Cover Crop and Tillage Affects on Soil Organic Carbon

by K.R. Olson, J.M. Lang and S.A. Ebelhar*

* Professor, NRES; Research Associate, NRES; and Agronomist, Crop Sci., University of Illinois at Urbana-Champaign, Turner Hall, 1102 S. Goodwin Avenue, Urbana, IL 61801.

Introduction

- The impact of tillage and cover crops on SOC sequestration (net increase) or loss has been the focus of many studies since these management techniques are thought to contribute to atmospheric C loss or sequestration. SOC sequestration or retention has been shown to retain more SOC with decreasing soil disturbance or enhanced crop rotation diversity.
- Continuous corn grain required additional tillage operations and as a result lost more SOC. The greater crop diversity in the corn-soybean rotation was thought to contribute SOC retention where residue was return approximately equal to the loss of SOC.
- Change in frequency and intensity of tillage practices altered the bulk density and soil organic matter in the soil profile.

Methods

- The effects of cover crop systems on three treatments (no-till (NT), chisel plow (CP) and moldboard plow (MP)) on soil organic carbon (C) content over time was measured. A previous tillage experiment with six replications of three tillage treatments was split in 2001 with half of each tillage block planted with rye cover crop following corn and hairy vetch following soybean. The plot area in southern Illinois on a Grantsburg soil (fine-silty, mixed, mesic Oxyaquic Fragiudalf) with a 6% slope. Three tillage treatments were randomized six times in 18 plots with 9 x 12 m size was split with half of each tillage block planted with a cover crop.

- The soil organic C was determined after removal of un-decomposed plant residue using the Walkley-Black procedure (Soil Survey Staff, 1984). Field moist core bulk density was determined (Soil Survey Staff, 1984) using a Model 2000 soil core sampler manufactured by Soil Moisture Equipment Corp.

- Statistical analyses (SAS Institute Inc., 2001) using a LSD procedure was used at the $P = 0.05$ level to determine if there were significant soil organic C differences between cover crop treatments on each of three tillage treatments for the same date and depth and for soil organic C differences for each tillage treatment with and without cover.

Objective

- The primary objectives of this research was to determine the effects of cover crops on individual tillage treatments (NT, CP and MP) used for corn and soybean production on the organic C contents of the surface layer, subsoil, and root zone of eroded soils.

Results and Discussion

- By 2007, as a result of years of tillage and corn-soybean production (Figs. 1, 2, 3) the organic C (Tables 1, 2, 3) on a volume basis in the whole soil was significantly (P= 0.05) different in NT system with and without cover (Table 1, column 5) vs. the CP and MP systems (Tables 2 and 3, column 5). In the 0 to 15-cm soil layer, the NT had higher organic C contents in the surface layer than CP and MP with and without cover crop treatments. The higher organic C content in the NT system also was result of less soil erosion (Hussain et al., 1999) due to more residues on the soil surface. Loss of macro-aggregates and organic C could make the tilled soil more vulnerable to water erosion.

- The CP with cover crops had more organic C in the surface layer than MP plots with cover crops in 2007 apparently due to better mixing of the residue into the surface layer of the MP treatment. Organic C contents in the whole soil decreased 9%, 20%, and 7% in the NT, CP and MP systems without cover crops when compared with the 2000 baseline levels. With the addition of cover crops to all treatments, the SOC reductions were 0%, 9%, and 2% respectively.

- The organic C values (Tables 1, 2, and 3, column 5) were expressed on a Mg ha^{-1} layer $^{-1}$ basis to make it easier for the reader to compare this experiment with other research results. The cover crop treatment effects for each tillage treatment (NT, CP and MP systems) show the effects of seven years of tillage and cover crops had on the input organic C rate change for the NT, CP and MP systems. These gains in soil organic carbon by each treatment is not the soil carbon sequestration rates since it is not compared to the 2000 baseline soil organic C values. The tillage effects reported in Tables 1, 2, 3 column 8 suggest that organic C levels in NT, CP and MP systems without cover crops are declining. However, with cover crop treatment for each tillage system in Tables 1, 2, 3, column 8 partially offset the organic C loses from tillage in NT, CP and MP systems.

- Only the NT system with cover crops maintained the 2000 baseline soil organic C level and NT without cover crops and CP and MP with and without cover crops also lost soil organic C when compared to 2000 baseline soil organic C. NT treatment with cover crops maintained soil organic C at 2000 levels which should reduce CO_2 emissions to the atmosphere compared to NT system without a cover crop or the CP and MP systems with or without cover crops.

Table 1. Effects of seven years of tillage and cover crops on the volumetric organic C content (Mg ha^{-1} $layer^{-1}$ or layer thickness x 100m x 100m) of the Grantsburg soil.

Treatment	Depth	August 2000 (prior to cover crop)	August 2003	July 2007	Tillage effect with or without cover crop organic C loss or gain		
(6 replications)	(cm)	----------Mg ha^{-1} $layer^{-1}$----------			Mg ha^{-1} $layer^{-1}$	%	Mg ha^{-1} $layer^{-1}$ $year^{-1}$
Without cover crop							
NT	0-15	26.8a**	29.6a	23.9a	-2.9b*	-11	-0.5
	15-75	20.2a	17.8a	18.8a	-1.4b	-7	-0.2
	0-75 (all)	47.0a	47.4a	42.7a	-4.3a	-9	-0.7
With cover crop							
NT	0-15	26.8a	30.2a	26.4a	-0.4a	0	-0.1
	15-75	20.2a	19.9b	20.5a	+0.3a	0	+0.1
	0-75 (all)	47.0a	50.7a	46.9a	-0.1a	0	0.0
NT	0-15	0.0a*	+0.6a	+2.5a			
Cover crop	15-75	0.0a	+2.1b	+1.7a			
effect	0-75 (all)	0.0a	+3.3a	+4.2a			

* *Mean of six replications with the same letter and in the same year and depth with a different tillage treatment are not significantly different at P = 0.05.

* Mean of six replications with the same letter in different cover crop or tillage treatments for the same depth and year are not significantly different at P = 0.05.

Table 2. Effects of seven years of tillage and cover crops on the volumetric organic C content (Mg ha^{-1} $layer^{-1}$ or layer thickness x 100m x 100m) of the Grantsburg soil.

Treatment	Depth	August 2000 (prior to cover crop)	August 2003	July 2007	Tillage effect with or without cover crop organic C loss or gain		
(6 replications)	(cm)	----------Mg ha^{-1} $layer^{-1}$----------			Mg ha^{-1} $layer^{-1}$	%	Mg ha^{-1} $layer^{-1}$ $year^{-1}$
Without cover crop							
CP	0-15	25.0a	25.1b	18.1b	-6.9b	-28	-1.2
	15-75	18.7ab	20.3ab	16.8b	-1.9b	-10	-0.3
	0-75	43.7a	45.4a	34.9b	-8.8b	-20	-1.3
With cover crop							
CP	0-15	25.0a	25.3b	21.8b	-3.2a	-13	-0.5
	15-75	18.7ab	21.7a	18.0b	-0.7b	-4	-0.1
	0-75	43.7a	47.0a	39.8b	-4.1b	-9	-0.6
CP	0-15	0.0a	+0.2a	+3.7b			
Cover crop	15-75	0.0a	+1.4a	+1.2a			
effect	0-75	0.0a	+1.6a	+4.9b			

* *Mean of six replications with the same letter and in the same year and depth with a different tillage treatment are not significantly different at P = 0.05.

* Mean of six replications with the same letter in different cover crop or tillage treatments for the same depth and year are not significantly different at P = 0.05.

Table 3. Effects of seven years of tillage and cover crops on the volumetric organic C content (Mg ha^{-1} $layer^{-1}$ or layer thickness x 100m x 100m) of the Grantsburg soil.

Treatment	Depth	August	August	July	Tillage effect with or without cover crop		
(6 replications)	(cm)	2000 (prior to cover crop)	2003	2007	organic C loss or gain		
		----------Mg ha^{-1} $layer^{-1}$----------			Mg ha^{-1} $layer^{-1}$	%	Mg ha^{-1} $layer^{-1}$ $year^{-1}$
Without cover crop							
MP	0-15	19.9b	18.8	17.2b	-2.7b	-14	-0.4
	15-75	17.8b	19.9	18.0a	+0.2b	+1	0.0
	0-75	37.7b	38.7	35.2b	-2.5a	-7	-0.4
With cover crop							
MP	0-15	19.9b	19.9c	18.1c	-1.8a	-9	-0.3
	15-75	17.8b	19.2b	18.7b	+0.9a	+5	+0.1
	0-75	37.7b	39.1b	36.8b	-0.9a	-2	-0.2
MP	0-15	0.0a	+1.1a	+0.9a			
Cover crop	15-75	0.0a	-0.7a	+0.7a			
effect	0-75	0.0a	+0.4a	+1.6a			

* *Mean of six replications with the same letter and in the same year and depth with a different tillage treatment are not significantly different at P = 0.05.
* Mean of six replications with the same letter in different cover crop or tillage treatments for the same depth and year are not significantly different at P = 0.05.

Captions for figures

Fig. 1 (0625)	Corn residue on no-till corn plots prior to planting.
Fig. 2. (0888)	Soybean plants on plot area.
Fig. 3. (1498)	Corn plants on chisel plow plots.

Summary

When determining whether soil carbon sequestration has occurred, it is critical that researchers establish the baseline soil organic C levels prior to any treatment applications and use those values, rather than ones from the last year of experiment, to determine soil organic C loss or sequestration during the experiment.

- NT treatment with cover crops did maintained more soil organic C than the CP and MP tillage systems with soil organic C grain from cover crops equal to any loss from any disturbance or mixing during planting, nitrogen injection in corn years and erosion during corn and soybean production.
- No soil carbon sequestration (net increase) occurred for any of the tillage treatments with cover crops when compared with 2000 soil organic C levels prior to application of the cover crops.

References

Hussain, I., K R. Olson, and S.A. Ebelhar. 1999. Long-term tillage effects on soil chemical properties and organic matter fractions. Soil Sci. Soc. Am. J. 63:1335-1341.

SAS Institute. 2001. SAS/STAT guide for personal computers. Version 6, SAS Inst., Cary, NC.

Soil Survey Staff. 1984. Procedure for collecting soil samples and methods of analysis for Soil survey. Soil survey Investigations. Rep. 1. U.S. Gov. Printing Office. Washington, D.C.