Soil organic carbon sequestration rates under crop sequence diversity, bio-covers, and no-tillage

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Introduction

Climate change may be partially mitigated through soil organic carbon (SOC) additions in no-till systems; however, influences of various crop management practices on the rate of SOC storage is not well defined. Therefore our objective was to evaluate C dynamics in efforts to optimize C storage and crop productivity by quantifying soil C impacts from bio-covers, cropping sequences, and their interactions under no-tillage production at Research and Education Centers (REC) in Milan (RECM) on Oxyaquic Fragiudalfs and at the Middle Tennessee Research and Education Center (MTREC) on a Typic Paleudalf.

Materials and Methods

A split-block treatment design with four replications was used, with whole-block treatment consisting of cropping sequences (see Table 1 for sequences) and split-block treatments of bio-covers. Different cropping sequences of corn, cotton, and soybean were repeated in 4-yr cycles (i.e., Phases I and II) at the Milan location. Bio-covers of wheat, vetch, poultry litter, and fallow control were repeated annually under no-tillage production. The same experiment was carried out at the MTREC location without cotton. This created 52 and 32 sequence x bio-cover combinations for RECM and MTREC, respectively, applied to separate 6.1 x 12.2 m subplots.

Prior to experimental initiation, the site was under no tillage production for 15 and 16-yrs at MTREC and MREC, respectively.

Poultry, wheat, and fallow bio-cover plots received the equivalent of 66.7 kg N ha^{-1}, while vetch plots received 50.4 kg N ha^{-1} prior to planting. Corn plots received 128.5 kg N ha^{-1} and the cotton received 33.4 kg N ha^{-1} as sidedress applications. Varieties planted were 'PM 1218 BG/RR' and 'DP 117 RRBG' cotton; 'DKC 6410 RR' and DKC63-81' corn; and, 'USG 7440nRR' soybean for Phase I and II, respectively. Cotton was planted on 102-cm rows with corn and soybean on 76-cm row spacing.

Baseline samples (yr-0) were taken at soil surfaces (0-5 cm) and sub-surfaces (5-15 cm) before cropping sequence and bio-cover treatments began in 2002 and again in 2004 (yr-2), 2006 (yr-4; end of Phase I) and 2009 (yr-8; end of Phase II).

Soil C was measured by near infrared diffuse reflectance spectroscopy (NIR), using Labspec Pro® scanning spectrophotometer (Analytical Spectral Devices, Inc., Boulder, CO) at 400-2500 nm. Near infrared reflectance spectroscopy is a good predictor of SOC compared to the combustion method [r^2=0.85 (Wight, 2007)].

Fluxes in soil carbon values (delta SOC=yr-x minus yr-0) over the 8-yr period were analyzed using the Mixed procedure (SAS, 2007) and mean separation performed by the SAS macro 'pdmix800' (Saxton, 1998) with Fisher's Least Significant Difference and Type I error rate of 5%.

Results

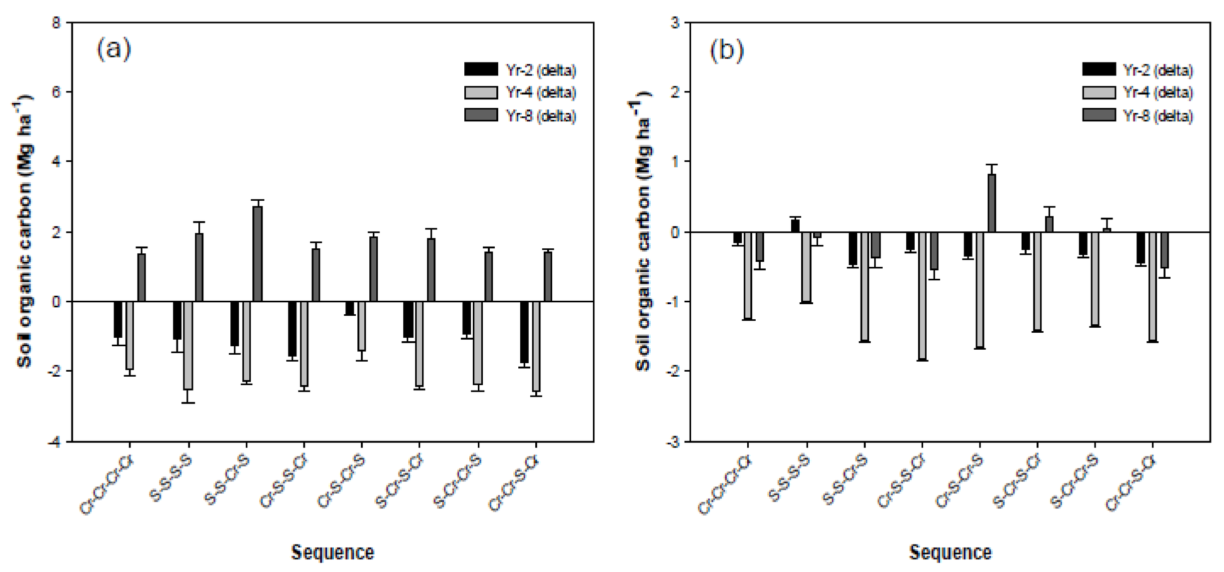

Figure 1. (a) Total organic soil carbon at 0-5 cm (a) and 5-15 cm depth (b) by cropping sequence (pooled across bio-cover treatments) at the Research and Education Center at Spring Hill, TN from 2000-2009. Vertical bars are +/- one standard deviation. Delta SOC (Change) was derived by subtracting Yr-0 from Yr-2, Yr-4, and Yr-8.

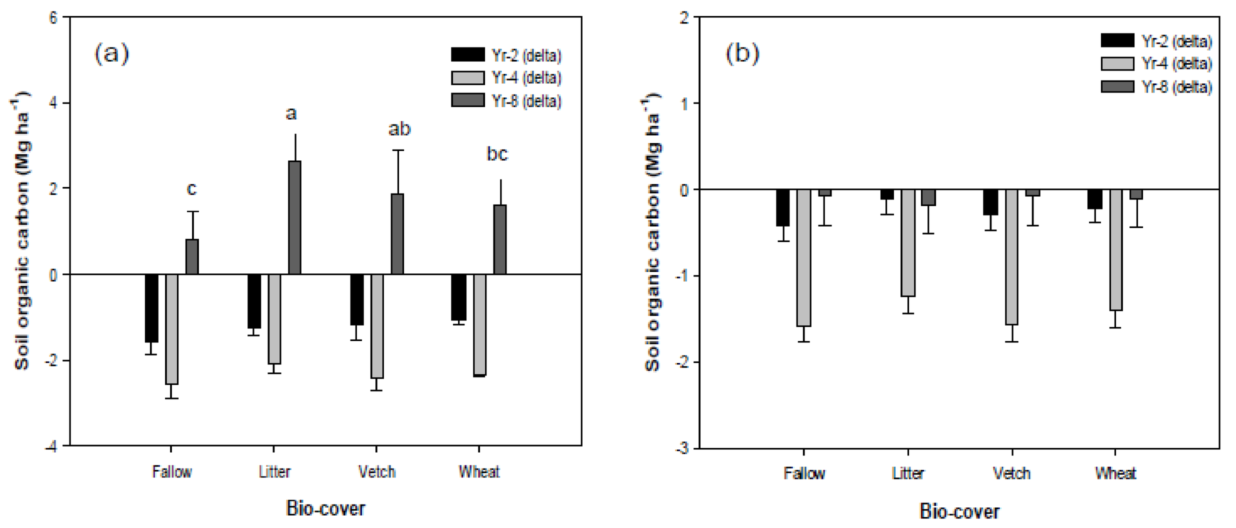

Figure 2. Total organic soil carbon at 0-5 cm depth (a) and 5-15 cm depth (b) and by cropping sequence (pooled across bio-cover treatments) at the Research and Education Center at Spring Hill, TN from 2000-2009. Vertical bars are +/- one standard deviation. Delta SOC (Change) was derived by subtracting Yr-0 from Yr-2, Yr-4, and Yr-8. Different letters indicate end of Phase II mean differences compared to Yr-0 among cropping sequences (P<0.05).

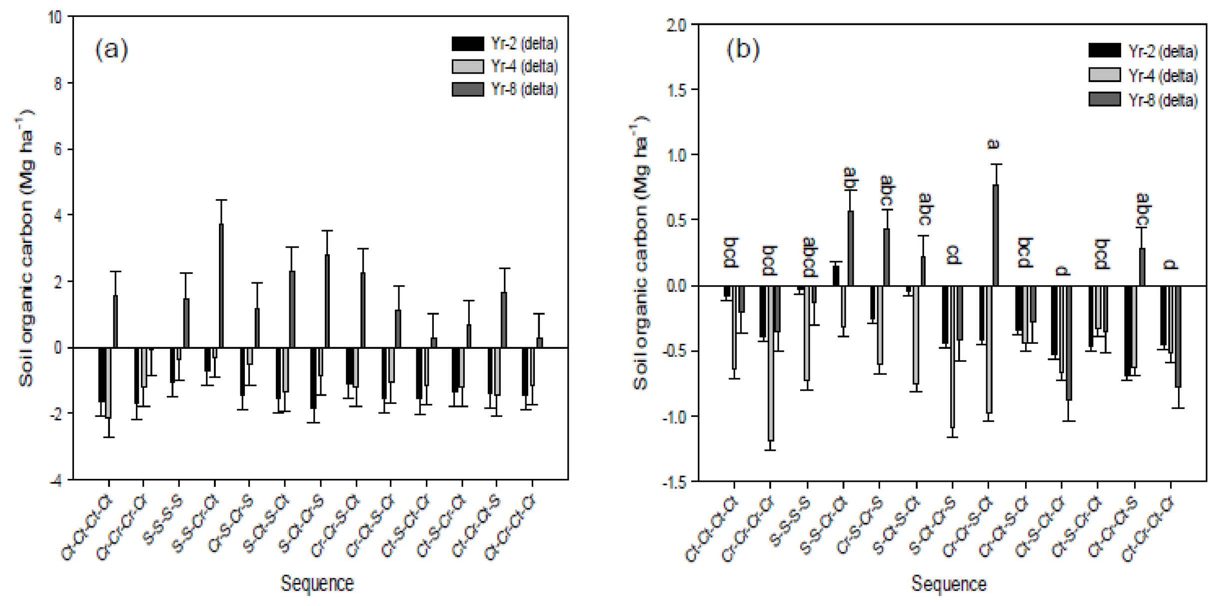

Figure 3. Total organic soil carbon at 0-5 cm depth (a) and 5-15 cm depth (b) and by cropping sequence (pooled across bio-cover treatments) at the Research and Education Center at Milan, TN from 2000-2009. Vertical bars are +/- one standard deviation. Delta SOC (Change) was derived by subtracting Yr-0 from Yr-2, Yr-4, and Yr-8. Different letters indicate end of Phase II mean differences compared to Yr-0 among cropping sequences (P<0.05).

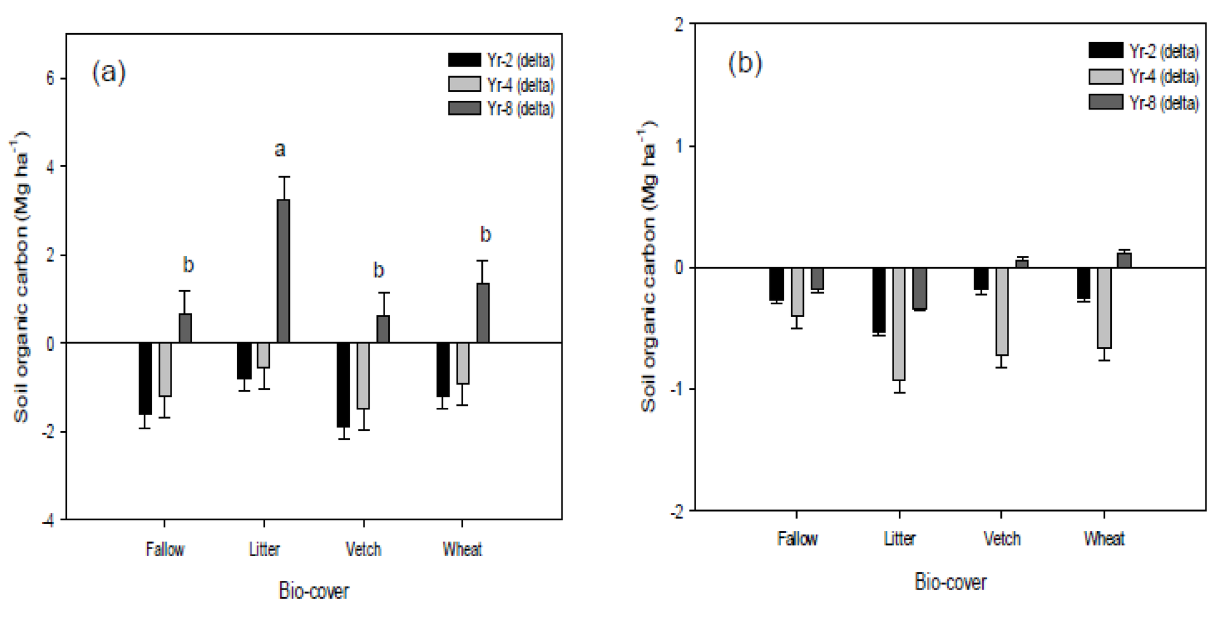

Figure 4. Total organic soil carbon at 0-5 cm depth (a) and 5-15 cm depth (b) by bio-cover (pooled across sequence) at the Research and Education Center at Milan, TN from 2000-2009. Vertical bars are +/- one standard deviation. Delta SOC (Change) was derived by subtracting Yr-0 from Yr-2, Yr-4, and Yr-8. Different letters indicate end of Phase II mean differences compared to Yr-0 among cropping sequences (P<0.05).

Table 1. Cropping sequences for total organic soil carbon measurements at two locations in Tennessee from 2002 (Yr-0)-2009 (Yr-8).

Middle Tennessee Research and Education Center				
	----------Year----------			
	2002† 2006†	2003 2007	2004 2008	2005 2009
Crop Sequence				
1	corn(Cr)	corn	corn	corn
2	soybean(S)	soybean	soybean	soybean
3	soybean	soybean	corn	soybean
4	corn	soybean	soybean	corn
5	corn	soybean	corn	soybean
6	soybean	corn	soybean	corn
7	soybean	corn	corn	soybean
8	corn	corn	soybean	corn
Research and Education Center at Milan				
	----------Year----------			
	2002† 2006†	2003 2007	2004 2008	2005 2009
Crop Sequence				
1	cotton(Ct)	cotton	cotton	cotton
2	corn(Cr)	corn	corn	corn
3	soybean(S)	soybean	soybean	soybean
4	soybean	soybean	corn	cotton
5	corn	soybean	corn	soybean
6	soybean	cotton	soybean	cotton
7	soybean	cotton	corn	soybean
8	corn	corn	soybean	cotton
9	corn	cotton	soybean	corn
10	cotton	soybean	cotton	corn
11	cotton	soybean	corn	cotton
12	cotton	corn	cotton	soybean
13	cotton	corn	cotton	corn

† 2002-2005=Phase I; 2006-2009=Phase II

Results & Discussion

- During the first 2-yrs, carbon losses occurred in all treatments and locations (1.40 and 1.20 Mg ha^{-1} at RECM and MTREC, respectively), with stabilization initiating by yr-4 (Figs. 1 & 3).
- By yr-8, sequences with high frequencies of soybean and greater temporal complexity gained more surface SOC.
- Poultry litter bio-covers gained more surface SOC compared to wheat, vetch, and fallow covers [P<0.05; Figs. 2 & 4 (a)].
- After 8 years, surface SOC surpassed initial levels (9.20 and 8.79 Mg ha^{-1}), with mean gains of 1.33 and 1.16 Mg C ha^{-1} at RECM and MTREC, respectively. During this time, nominal losses occurred in subsoil layers [Figs. 1 & 3 (b)] at MTREC and RECM (0.11 and 0.09 Mg ha^{-1}, respectively).
- Results suggest surface carbon storage may be enhanced by crop sequence diversity combined with poultry litter bio-covers, whereas, minor reductions in sub-surfaces may occur in no-till systems.

Conclusions

- If continuous no-tillage occurs with enhancement of rotation complexity, concomitant with bio-covers, greater surface (0–5 cm) C sequestration will occur (over an 8-yr period, 11.1 and 12.1%); albeit, sub-soil levels may result in minor decreases (0.4 and 1.3% C yr^{-1} at MTREC and RECM, respectively).
- Initial losses could be attributed to the 'priming effect' as depolymerization rates likely increased due to applications of nutrient-rich residue and fertilizer following a fallow period (with low quality C sources).
- After 8-yrs of no-tillage implementation, nominal sub-surface losses occurred compared to baseline levels, however, surface C gains greatly offset any sub-surface losses. The vetch and wheat biocovers as well as some cropping sequences resulted in a recovery and slight increase in sub-surface C at RECM by yr-8.
- Changes in SOC storage suggest systems lacking tillage have minimal organic matter oxidation and may promote C sequestration, particularly when combined with greater cropping sequence diversity and poultry litter applications within 8-yrs of implementation.
- More long-term and deeper profile SOC measurements are planned to determine affects of no-tillage on profile-level carbon sequestration as systems in this study may be approaching a new 'steady carbon state.

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