Prairie Soil Carbon Balance project: Monitoring SOC on commercial direct-seeded fields across Saskatchewan - Phase 4: Soil Carbon Nature and Permanence Component

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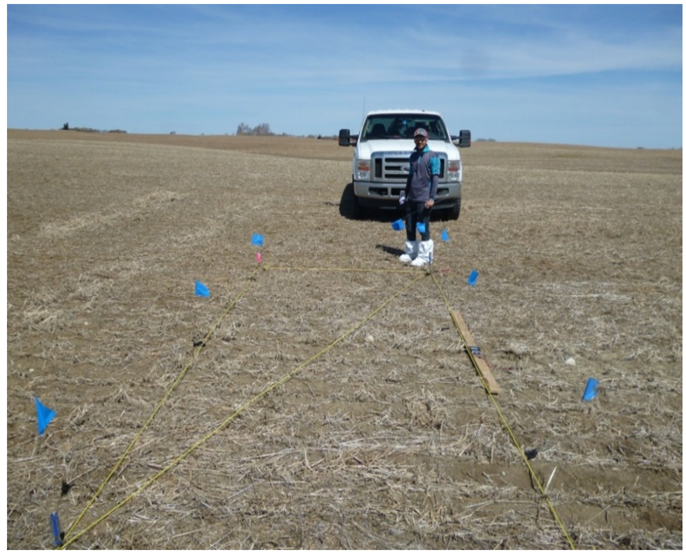
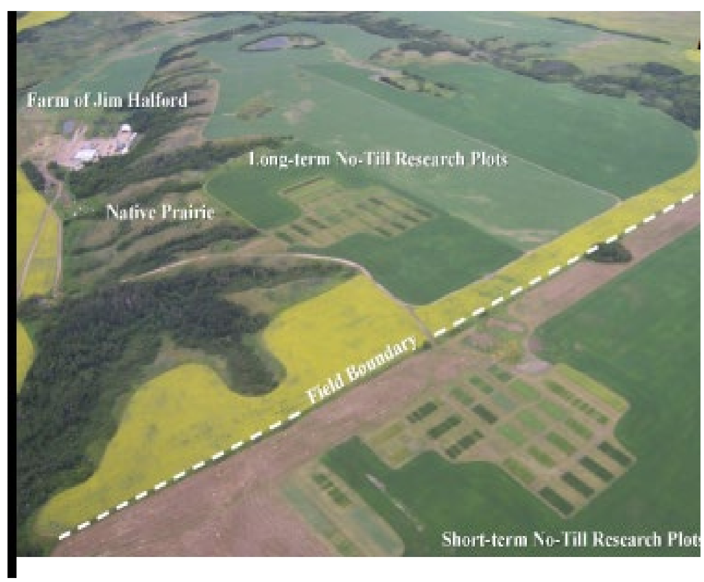
Researchers at the University of Saskatchewan conducted a study to assess the nature and permanence of sequestered soil organic carbon (SOC) i) in contrasting Saskatchewan soils after 21 years of conservation management practices and ii) in soils with contrasting land management histories. Two studies were conducted to achieve research objectives. In study one, ninety commercial direct-seeded fields representing a diverse collection of soil types from within the five soil zones of the province were sampled in 1996 and again at the same locations in 2018. In study two, two neighboring fields with contrasting land management histories: i) native prairie, ii) short-term (18 years), and iii) long-term (40 years) no-till continuous-cropping systems were sampled. Overall, the study results suggest that after 21 years of conservation management practices, the greatest soil C sequestration potential occurred with soils having the lowest initial SOC content. The results of the analyses point to positive changes in the amounts and quality of key SOC fractions in Saskatchewan soils that benefit the storage and cycling of C.

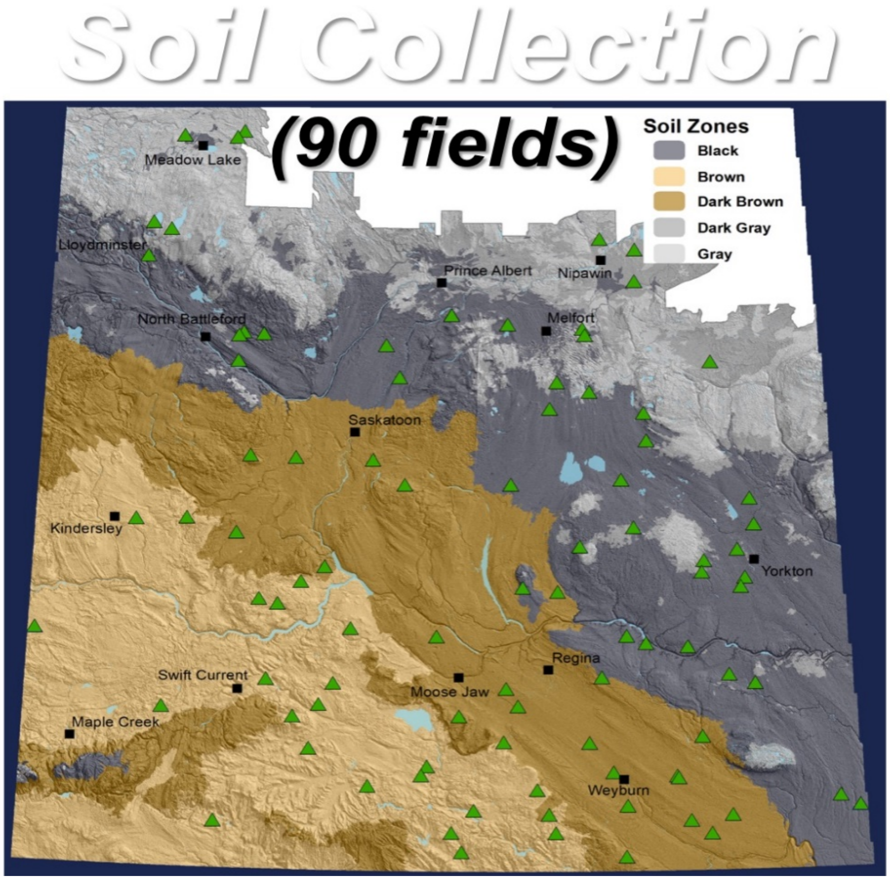
Soils are the largest terrestrial carbon sink on Earth and increasing soil organic carbon (SOC) content is a means of sequestering atmospheric CO_2. The SOC content, which is a key metric of soil quality, is associated with numerous physical, chemical, and biological properties controlling soil productivity and general agroecosystem health. The western prairies contain approximately 80% of Canada's arable land. Since the late 1800's, the conversion of native prairies to cultivated cropland has decreased SOC levels considerably, due to accelerated SOC mineralization, SOC losses from wind, water, and tillage erosion. However, with the introduction of conservation agriculture management practices, such as reduced fallow, minimal disturbance, direct seeding, and diversified rotations, the SOC levels in once conventionally tilled degraded agricultural soils is increasing. Although past research has provided valuable information regarding the short-term efficacy of conservation agriculture management practices to increase SOC levels, limited work has been done to examine the long-term effects of conservation agriculture management practices on the stability of sequestered SOC in prairie soils. Researchers at the University of Saskatchewan conducted a study to assess the nature and permanence of sequestered soil organic carbon (SOC) in i) contrasting Saskatchewan soils after 21 years of conservation management practices and ii) soils with contrasting land management histories.



In study one, ninety commercial direct-seeded fields, representing a diverse collection of soil types from within the five soil zones of the province, were sampled in 1996 and again at the same locations in 2018. Each site was under conventional tillage prior to 1996 and then converted to minimum tillage either at the beginning of the 1996 crop year or immediately thereafter. Comparisons were made between the 1996 and 2018 soils (0-10 cm) in SOC concentration, along with various labile and dynamic SOC fractions: water-extractable, light fraction, microbial biomass, respirable CO_2-C during a six-week incubation, and spectroscopic ($^{13}C/^{12}C$ stable isotope ratio and FTIR) characterization of the SOC.



In study two, assessing the nature and permanence of sequestered SOC in soils with contrasting land management histories was accomplished collecting soils from two neighboring fields with contrasting land management histories: i) native prairie, ii) short-term (18 years), and iii) long-term (40 years) no-till continuous-cropping systems and quantifying the concentrations of total SOC and two various labile and dynamic soil C fractions (water-extractable and microbial biomass), along with respirable CO_2-C during a six-week incubation .



According to study one, the measured SOC concentration and content ranged from 1.6-3.7% and 20.4-55.4 Mg/ha, respectively, in the 0-10 cm depth. Before conservation management practices were implemented in 1996, the SOC concentration and content in the Black, Dark Gray, and Gray soils was greater compared to the Brown and Dark Brown soils. This zonal SOC trend may be explained by environmental conditions and production practices that support higher yields and, therefore, greater above- and below-ground plant residue inputs especially in the moister Black, Dark Gray, and Gray soils, compared to the drier Brown and Dark Brown regions of the province. The SOC concentration for the Black, Dark Gray, and Gray soils did not change following 21 years of conservation management practices, but increased about 15% in the Brown and Dark Brown soils, which is likely a function of the comparatively smaller initial SOC concentrations in these regions, particularly the Brown soils. The SOC content within all soil types increased about 25% following 21 years of agriculture conservation management practices, ranging from 4.7-9.8 Mg C/ha or 220-454 kg C/ha/year. The study results showed that regardless of soil type and sampling year, there were few differences in CO_2 emissions among weeks, with the largest CO_2 emissions observed in the second week. This apparent lag phase occurs as the microbial community activates upon re-wetting of the soil and begins to metabolize the available labile C. Respiration was lowest in soils from the Brown Soil Zone, reflecting the lower organic matter of these soils. There was a minor increase in water extractable organic carbon content (3%), no change in light fraction carbon content, and a substantial increase in microbial biomass carbon content (41%). Except for greater CO_2-C emissions from the 2018 Black soils, there was no difference in CO_2-C emissions or percentage of SOC respired between the 2018 and 1996 soils, which suggests similar or greater permanence of the sequestered SOC. Research results suggest that after 21 years of agriculture conservation management practices, more of the SOC is present in an active, dynamic fraction that contributes to soil health and nutrient cycling.

According to study two, the SOC concentration values ranged from 2.9-4.2% in the 0-15 cm depth. The only difference among the three sites was the 45% greater SOC concentration within the native soil compared to the short-term soil. The SOC contents ranged from 41-48 Mg C/ha and indicate both the long-term and native soils contain about 20% more SOC than the short-term soil. The similarity in SOC content between the long-term and native soils has been attributed to the effect of increased net primary production under conservation agriculture practices, resulting in larger above- and below-ground crop residue inputs, particularly from root-derived SOC.

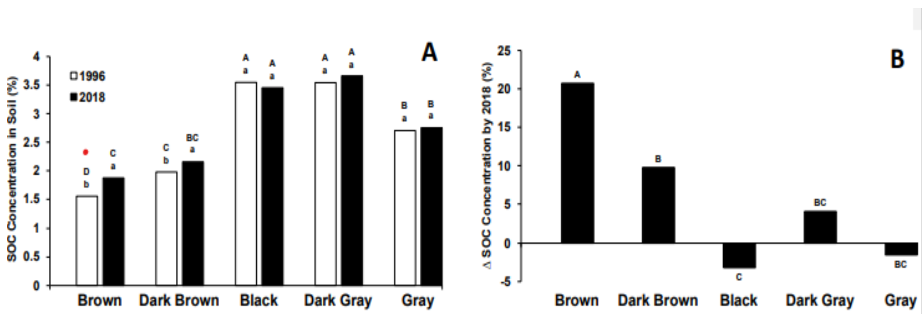


Figure 1. Mean (n=6-31; 0-10 cm) soil organic carbon (SOC) concentration (A), and percent change (delta; Δ) in SOC concentration (B), within different soil types before (1996) and after (2018) 21 years of conservation agriculture management practices.

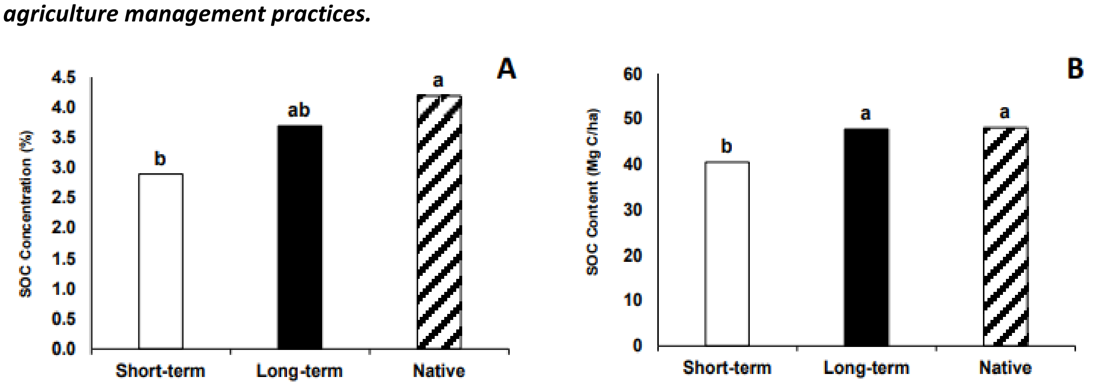


Figure 2. Mean (n=6; 0-15 cm) soil organic carbon (SOC) concentration (A) and content (B) of soils collected at adjacent locations with contrasting land management histories: a native prairie adjacent to two cropped fields under conservation agriculture management practices for either 18 (Short-term) or 40 (Long-term) years.

Overall, the results of this study suggest that after 21 years of conservation management practices, the greatest soil C sequestration potential occurred with soils having the lowest initial SOC content. Increasing SOC levels through the adoption of conservation agriculture management practices by Saskatchewan growers not only improves crop production by enhancing soil health and nutrient cycling, but also, appears to provide a natural means of sequestering more atmospheric CO_2 within an active, dynamic SOC fraction, along with relatively stable recalcitrant SOC, which is resistant to loss as CO_2 via heterotrophic microbial respiration. The results of this research also indicate that given enough time, the adoption of conservation agriculture practices is able to restore the SOC levels, along with certain active, dynamic fractions within degraded agricultural soils to a pre-cultivated condition. Researchers noted that given the stabilizing effects of both soil mineralogy and microbial community structure on sequestered SOC permanence, future work on these field soils should examine differences in texture, quantities of occluded and heavy fraction SOC, and microbial community structure between the 1996 and 2018 samples. Such analyses and comparisons should help to clarifying the observed SOC trends before and after 21 years of conservation management practices and the associated mechanisms involved.

Full research summary can also be found on Saskatchewan Soil Conservation Association website. Please click **here** to get access.

Acknowledgement:

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