Sequestration of Soil Organic Carbon by Long-Term No-Tillage in a Cool Semi-Arid Region

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Introduction

- Intensive tillage in clean till (CT) systems accelerates SOC mineralization and release of CO_2 into the atmosphere relative to undisturbed native prairie
- Conservation-tillage, particularly no-till (NT), have been suggested as possible strategies for enhancing SOC capture and retention
- Some studies have suggested SOC increases that have been documented under NT were limited to shallow depths, with no differences in NT vs CT when soil were collected to depth greater than about 30 cm
- A review of 62 Canadian studies indicated that SOC sequestration was most likely under NT vs CT when mean annual precip. was <550 mm and mean annual temp. was ≤5°C
- This study sought to determine if SOC accumulated when surface and subsurface depths are considered following adoption of NT in the Northern Great Plains

Materials and Methods

- This research was conducted in tillage plots established in 1993 at the Dickinson Research Extension Center in southwestern North Dakota, USA (45°53¢ N, 102°49¢ W; 760 m [2500 ft] elevation); sampling was in 2012 and 2013
- CT plots were managed by mixing soil to a 10-cm depth after crop harvest in the fall using a light tandem disk with a second disking to an 8-cm depth the following spring
- Spring tillage was identical in reduced-till (RT) as in CT plots, but there was no fall tillage
- Soil disturbance in NT plots was limited to seeding with low-disturbance disk drills
- Tillage plots were 27 by 12 m and arranged in a randomized complete block with tillage treatments replicated eight times
- Six, 3.2-cm (1.25 in) diam. soil cores were collected in a grid pattern within the southern third of each tillage plot to 90 cm
- Bulk density was computed by drying the core samples for 24 h at 105°C
- SOM content was determined by loss on ignition by combusting for 2 h at 360°C

Table 1. Organic matter concentration on a mass basis of soil cores collected during 2012 and 2013 in clean-till (CT), reduced-till (RT), and no-till (NT) plots in southwestern North Dakota, USA.

Soil depth	CT	RT	NT
cm		kg Mg^{-1}	
0–30	21.6 aB†	21.7 aB	25.5 aA
30–60	16.8 bAB	15.5 bB	18.6 bA
60–90	15.2 bA	12.1 cB	16.9 bA
		$SE_{tillage}$ = 1.2	
		SE_{depth} = 1.1	
		Orthogonal contrasts	
TL‡		*	
TQ		*	
DL		***	
DQ		*	
TLDL		***	
TLDQ		***	
TQDL		*	
TQDQ		NS	

* = $P < 0.05$, *** = $P < 0.001$, and NS = not significant at the $P < 0.05$ level.
† Numbers with different uppercase letters across rows are significantly different at $P < 0.05$ and those with lowercase letters in columns within a year are significantly different at $P < 0.05$.
‡ T = tillage, D = soil depth, L = linear, Q = quadratic.

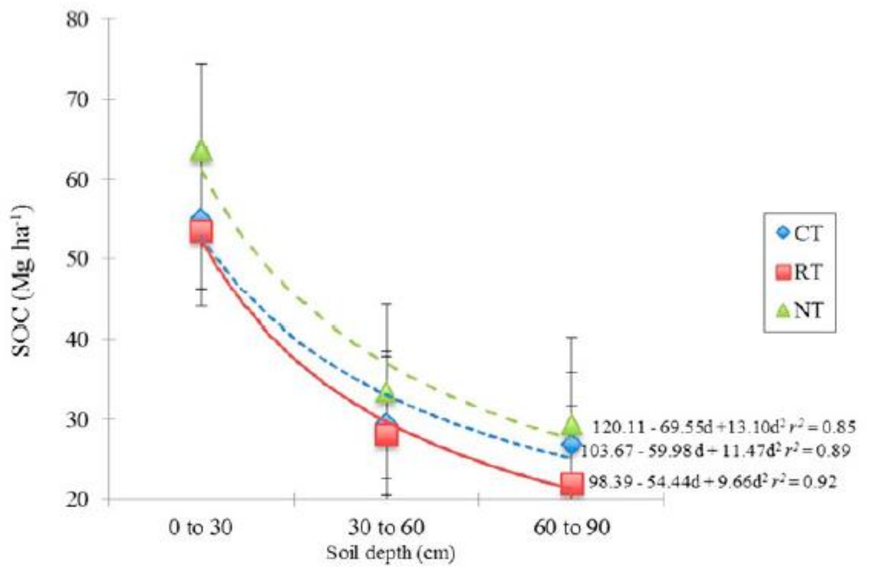

Fig. 1. Soil organic carbon mass per unit area at 0- to 30-, 30- to 60-, and 60- to 90-cm depth increments in long-term clean-till (CT), reduced-till (RT), and no-till (NT) plots at Dickinson in southwestern North Dakota, USA.

Materials and Methods (continued)

- SOM was converted to SOC by multiplying SOM by 0.58 for the 0- to 30-cm depth and by 0.40 for greater depths

Results

- 20 yr after tillage systems first were established, SOM concentration was elevated under NT compared to RT and CT (Table 1)
- SOM was greater under NT (19 kg Mg^{-1}) than RT (16 kg Mg^{-1}) at the 30- to 60-cm depth ($P = < 0.001$), while no difference was detected between NT and CT ($P = 0.14$)
- Differences were not detected in SOM between NT and CT at the 60- to 90-cm soil depth ($P = 0.18$), while SOM concentration was higher under NT (17 kg Mg^{-1}) compared with RT (12 kg Mg^{-1}; $P = < 0.001$)
- SOC per unit area decreased in transitioning from the 0- to 30-cm to the 30- to 60-cm depth, regardless of tillage system
- Regression analyses indicated that models explained ≥85% of the variation in SOC on an area basis within each tillage system across the three soil depth increments (Fig. 1)

Discussion and Conclusions

- Some have questioned whether NT sequesters SOC when comparted to CT at depth
- An analysis of 62 Canadian studies concluded that SOC was sequestered under NT in western but not eastern Canadian soils
- The site characteristics that contribute to SOC sequestration following a transition from CT to NT in western Canada can be extended to a large area within the US northern Great Plains
- An additional 15 Mg ha^{-1} of SOC was gained under NT compared with CT management in the 20 yr after first establishing tillage treatments in this study
- Significant increases in SOC were limited to the upper 30-cm of soil, but there was a net SOC increase under NT even when soils extending to a 90-cm depth were compared
- Moreover, there was a nonsignificant trend for SOC to be sequestered under NT compared with CT at surface and subsurface soil depths