation since 1988. Sub-sample were air-dried, fine-ground and 20 milligrams of soil were weighed for total soil carbon analysis using an elemental analyzer (ESC 4010, Costech Analytical Technologies Inc. Valencia, CA). Samples were tested for free calcium carbonates. Soil bulk density (BD) was determined on separate samples at same depth intervals in 2009. Soil C stocks were calculated on an equivalent mass basis in order to account for differences in BD (Ellert and Bethany, 1995) and adjusted to 400, 800 and 1200 kg of dry soil m^{-2} (82, 164 and 245 lbs ft^{-2}) which approximately represented 12, 24 and 36 in depth (Gifford and Roderick, 2003). Missing BD samples for 1998 were estimated using the soil C-BD relationship established from 2009 soil samples.

Results and Discussion

The analysis of variance determined there was no significant nitrogen rates effect on SOC content therefore values were averaged over nitrogen rates. When the 1200 kg of soil m^{-2} (245 lbs of soil ft^{-2}) soil profile was considered the SOC content was significantly higher under CC than under the CB rotation ($P<0.05$) (Fig. 1).

In Fig. 2, SOC quantities are presented in equivalent soil mass intervals showing the distribution of carbon in the soil profile. Although not significant, differences are observed between CC and CB at the 400-800 and 800-1200 kg m^{-2} (82-164 and 164-245 lbs ft^{-2}) intervals. If we were to draw conclusions from these results then we would state that more SOC if present under the CB rotation than under CC when sampled at depth. But we would only be able to hypothesis about the differences observed between crop rotations at depth.

Soil samples obtained in 1998, at the beginning of the experiment were analyzed for SOC and values compared to those obtained in 2009. Differences between rotations in the measured soil profile were already present in 1998, most probably due to the soils' great variability in deeper horizons (Fig. 3). The slopes of the functions in Fig. 3 are the yearly rate of SOC change. Although not significantly different, there is more carbon being lost under CB (-677 lbs $acre^{-1}$) than under CC (-490 lbs $acre^{-1}$) per year.

Table 1. Soil organic carbon stocks and differences in the whole soil profile and at different soil mass increments (averaged over rotation and nitrogen rate).

	Soil Organic Carbon (Standard error of the mean)			
	0-1200 kg m^{-2}	**0-400 kg m^{-2}**	**400-800 kg m^{-2}**	**800-1200 kg m^{-2}**
	------------------kg m^{-2}------------------			
1998	17.02 (0.9)	7.46 (0.2)	5.61 (0.4)	3.90 (0.3)
2009	16.30 (0.9)	7.15 (0.2)	5.44 (0.4)	3.71 (0.3)
Difference	-0.718	-0.310*	-0.223	-0.189

* *Significant difference between years at α=0.05*

Differences observed between CC and CB at deeper soil increments in 2009 were also present in 1998 (Fig. 4). When SOC levels were analyzed over time at 0-400, 400-800 and 800-1200 kg of soil m^{-2} (0-82, 82-164 and 164-245 lbs ft^{-2}) intervals, rotation had no significant effect. Therefore, values of SOC in 1998 and 2009 at each soil mass interval were averaged over rotation and presented in table 1. There was a significant loss of SOC in the 0-400 kg of soil m^{-2} layer (approx 1 ft), but no significant changes in soil OC stocks in deeper layers The only significant changes in SOC over the length of the study were observed in the surface soil layer and were not different among the evaluated treatments.

Summary

These findings support the idea that conclusions based solely on one sampling date in paired experiments do not account for possible initial differences. There was 2.97 and 3.70 lbs C ft^{-2} for CC and CB, respectively, when sampled in 2009. But there was 3.09 and 3.87 lbs C ft^{-2} for CC and CB, respectively when sampled in 1998. Although not significantly different, more C was lost under CB (-0.17 lbs C ft^{-2}) than the CC (-0.12 lbs C ft^{-2}) over the 11 years, however, when the 2009 data is presented without the 1998 data, one might conclude that more C was sequestered by the CB rotation. Given the great natural variability of carbon in the soil and the relatively small changes compared to the SOC content, analyzing changes of SOC over time with initial measurements allowed a better understanding of the effect of management practices.

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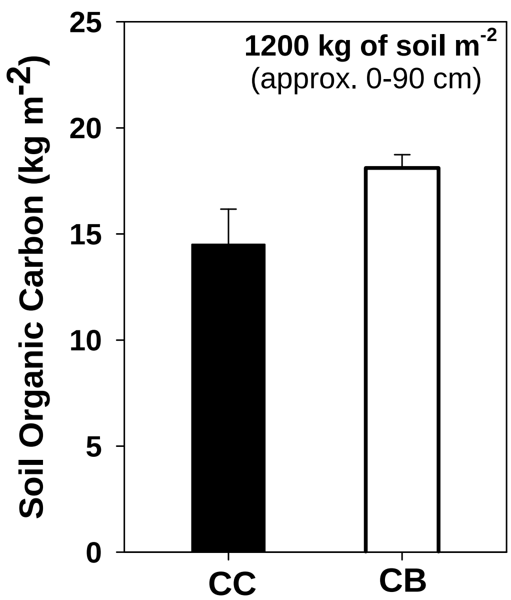

Figure 1. Soil organic carbon stocks in 2009 under continuous corn and corn-soybean rotation.

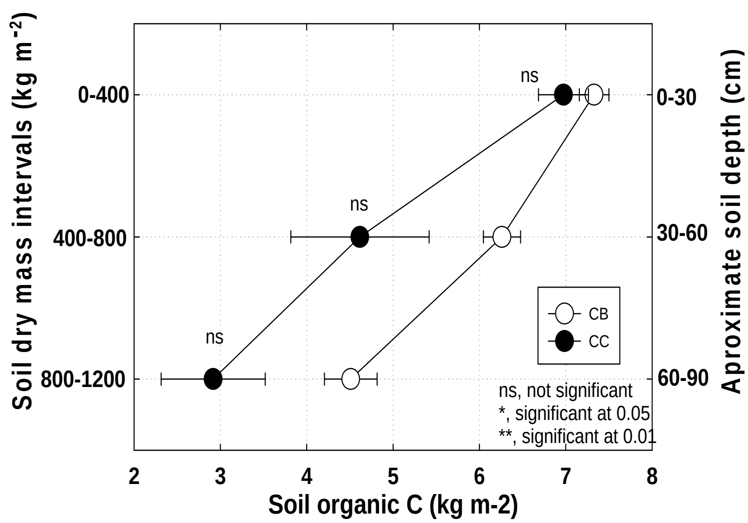

Figure 2. Soil organic carbon under continuous corn and corn soybean rotation at different soil intervals (2009).

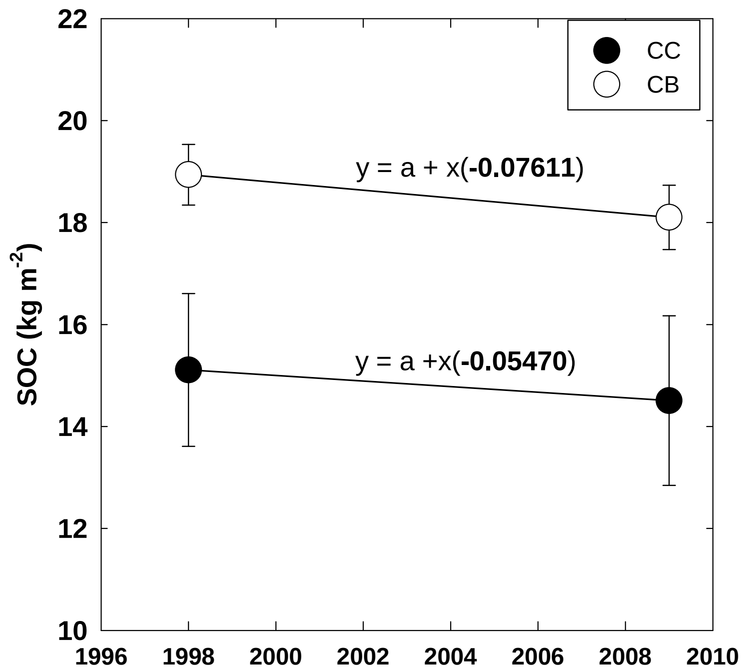

Figure 3. Soil organic carbon levels and rate of change under continuous corn and corn-soybean rotation over 11 years in 0-1200 kg of soil m^{-2}.

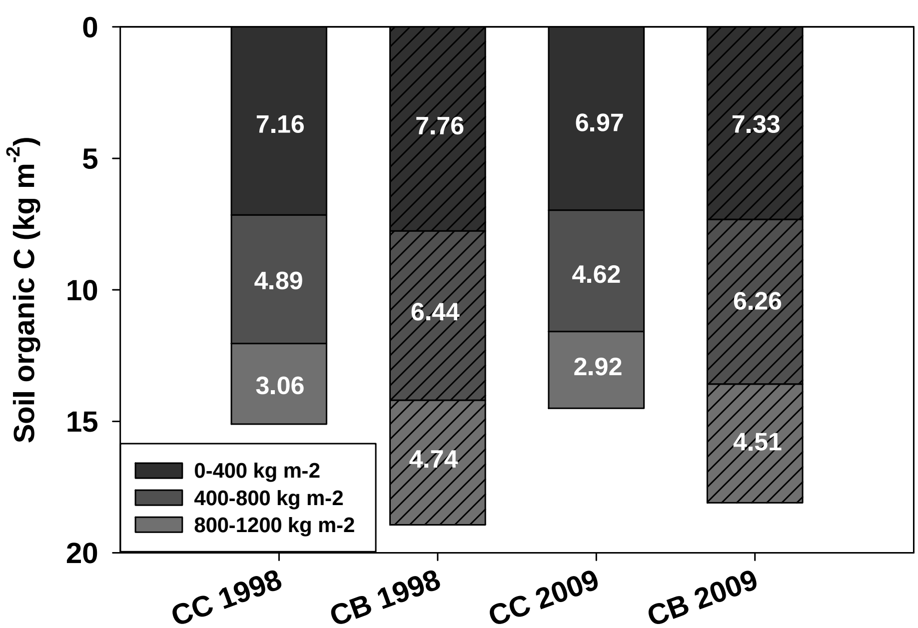

Figure 4. Soil organic carbon levels over time for continuous corn and corn-soybean rotation at 0-400, 400-800 and 800-1200 kg of soil m^{-2} (0-82, 82-164 and 164-245 lbs ft^{-2}) intervals.

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