Prairie Soil Carbon Balance Project

Monitoring SOC Change Across Saskatchewan Farms from 1996 to 2018

Component: Compare PSCB Project Results with those from Conventional Small-Plot Experiments

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Abstract

Increasing soil organic carbon (SOC) content is vital to reducing carbon dioxide from the atmosphere, and enhancing soil and environmental health. The objective of this study was to gain a better understanding of how nitrogen (N) and C within whole soils and physical fractions of soil organic matter (SOM) in the Brown Chernozem soils in the Prairie Soil Carbon Balance Project (PSCB) responded to 21 years of conservation management practices, and to compare their response to a long-term field experiment in the same soil zone. Soils from the PSCB were sampled in 1996 and 2018 at the 0-10, 10-20 and 20-30 cm layers, while soils from the long-term field experiment were sampled in 1998 and 2016 at the 0-7.5, 7.5-15 and 15-30 cm depths. Soils were fractionated into particulate organic matter N and C (sand-size fraction; POMN and POMC) and mineral-associated organic matter (silt + clay fraction; MAOMN and MAOMC). For the PSCB, soil total N (STN) and SOC increased by 18% and 13%, respectively, and was more pronounced in fine- than coarse-textured soils. Changes in SOM in the PSCB soils were more pronounced in the MAOM fraction, which increased in the 0-10, 10-20, 0-20 and 0-30 cm depths. The highest gain in SOC in the long-term field experiment was much lower than that of the PSCB, while loss of STN was observed in the long-term field experiment versus a gain in the PSCB. Overall, MAOM contained the majority of N and C in both studies, but MAOMN and MAOMC decreased in the long-term field experiment compared to increases in the PSCB sites. These results suggest that the conservation practices likely enhanced the formation and stability of MAOM in the PSCB soils.

Introduction

Soil organic carbon (SOC) and soil total nitrogen (STN), the main components within soil organic matter (SOM), are critical for the health and productivity of agricultural systems. It is well-known that agricultural management practices have profound effects on SOC and STN. This was evident in the Prairie Soil Carbon Balance (PSCB) project, which has historically focused on commercial fields. However, it is unclear whether or not the change in SOC and STN on commercial fields is different from small-plot experiments.

Due to the heterogeneous nature of SOM, changes in SOC and STN may not also be evident. Fractionation of SOM into distinct components that differ in chemical and physical characteristics, as well as function may provide further insights into changes in SOM (Cotrufo et al., 2019; Haddix et al., 2020; Jilling et al., 2020). These fractions of SOM are known to respond more rapidly to changes in agricultural management practices (Cambardella and Elliott, 1992; Six et al., 2000). Particulate organic matte (POM; sand-sized) fraction has a relatively wide C/N ratio, and is predominantly of plant origin. The POM is considered an active fraction, and serves as the major source of plant-available N and is more easily accessible to microbes (Cambardella and Elliott, 1992; 2013; St. Luce et al., 2014). Conversely, mineral-associated organic matter (MAOMN; silt and clay-sized) fraction tend to accumulate in soils as they're protected from microbes through chemical bonding with minerals, and thus loss C and N more slowly (von Lützow et al., 2006; Llorente et al., 2010; Jilling et al., 2020). The MAOM is predominantly of microbial origin (Kallenbach et al., 2016)and is mostly made of thermolabile compunds (Giannetta et al., 2018). Hence, MAOM could be viewed as a long-term sink for C and N.

The objective of this component of the PSCB project was to better understand changes in SOC and STN over time and depth and to relate the results on small-plot experiments to commercial farm fields by examining both whole and physical fractions of SOM.

Methods

Field experiment and soil sampling

This component focused on the Brown Chernozem group (n = 20) since the small-plot experiment used for comparison is located in this soil zone. Hence, soil samples taken at the initiation (1996) and last sampling (2018) of the PSCB in the Brown Chernozem were selected. Soil samples collected at the 0-10, 10-20 and 20-30 cm depths were selected.

A long-term field experiment at the Swift Current Research and Development Centre of Agriculture and Agri-Food Canada was selected as the small-plot experiment to compare with the PSCB. The study was initiated in 1981 on a wheat stubble as randomized complete block with four replicates to investigate the effect of tillage and crop rotation on soil quality and crop production (McConkey et al., 2003; Maillard et al., 2018). The soil is a silt loam soil (Swinton series) and is classified as an Orthic Brown Chernozem. We selected six systems from the small-plot study: (1) continuous wheat under conventional tillage (CW-CT), (2) continuous wheat under no-tillage (CW-NT), (3) fallow-wheat under CT (FW-CT), (4) fallow-wheat under NT (FW-NT), (5) pulse-wheat under CT (PW-CT) and (6) pulse-wheat under NT (PW-NT). All these systems were in place from the initiation of the experiment, except for the PW systems, which commenced in 1997. The PW systems were implemented on plots that were previously FW-NT. Details concerning the cropping systems and crop and soil management were previously reported (Maillard et al., 2018). Soil samples were collected at the 0-7.5, 7.5-15 and 15-30 cm depths. For better comparison with the PSCB project, where soil sampling in the small-plot study was predominantly done at 6-year intervals, soil samples collected in 1998 and 2016 were selected for this component.

SOM fractionation and soil analyses

Physical fractionation using the wet sieving method was used to isolate the POM fraction (Gregorich and Beare, 2008). Briefly, 25 g of air-dried soil was dispersed by shaking in 100 mL deionized water and 10 glass beads (6 mm diameter) for 16 hours. The dispersed soil was passed through a 53-µm sieve and the retained sand and macroorganic matter was dried at 50 ^{o}C, weighed and ground (< 250 µm). Whole soil and POM were analyzed for C and N using dry combustion, after soil inorganic carbon was removed using acid treatment. The MAOMN and MAOMC was the difference between STN and SOC, and POMN and POMC, respectively. The SOC, STN and the SOM fractions were expressed on an equivalent mass basis, as described previously.

Statistical analyses

Statistical analysis for the PSCB soils from the Brown Chernozem group was performed to determine the effect of sampling year on the measured parameters for each sampling depth using Proc Mixed of SAS (SAS Institute, 2013). In addition, the soils were partitioned into coarse-textured (<30% clay; n =11) and fine-textured soils (>30% clay; n = 9), and statistical analysis was performed as described above within each textural group. Separating the sites into three textural classes, that is, coarse, medium and fine, would have been ideal. However, only 20 sites within the Brown Chernozem group were available for this component. For the long-term field experiment, statistical analysis was done to test the interactive effect of sampling year and cropping system on the measured parameters, separately for each sampling depth using Proc Mixed of SAS (SAS Institute, 2013).

Results and discussion

PSCB sites in the Brown Chernozem group

The STN and SOC in the Brown Chernozem group increased from 1996 to 2018 in all depths except the 20-30 cm depth (Figure 1). The STN increased by 18%, 10%, 15% and 18% of the initial levels in the 0-10, 10-20, 0-20 and 0-30 cm depths, respectively, while for SOC, the change was 13%, 18%, 15% and 13%, respectively. Within the sampled profile (0-30 cm), the mean STN was 3.28 Mg ha^{-1} and 3.88 Mg ha^{-1} in 1996 and 2018, respectively; for SOC, it was 41.6 Mg ha^{-1} and 47.1 Mg ha^{-1} in 1996 and 2018, respectively. Hence, the rate of change was 0.03 Mg ha^{-1} yr^{-1} for STN, and 0.26 Mg ha^{-1} yr^{-1} for SOC for the sampled profile (0-30 cm). About 45% of the STN and SOC were in the 0-10 cm layer. Together, these findings indicate that conservation management practices and continuous cropping led to increased STN and SOC in the Brown Chernozem group.

Soil texture plays a critical role in carbon sequestration potential and nutrient cycling as it affects aggregation, microbial activity and diversity, water retention and decomposition rates (Plante et al., 2006; St. Luce et al., 2014). In fine-textured soils, STN and SOC increased from 1996 to 2018 at the 0-10, 0-20 and 0-30 cm depths (Figure 2). In coarse-textured soils, STN increased in the 0-10, 10-20 and 0-20 cm depths, while there was no significant change in SOC (Figure 2).

The somewhat higher variability in STN and SOC within the coarse-textured soils could partly explain the non-significant results. Coarse-textured soils are limited in their capacity to build and protect SOC and STN due to less aggregation, physical protection and organo-mineral interactions (McConkey et al., 2003). Campbell et al. (1997) reported that a period of 11 years to detect measurable tillage effects on SOC and STN is a coarse-textured Brown Chernozem. Numerous studies have related SOC, STN and overall C sequestration to clay content (Campbell et al., 1996; McConkey et al., 2003). Nevertheless, additional SOC storage may be higher in coarse-textured than fine- or medium-textured soils due their lower initial SOC content, and thus greater potential to gain SOC (Liang et al., 2020).

The change in SOM fractions from 1996 to 2018 did not always follow the same trend as STN and SOC. The POMN increased from 1996 to 2018 in the 0-10 cm layer, likely due to increased crop residue inputs on the soil surface in these conservation agricultural sites (Figure 3). The POMC decreased in the 20-30 cm layer, and was probably due to less residue input as a result of reduced soil disturbance. In comparison, MAOMN increased in the 0-10, 10-20 and 0-20 cm depths, while MAOMC increased in the 0-10, 10-20, 0-20 and 0-30 cm depths. It is therefore interesting that changes were more often observed in MAOM fraction. There were clear differences in the response of POM and MAOM to agricultural management, which was in agreement with other studies (Haddix et al., 2020; Jilling et al., 2020). The POM is a rapid indicator of soil and management effects, and may be depleted over time. It was widely thought that depletion of POM led to the replenishment or increase in MAOM (Cambardella and Elliott, 1992). Recently, Haddix et al. (2020) found no consistent evidence that the formation of MAOM occurred from the decomposition of POM, suggesting that these SOM fractions may be formed by two separate pathways. Due to the labile characteristics and fast turnover rate of POM, it is likely that C and N were quickly cycled in the POM fraction, to meet both plant and microbial demand. Awale et al. (2013) reported that POMC was a very sensitive fraction to tillage changes in a silty-clay soil in North Dakota. There is evidence that roots and root exudates, more so than above-ground residues, contribute to stable SOM formation. The conservation practices, continuous cropping and crop diversity likely enhanced the formation and stability of MAOM (Jilling et al., 2020).

The POM was more responsive in the coarse-textured soils where POMN increased by 39% from 1996 to 2018 at the 0-10 cm depth (Figure 4b), while POMC decreased by 27% at the 20-30 cm depth (Figure 4d). In contrast, changes in MAOM were more apparent in the fine-textured soils. The MAOMN and MAOMC increased from 1996 to 2018 in the 0-10, 0-20 and 0-30 cm depths. The majority of the C and N were concentrated in the MOAM fractions (Figure 5e, g). On average across depths and years, 85% of N and 88% of C was stored within MOAM. Nitrogen distribution was similar between 1996 and 2018 at all sampling depths for both POM and MAOM. However, the proportion of C in POM decreased from 1996 to 2018 at the 10-20 and 20-30 cm depths. On the other hand, the proportion of C in MAOM increased from 1996 to 2018 at these same depths. Haddix et al. (2020) noted that for soils with relatively low SOC content, there is a positive feedback between new SOM stabilization and SOC. In addition, McConkey et al. (2003) concluded that fine-textured soils have a greater potential for gains in SOC under NT systems in the Canadian prairies. We therefore postulate that conservation practices preserved SOC and STN in the form of MAOM.

PSCB sites in the Brown Chernozem group compared with the long-term field experiment

There was a significant interaction between cropping system and year on STN and SOC at the 0-7.5 cm depth (Table 1) in the long-term field experiment. The STN increased from 1998 to 2016 in the CW-NT and PW-NT, while SOC increased in the CW-NT, PW-CT and PW-NT. Tillage effect within a system was observed for CW and FW at the 0-7.5 cm depth, where in both cases, STN and SOC were higher under NT than CT. The published results from this long-term field experiment showed a more pronounced tillage effect for the FW system, with higher SOC under NT than CT (Maillard et al., 2018). The STN was highest for the CW systems and lowest under FW-CT at 7.5-15 cm, 0-15 cm and 0-30 cm depths; it was similar between CW systems and the PW systems at 7.5-15 cm. Over the sampled profile (0-30 cm), STN was highest for the CW systems, followed by the PW systems and lowest for the fallow systems. Our findings were not surprising, especially at the 0-7.5 cm depth, as we expected an increase in SOC and STN in continuously cropped than fallow systems due to higher biomass inputs from above- and below-ground residues, and also higher SOC and STN under NT than CT as a result of lower rates of decomposition due to less soil disturbance (Campbell et al., 1995; McConkey et al., 2012; Aziz et al., 2013). Overall, STN decreased from 1998 to 2016 at the 15-30 and 0-30 cm depths, but increased in the 0-7.5 cm depth. At 15-30 cm, SOC was highest for the CW systems than all other systems. At 0-15 and 0-30 cm, SOC was or the CW systems, followed by the PW systems and lowest for the fallow systems. Overall, there was no change in SOC between years, except at the 0-7.5 cm depth, where an increase was observed. Previous findings from this long-term field experiment also reported that changes in SOM were mostly observed in the 0-7.5 cm depth (Campbell et al., 1995; 1997; Maillard et al., 2018). Over the sampled profile (0-30 cm), the rate of change in STN was -0.02 Mg ha^{-1} yr^{-1} for CW-CT, -0.01 Mg ha^{-1} yr^{-1} for CW-NT, -0.02 Mg ha^{-1} yr^{-1} for FW-CT, -0.03 Mg ha^{-1} yr^{-1} for FW-NT, -0.04 Mg ha^{-1} yr^{-1} for PW-CT, and -0.02 Mg ha^{-1} yr^{-1} for PW-NT. The rate of change in SOC in the sampled profile was -0.02 Mg ha^{-1} yr^{-1} for CW-CT, 0.09 Mg ha^{-1} yr^{-1} for CW-NT, -0.05 Mg ha^{-1} yr^{-1} for FW-CT, -0.07 Mg ha^{-1} yr^{-1} for FW-NT, 0.06 Mg ha^{-1} yr^{-1} for PW-CT, and 0.14 Mg ha^{-1} yr^{-1} for PW-NT. These findings for the rate of SOC change are similar to that reported recently by Maillard et al. (2018) from the same long-term field experiment. Maillard et al. (2018) explained that SOC might be highly influenced by precipitation, and that the increase of apparent decomposition by precipitation may exceed that of plant biomass C inputs, potentially leading to loss of SOC. Moreover, our findings confirm those of Maillard et al. (2018) in that replacement of fallow with a pulse crop has great potential to rebuild SOC, particularly in combination with NT. The highest gain in SOC in the long-term field experiment was much lower than that of the PSCB, while loss of STN was observed in the long-term field experiment versus a gain in the PSCB. These differences between the PSCB and the long-term field experiment were probably related to greater diversity of crops in the PSCB sites, with positive impacts on residue quality and quantity. Higher N fertilizer rates, possibly increasing crop biomass input in the PSCB sites may also explain the different trends in STN and SOC observed between the PSCB and the long-term field experiment.

The MAOMN was significantly influenced by the interaction between cropping system and year at the 0-7.5 cm depth (Figure 6c). Only the PW-NT had a significant increase in MAOMN between 1998 and 2016. In addition, for both the CW and FW at the 0-7.5 cm depth, MAOMN was higher under NT than CT. Only significant main effects (rotation system and year) were observed for POMN, POMC and MAOMC stocks at various soil depths in the long-term field experiment (Table 2). Generally, the SOM fractions were higher for the CW systems and lower for the FW systems, with a tillage effect in a few cases. For the FW system, POMN and MAOMN were higher under NT than CT at 0-7.5 cm and 0-15 cm depths, respectively (Table 2). For the CW system, MAOMC was higher under NT than CT at the 0-7.5 cm depth (Table 2). Overall, there was a significant increase in POMN (at all depths) and POMC (all depths except 15-30 cm) from 1998 to 2016. This differed from the PSCB results of the Brown Chernozem group, where POMN increased only in the 0-10 cm layer, and POMC decreased in the 20-30 cm layer (Figure 3a, b). With respect to MAOM, MAOMN decreased from 1998 to 2016 at the 7.5-15, 15-30 and 0-30 cm depths, while MAOMC decreased at the 7.5-15 cm depth in the long-term field experiment (Table 2). This was also contrary to the PSCB results of the Brown Chernozem group, where MAOMN and MAOMC increased at all depths, except the 20-30 cm (Figure 3c, d). Interestingly, there was a tillage effect in the FW system for C distribution in the SOM fractions, whereby the CT had a higher proportion of C in POM than NT, with the opposite effect occurring for MAOM. Although this was not observed in the entire plow layer (0-15 cm), our result seems to suggest that CT in the fallow system enhanced the decomposition of POM at the 7.5-15 cm layer, thereby depleting N and widening the C/N ratio of POM fraction. Conversely, NT likely preserved C within the MAOM fraction at the 7.5-15 cm layer. The MAOM tends to have a lower C/N ratio than POM as it is dominated by N-rich compounds (Jilling et al., 2020).

Conclusions

After 21 years of conservation agricultural practices, there was an increase in STN and SOC in the 0-10, 10-20, 0-20 and 0-30 cm depths. Within the sampled profile (0-30 cm), the rate of change was 0.03 Mg ha^{-1} yr^{-1} for STN, and 0.26 Mg ha^{-1} yr^{-1} for SOC. Interestingly, the increase in STN and SOC was more pronounced in the fine-textured than coarse-textured soils, likely due to greater potential for C sequestration in fine-textured soils as a result of higher clay content. The POMN increased from 1996 to 2018 in the 0-10 cm layer, while POMC decreased in the 20-30 cm layer. In comparison, MAOMN increased in the 0-10, 10-20 and 0-20 cm depths, while MAOMC increased in the 0-10, 10-20, 0-20 and 0-30 cm depths. Hence, changes in SOM were more pronounced in the MAOM fraction. The highest gain in SOC in the long-term field experiment was lower than that of the PSCB, while loss of STN was observed in the long-term field experiment versus a gain in the PSCB. In both the PSCB and long-term field experiment, MAOM contained the majority of N and C. The conservation practices, continuous cropping and crop diversity likely enhanced the formation and stability of MAOM. In general, MAOMN and C decreased over time in the long-term field experiment but increased in the PSCB sites of the Brown Chernozem group.

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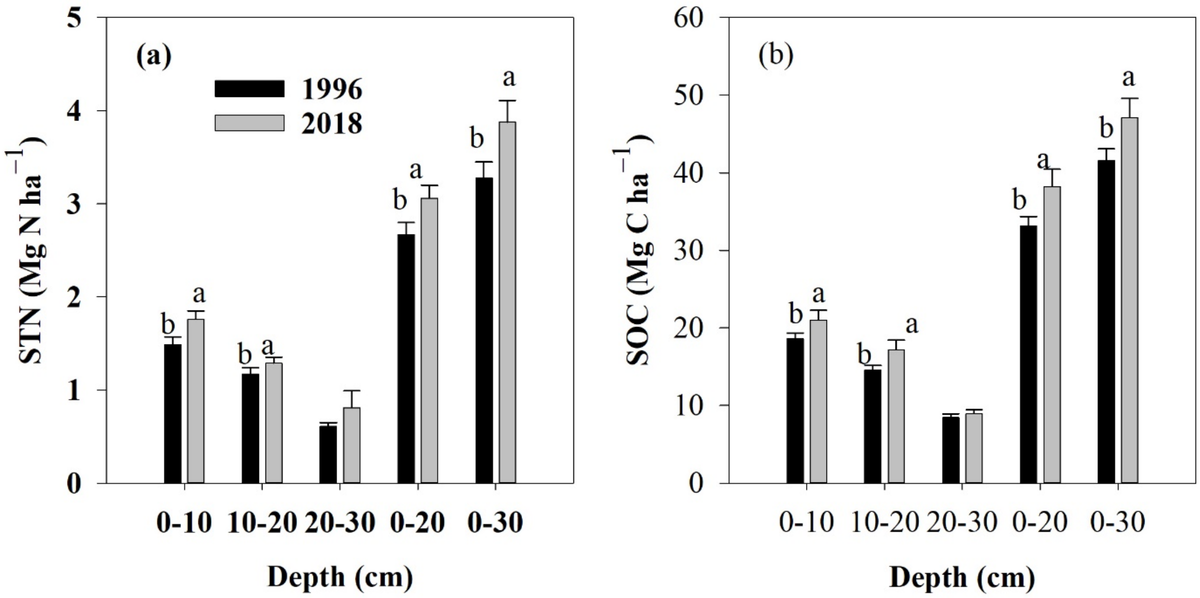

Figure 1. Soil total N (a) and soil organic carbon (b) in 1996 vs 2018 in the Brown Chernozem group. Different lower case letters within each depth indicate significant difference between years at the 0.05 probability level.

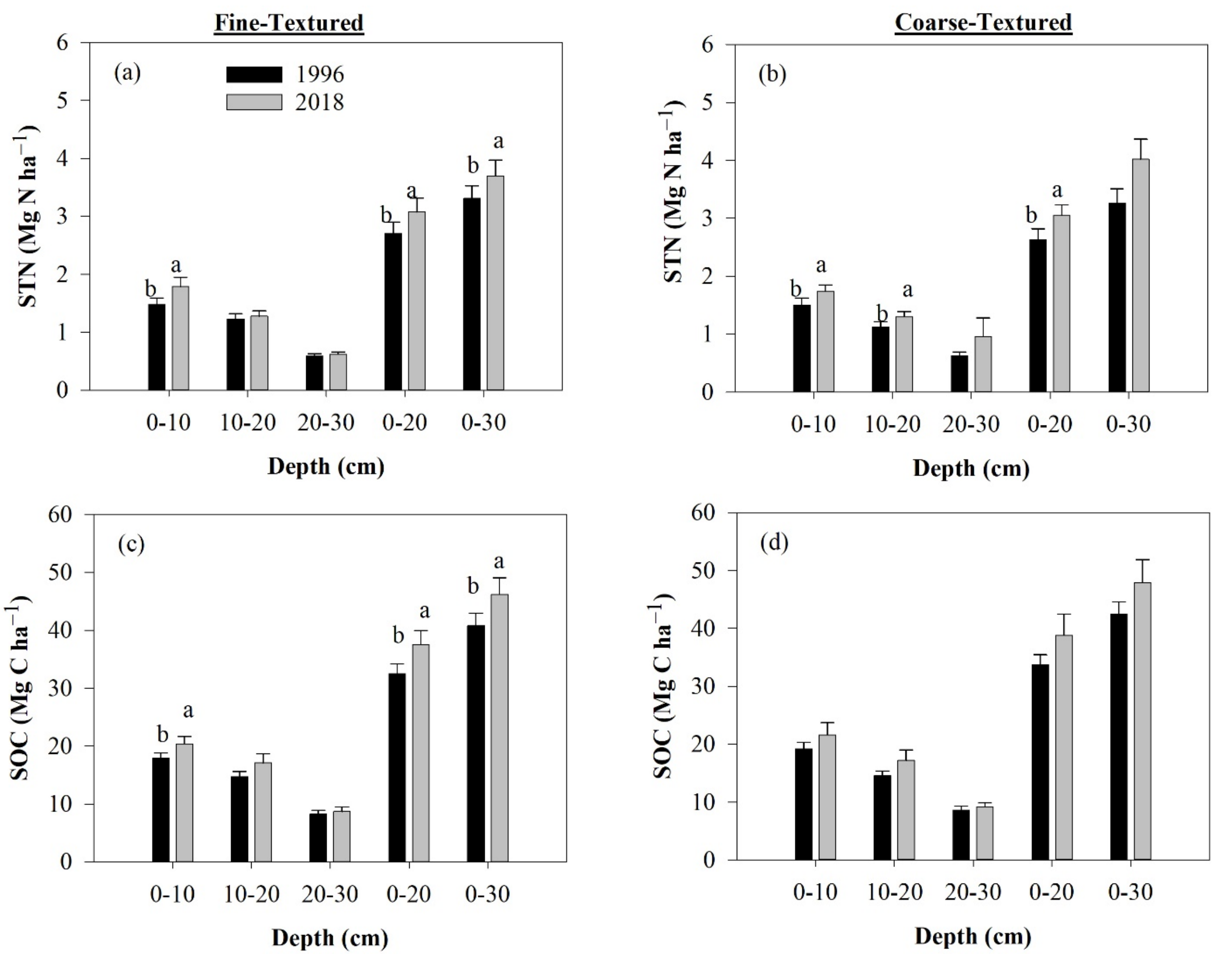

Figure 2. Soil total N (a, b) and soil organic carbon (c, d) in 1996 vs 2018 for fine- and coarse-textured soils in the Brown Chernozem group. Different lower case letters within each depth indicate significant difference between years at the 0.05 probability level.

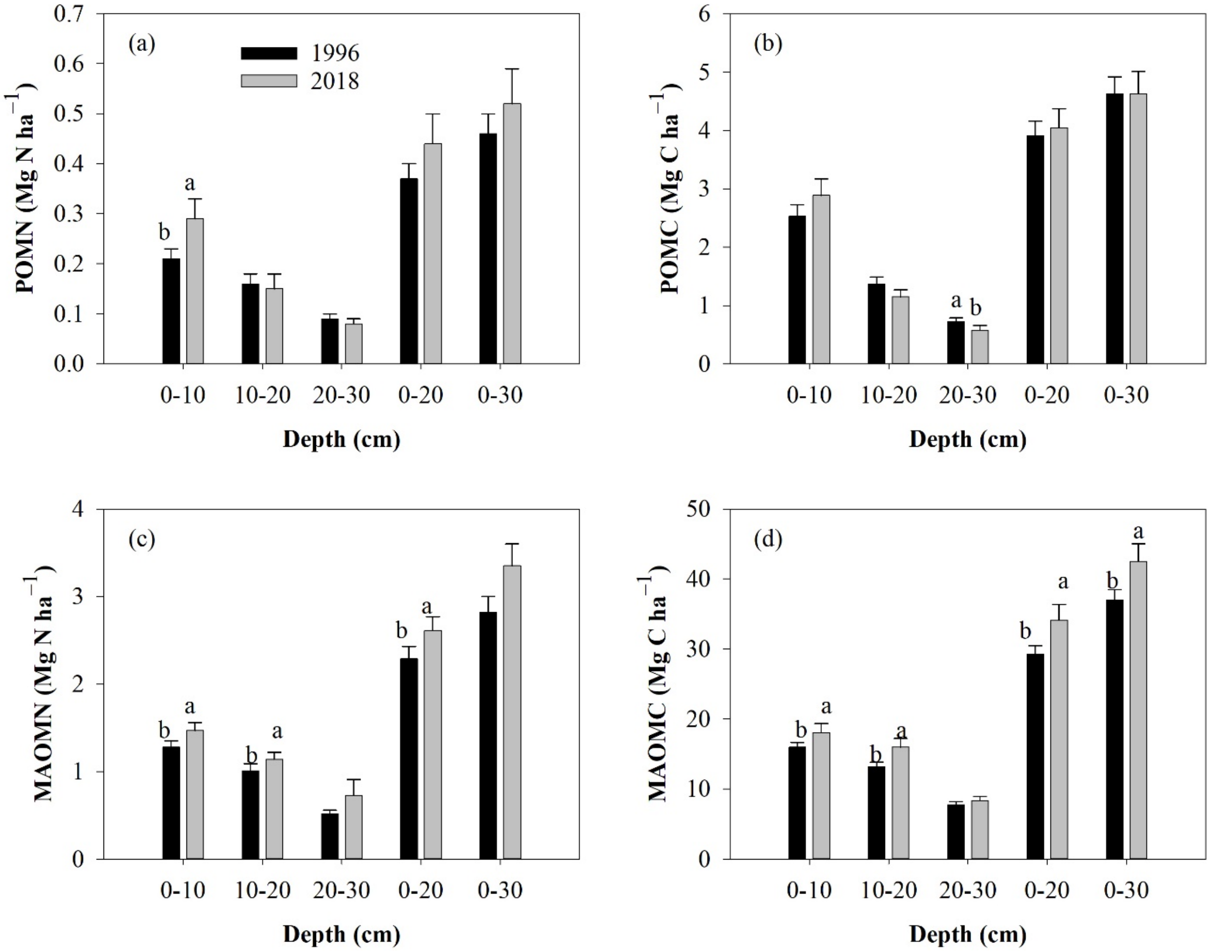

Figure 3. Particulate (a, b) and mineral-associated organic matter (c, d) C and N content in 1996 vs 2018 in the Brown Chernozem group. Different lower case letters within each depth indicate significant difference between years at the 0.05 probability level.

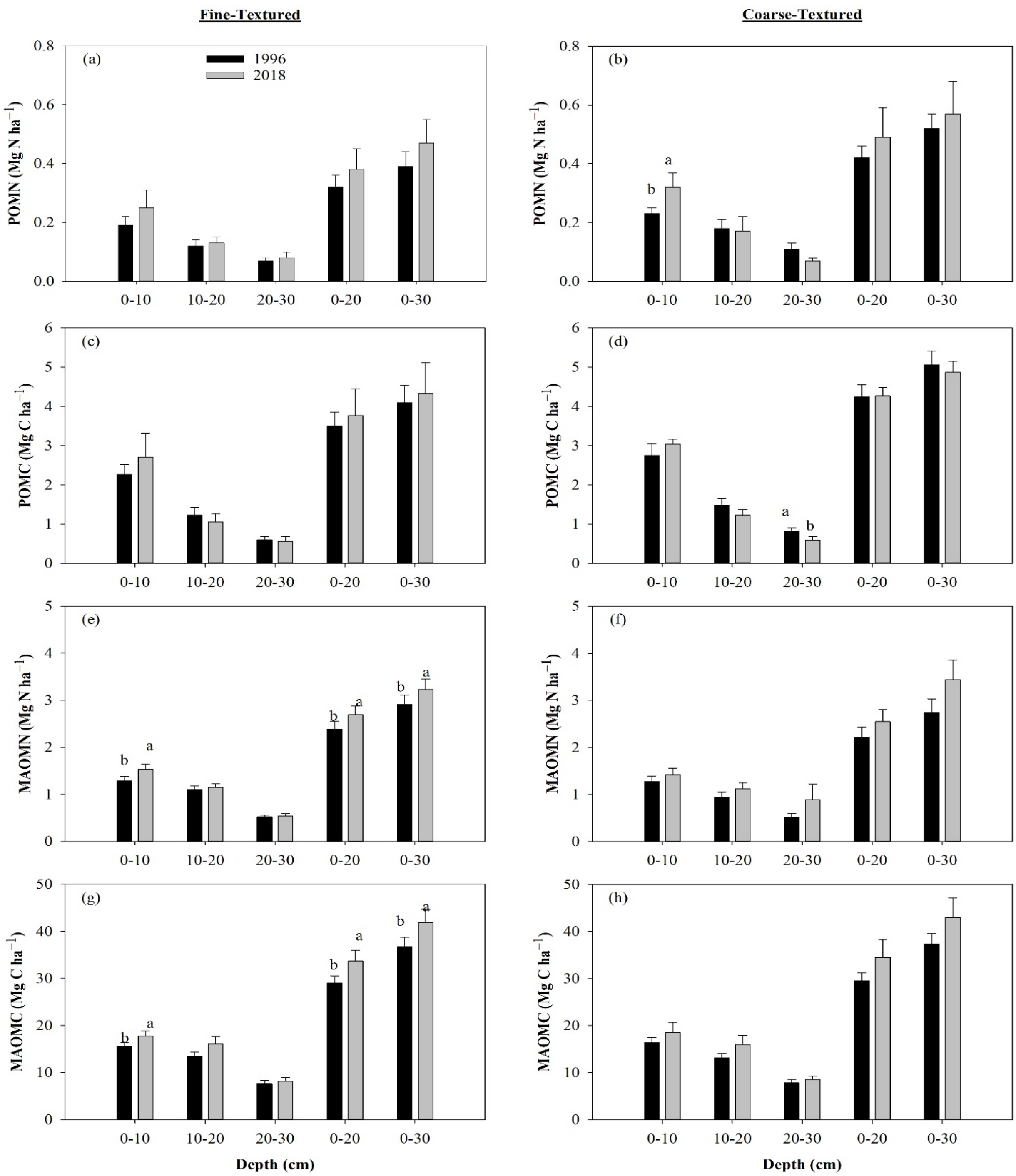

Figure 4. Particulate (a, b, c, d) and mineral-associated organic matter (e, f, g, h) C and N content in 1996 vs 2018 for fine- and coarse-textured soils in the Brown soil zone. Different lower case letters within each depth indicate significant difference between years at the 0.05 probability level.

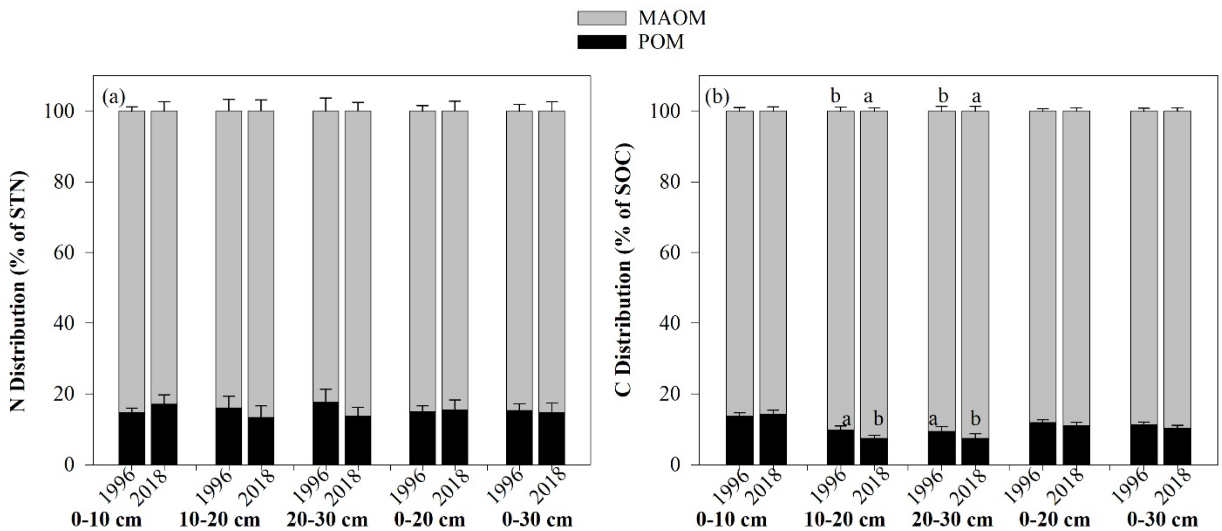

Figure 5. Nitrogen (a) and carbon (b) distribution in particulate organic matter (POM) and mineral-associated organic matter (MAOM) fractions in the Brown Chernozem group. Different lower case letters within each depth and soil organic matter fraction indicate significant difference between years at the 0.05 probability level.

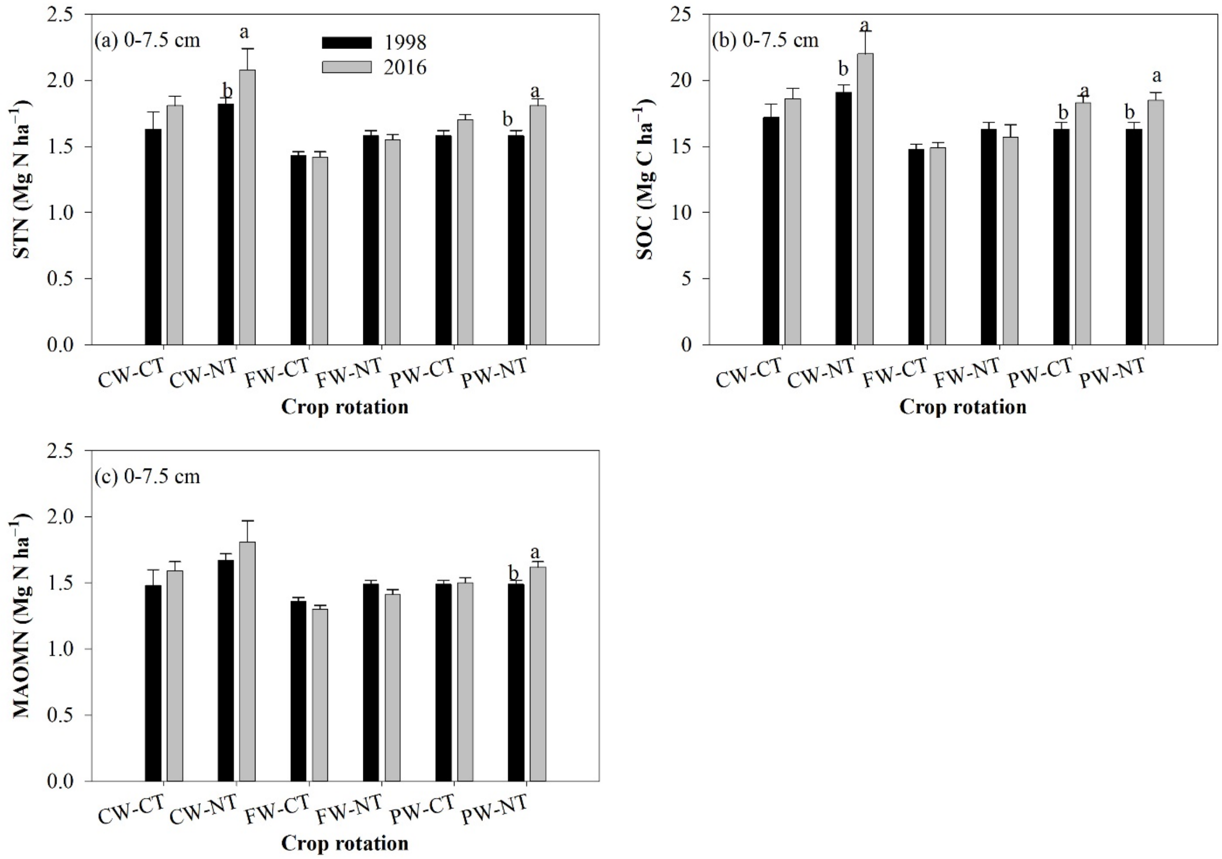

Figure 6. Interactive effect of cropping system and year on soil total N (a), soil organic carbon (b) and mineral-associated organic matter nitrogen (c) C and N content at the 0-7.5 cm depth in a long-term study in Swift Current, SK. Different lower case letters within each cropping system indicate significant difference between years at the 0.05 probability level.

Table 1. Effect of crop rotation system and year on soil total N (STN) and soil organic carbon (SOC) stocks in a long-term field experiment in Swift Current, SK.

	STN (Mg ha^{-1})				SOC (Mg ha^{-1})			
	7.5-15	15-30	0-15	0-30	7.5-15	15-30	0-15	0-30
	Depth (cm)							
System								
CW-CT	1.65a	2.35	3.37ab	5.73ab	15.8	18.1a	33.7ab	51.7ab
CW-NT	1.62ab	2.26	3.57a	5.84a	15.7	18.4a	36.2a	54.6a
FW-CT	1.44c	2.08	2.87e	4.96d	13.8	15.4b	28.7d	44.1d
FW-NT	1.49bc	2.13	3.06d	5.20cd	14.5	15.0b	30.5cd	45.5cd
PW-CT	1.52abc	2.19	3.16cd	5.36c	14.7	15.4b	32.0bc	47.4c
PW-NT	1.55abc	2.22	3.24bc	5.48bc	14.9	15.8b	32.4bc	48.1bc
Year								
1998	1.57	2.59a	3.18	5.78a	15.2	16.6	31.9	48.4
2016	1.52	1.82b	3.25	5.08b	14.6	16.1	32.6	48.7

Different lower case letters within each column for system and year are significantly different at the 0.05 probability level.

Table 2. Particulate organic matter N and C (POMN, POMC) and mineral-associated organic matter N and C (MAOMN, MAOMC) in a long-term field experiment in Swift Current, SK.

	POMN (Mg ha^{-1})					POMC (Mg ha^{-1})				
	0-7.5	7.5-15	15-30	0-15	0-30	0-7.5	7.5-15	15-30	0-15	0-30
	Depth (cm)									
System										
CW-CT	0.18a	0.08	0.09a	0.26a	0.36a	3.03ab	1.09a	1.27a	4.13ab	5.40a
CW-NT	0.20a	0.07	0.08a	0.28a	0.36a	3.57a	1.03ab	1.08a	4.61a	5.69a
FW-CT	0.09d	0.05	0.06b	0.15c	0.21c	1.80d	0.90abc	0.79b	2.71d	3.50b
FW-NT	0.11c	0.05	0.05b	0.17bc	0.23bc	2.14cd	0.79c	0.72b	2.93cd	3.65b
PW-CT	0.14b	0.05	0.04b	0.20b	0.25b	2.62bc	0.84bc	0.71b	3.47bc	4.18b
PW-NT	0.14bc	0.05	0.05b	0.19b	0.25b	2.32cd	0.85bc	0.77b	3.17cd	3.94b
Year										
1998	0.11b	0.04b	0.04b	0.15b	0.19b	2.25b	0.83b	0.87	3.08b	3.95b
2016	0.18a	0.08a	0.08a	0.27a	0.36a	2.91a	1.00a	0.91	3.92a	4.84a

	MAOMN (Mg ha^{-1})					MAOMC (Mg ha^{-1})				
	0-7.5	7.5-15	15-30	0-15	0-30	0-7.5	7.5-15	15-30	0-15	0-30
	Depth (cm)									
System										
CW-CT		1.57a	2.26	3.11ab	5.37ab	14.9bc	14.7	16.8a	29.5ab	46.3ab
CW-NT		1.54a	2.19	3.29a	5.48a	17.0a	14.6	17.3a	31.6a	48.9a
FW-CT		1.38b	2.02	2.72d	4.74d	13.1d	12.9	14.6b	26.0c	40.6d
FW-NT		1.44ab	2.08	2.89c	4.97cd	13.9cd	13.7	14.2b	27.6bc	41.8cd
PW-CT		1.46ab	2.14	2.96bc	5.10bc	14.7bc	13.8	14.7b	28.5b	43.2bcd
PW-NT		1.49a	2.17	3.05b	5.22abc	15.1b	14.1	15.0b	29.2b	44.2bc
Year										
1998		1.53a	2.55a	3.03	5.58a	14.4	14.3a	15.7	28.8	44.5
2016		1.43b	1.74b	2.97	4.72b	15.1	13.6b	15.2	28.7	43.9

Different lower case letters within each column for system and year are significantly different at the 0.05 probability level.

Table 3. Distribution of N and C in particulate organic matter (POM) and mineral-associated organic matter (MAOM) fractions in a long-term field experiment in Swift Current, SK.

	N Distribution (%)					C Distribution (%)				
	POM									
	0-7.5	7.5-15	15-30	0-15	0-30	0-7.5	7.5-15	15-30	0-15	0-30
	Depth (cm)									
System										
CW-CT	10.6a	4.9	4.2a	7.8a	6.3a	17.0ab	6.9a	6.8a	12.3a	10.4a
CW-NT	10.7a	4.4	3.9a	7.9a	6.3a	17.7a	6.4abc	5.9ab	12.8a	10.5a
FW-CT	6.9c	4.0	3.2b	5.4c	4.5b	12.1c	6.5ab	5.1bc	9.5b	7.9b
FW-NT	7.4bc	3.9	3.0bc	5.7bc	4.6b	13.8bc	5.5d	4.8c	9.8b	8.1b
PW-CT	8.9b	3.9	2.2c	6.5b	4.8b	15.0abc	5.9bcd	4.6c	10.9ab	8.8b
PW-NT	8.1b	3.6	2.8bc	6.0bc	4.7b	13.2c	5.7cd	4.9c	9.8b	8.2b
Year										
1998	6.7b	2.6b	1.6b	4.7b	3.3b	13.3b	5.5b	5.1b	9.6b	8.1b
2016	10.8a	5.6a	4.9a	8.4a	7.1a	16.3a	6.9a	5.6a	12.1a	9.9a
	MAOM									
	0-7.5	7.5-15	15-30	0-15	0-30	0-7.5	7.5-15	15-30	0-15	0-30
	Depth (cm)									
System										
CW-CT	89.4c	95.1	95.8d	92.2c	93.7b	82.7bc	93.1c	94.5ab	87.7bc	89.6b
CW-NT	89.3c	95.5	96.0cd	92.1c	93.7b	82.3c	93.5bc	94.1b	87.2c	89.5b
FW-CT	93.1a	96.0	96.7bc	94.5a	95.5a	87.8a	93.4bc	94.8ab	90.5a	92.0a
FW-NT	92.5a	96.1	97.0b	94.3ab	95.4a	87.5ab	94.5a	95.1a	90.2ab	91.9a
PW-CT	91.1b	96.1	97.8a	93.4b	95.2a	85.0abc	94.1ab	95.4a	89.1abc	91.1ab
PW-NT	91.9ab	96.4	97.2ab	94.0b	95.3a	87.4ab	94.5a	95.1a	90.7a	92.0a
Year										
1998	93.2a	97.3a	98.4a	95.3a	96.7a	86.6	94.5a	95.3a	90.3a	91.9a
2016	89.2b	94.4b	95.1b	91.6b	92.9b	84.3	93.2b	94.4b	88.1b	90.1b

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