What Happens to the Soil Organic Matter if I Till Long-Term No-Till?

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Abstract

The long-term practice of no-till (low-disturbance direct seeding) is an effective method to increase the soil organic matter (SOM) content of the soil. If that increased soil organic matter is traded as an offset for greenhouse-gas emissions, then we need to know what happens to SOM if, for whatever reason, the soil is tilled. The results in south-western Saskatchewan indicated that if the land is cropped, there is evidence of large losses of SOM from single tillage on long-term (13-yr) no-till on sandy loam soil but little loss of SOM on a loam and clay soil from single tillage of long-term (23-yr and 13-yr) no-till. However, if the land was summerfallowed, there were large losses of SOM. As the pioneers discovered when they broke the land, we also found that the faster the SOM is decreased, the greater the release of nutrients, especially nitrogen (N), from SOM. Through this release of N, summerfallow on long-term continuously cropped no-till increased the release of the potent greenhouse gas, nitrous oxide (N_2O).

Methods

Sandy Loam and Clay Soil Sites

These sites, within 50 km of Swift Current, SK, had been in long-term tilled wheat-fallow converted to no-till and minimum-tillage continuous wheat in 1982. The minimum tillage treatment involved a single tillage with heavy-duty cultivator and mounted harrows or dead rod immediately prior to seeding. Fertilizer N and P were applied according to fall soil nitrates to 60 cm (average rate of N as 50 kg ha^{-1}). Two different no-till drills had been used (hoe and disc) but there had been no significant difference in yields or SOM between drills. In 1995, all plots were seeded with a hoe drill but the plots that had been seeded with a disc drill received a single pre-seeding tillage similar to min-till plots. This tillage was repeated every second year (the sandy loam site was discontinued in fall 1997). There were 3 replicates.

Loam Soil Site

The loam soil site, on the Semiarid Prairie Agricultural Research Centre, which had been 70 yr in tilled wheat-fallow was converted to min-till (MT) and no-till (NT) continuous wheat in 1981. One treatment preserved the conventional tillage (CT) wheat-fallow (2-4 tillages) during summerfallow year with heavy-duty cultivator or rodweeder and one pre-seeding tillage with heavy duty cultivator and mounted harrows or dead rod. In 2003 , a long-term (23-yr) no-till continuous wheat plot was split and a CT wheat-fallow system reinstated. In 2004, additional splits were made to have another tilled wheat-fallow (in opposite phase from 2003 conversion) and MT continuous wheat. Soil CO_2 flux was measured about twice weekly with a LICOR IRGA CO_2 analyzer/6000 soil chamber system and N_2O measured about twice weekly in early season and less frequently in later season with static chamber followed by GC (ECD detector) analysis of gas samples. There are 4 replicates.

Results

Sandy Loam and Clay Soil Sites

At the sandy loam site, the wheat grain yield was similar between two NT treatments prior to 1995 (Fig 1.). However, the grain yield was much higher in the NT plots that were tilled in 1995. We attribute that to the yield enhancing effect of N, phosphorus, and sulfur released from tillage-induced breakdown of SOM. In this sandy soil, the SOM would not be protected from decomposition in clay-SOM complexes so would be more readily decomposed from tillage disturbance. The effect continued into 1996, even though the treatment was not tilled that year.

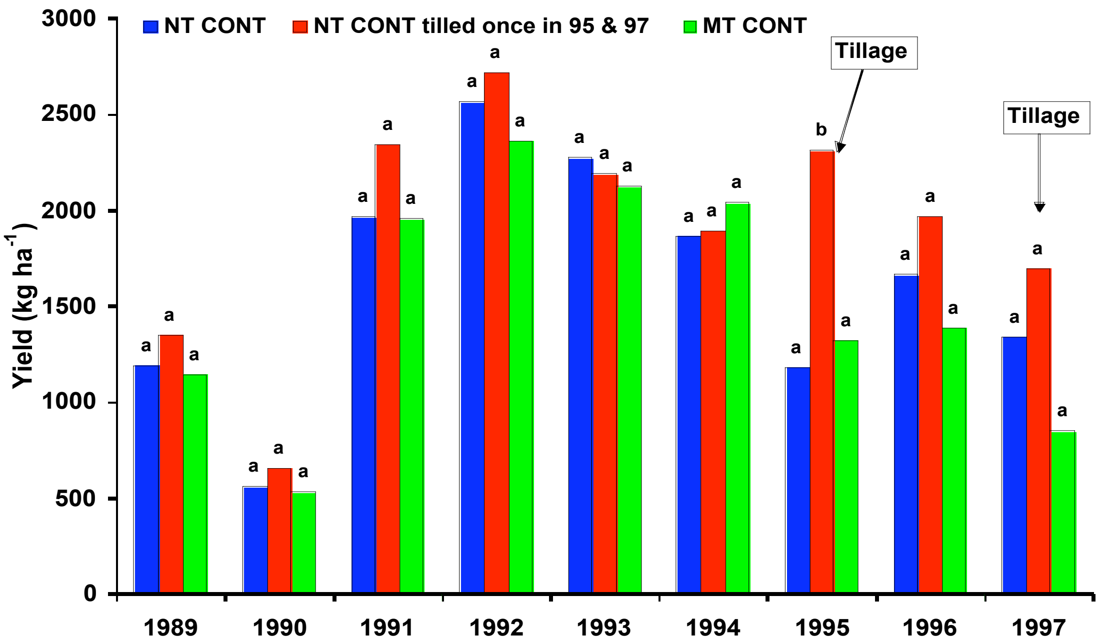

Figure 1. Wheat grain yield at sandy loam site fr om 1989 to 1997 (different letters indicat e significant differences at p=0.10)

In contrast to the sandy loam soil, there was no dramatic yield effect of single tillage on the clay soil (Fig. 2). The yield off periodically tilled plots was the same as long-term NT. However, twice in the year following tillage (2000 and 2002), the periodically tilled plots yielded more than regularly tilled (MT) plots, indicating some impact of periodic tillage on the soil. This indicates the tillage did not induce faster breakdown of SOM. Consistent with this, in 2003, SOM was similar among all tillage treatments with trend that the treatment with receiving biennial tillage from 1995 on, had intermediate SOM to long-term min-till and no-till wheat.

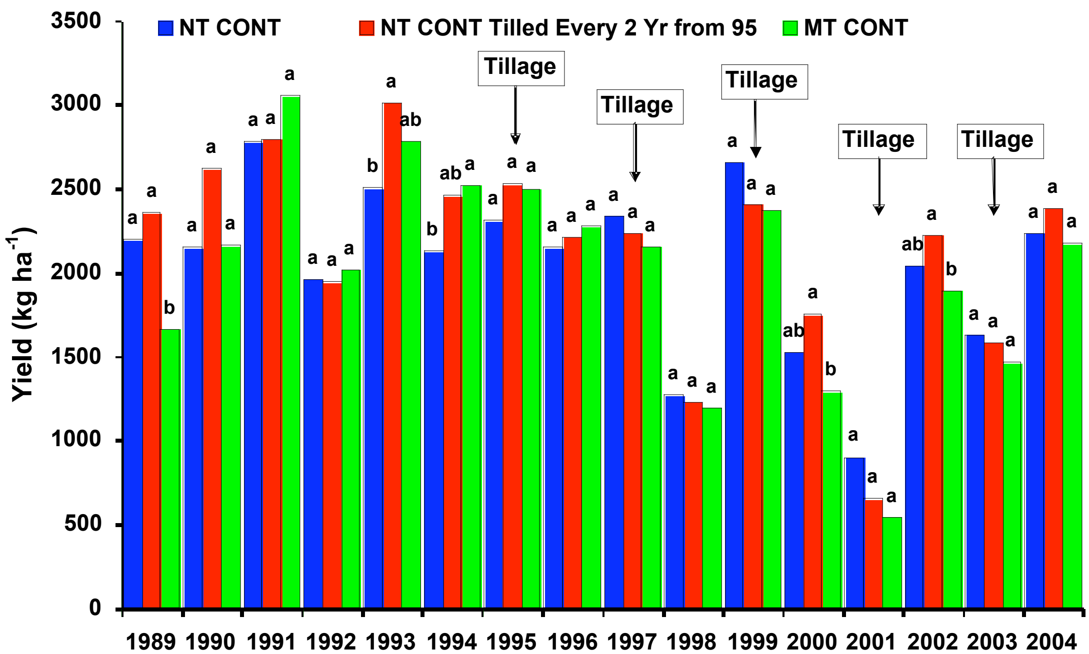

Figure 2. Wheat grain yield at clay site from 1989 to 2004 (different letters indicate significant differences at p=0.10)

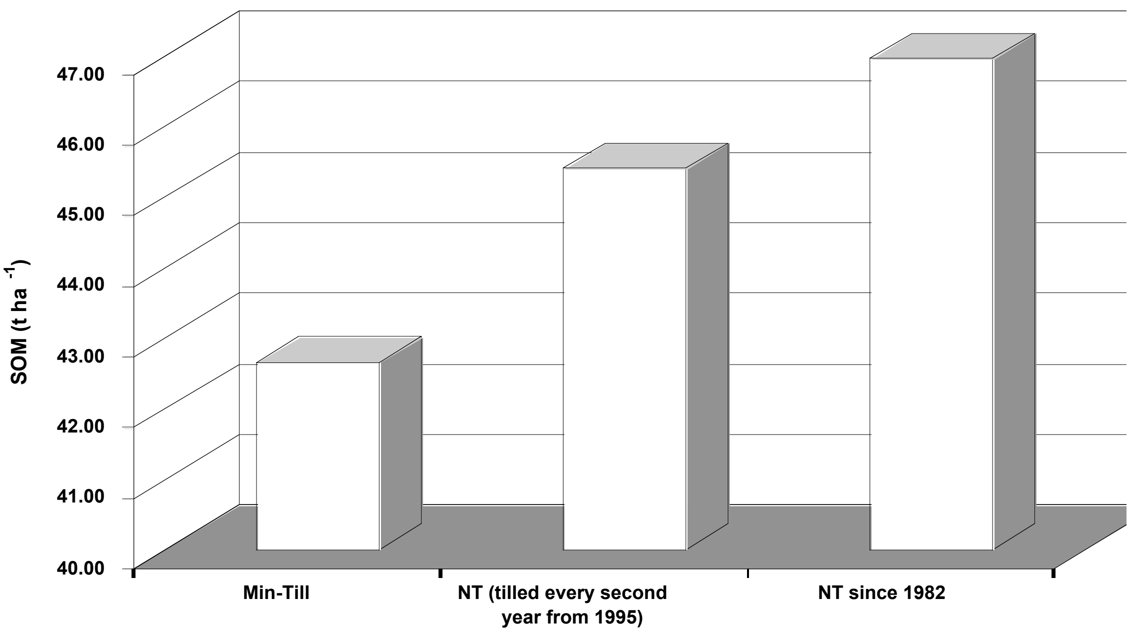

Figure 3. SOM at clay site in October 2003 (no si gnificant difference at p=0.10)

(to convert to SOC divide by 1.72)

Loam Soil Site

In fall 2003, the continuous cropped treatments had sequestered significant amounts of C compared to long-term CT wheat fallow, with the NT continuous wheat having accumulated about twice as much soil C as the MT continuous wheat (Table 1).

Table 1. Soil organic carbon and surface litter carbon in October 2003

System	Soil Organic Carbon		Litter
	0-7.5cm	0-15cm	Carbon
	------------ Mg ha-1 ------------		
Long Term CT W-F	12.0c	25.6c	0.7b
Long Term MT Cont W	15.0b	29.6b	1.1a
Long Term NT Cont W	17.4a	33.5a	1.4a

The long-term NT continuous plots converted to tilled wheat fallow had greater CO_2 emissions from the soil at every measurement (Fig. 4). These increased emissions represent decomposition of sequestered SOM.

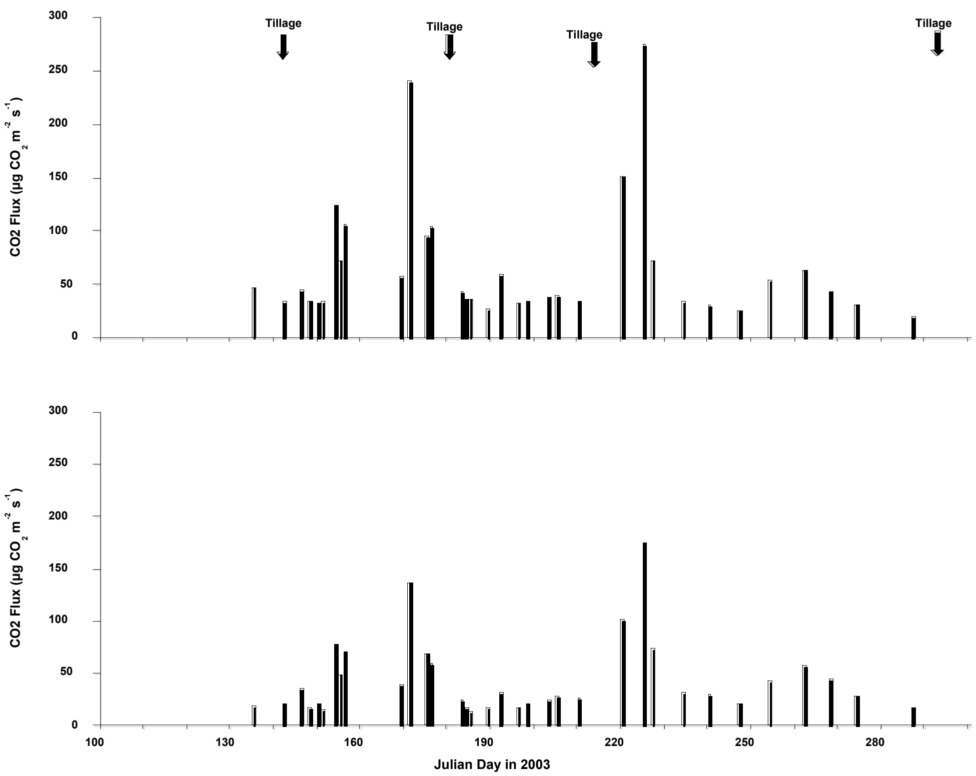

Figure 4. CO_2-C flux from soil for new (top) and long-term (bottom) tilled wheat fallow

Over April-October, the soil under NT continuous wheat converted to tilled wheat-fallow lost about 0.9 Mg C ha^{-1} compared to its long-term wheat-fallow counterpart (Table 2).

About half of this loss was SOM with the other half being decomposition of accumulated surface litter under long-term NT continuous wheat. In the year following the initial conversion (i.e. wheat phase of the tilled wheat-fallow rotation), there was 0.5 Mg C ha^{-1} loss from the recently converted land that represents continued SOM loss. This indicates the loss continues. Surprisingly the NT continuous wheat converted to MT had lower CO_2-C emissions than long-term NT continuous wheat. Clearly providing the land is cropped, a single tillage does not necessarily produce large SOM losses. (Note, because our CO2 flux measurements include respiration from roots and decomposition of recent root exudates, flux from cropped plots is always higher than fallowed plots but fallowed plots are always losing more SOM than cropped plots)

Table 2. Cumulative CO2-C flux and change in litter

System	CO2-C Flux		ΔLitter C [+]	
	2003	2004	2003	2004
	------------ Mg ha-1 -------------			
NT Cont.W_old	2.65 a	3.55 a*	-0.41 a	0.04 b
CT W-(F)**_old	1.75 b	1.46 e	-0.74 ab	-0.76 c
CT W-(F)_new	2.61 a	2.38 cd	-1.29 b	-1.19 c
CT (W)-F_old	--	2.18 d	--	1.16 a
CT (W)-F_new***	--	2.70 bc	--	1.12 a
MT Cont W_new	--	3.08 b	--	-0.06 b

*Different letter in column indicates significant difference (p=0.10)

**Current rotation phase in ( )

***Converted in 2003

[+] negative value is a loss of litter, positive value is a gain

As expected, the plots converted from NT continuous wheat to CT wheat-fallow were accumulating N mineralized from SOM.

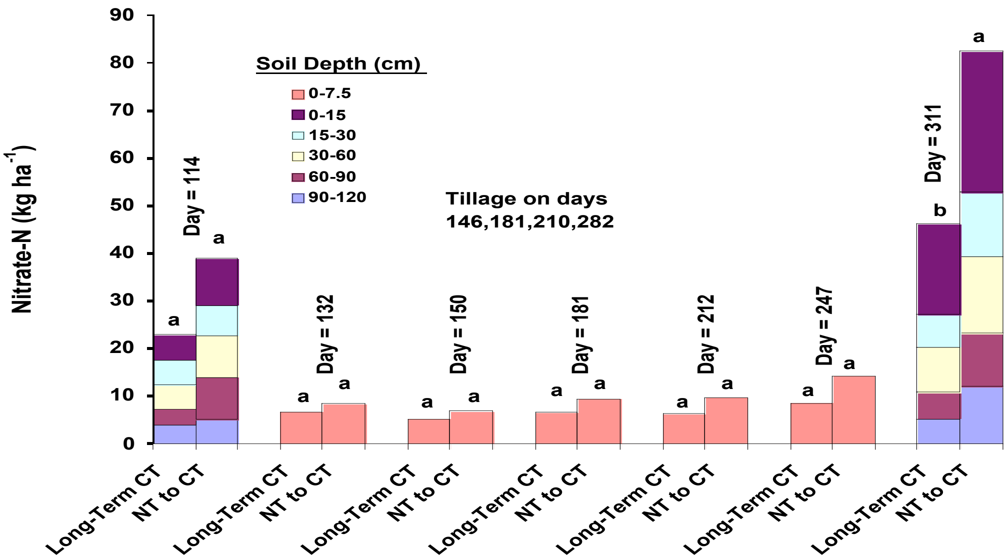

Figure 5. Soil nitrate a ccumulation during 2003 (different letters indicate significant differ ences at p=0.10)

As there was more mineral N, the new CT wheat-fallow converted from NT continuous wheat had higher N_2O emissions than its long-term counterpart, particularly in the spring thaw period (Table 3). Therefore, summerfallowing land that has been in long-term NT increases greenhouse gas emissions as additional CO_2 is released to atmosphere from loss of sequestered SOM and N_2O emission are increased.

Table 3. Estimated 2003 seasonal and 2004 thaw total cumulative N_2O emissions

Treatment	Growing Season	Spring Thaw	Total
	______	g N ha -1	______
NT Cont.W	150	70	220
CT W-(F)	40	100	140
CT W-(F)_New	100	400	500

Conclusions

The effect of tilling long-term no-till depends on soil texture and rotation. Tilling sandy soils that have been in NT will produce large losses of SOM. However, providing the land is cropped, on medium- or fine-textured soils (loam to clay), tilling long-term no-till land produces small losses of SOM. These soil texture effects are identical to what VandenBygaart and Kay (2004, Soil Sci. Soc. Am. J. 68: 1394-1402) found after tilling 22-yr no-till in southern Ontario – a single tillage caused little SOM loss in medium- or fine-textured soils but a large loss in sandy soils. Tilled summerfallow on land that has been long-term NT continuous cropping produces large losses of SOM. Losses of SOM provide a flush of nutrients, particularly N. Although SOM losses from tilled summerfallow are large, they are not unexpected or catastrophic in the sense the annual loss is probably equivalent to the annual gain in SOM when long-term tilled wheat-fallow was first converted to NT continuous cropping. Decreasing SOM becomes an additional source of mineral N and thereby increases N_2O emissions.