



# Soil Organic Matter Indicator

## Agri-Environmental Indicators Report

### The Environmental Sustainability of Canadian Agriculture Census Year 2021



## **Soil Organic Matter Indicator**

Agri-Environmental Indicators Report, Census Year 2021

Status: National Coverage, 1981-2021

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## Summary

**Carbon (C)**<sup>1</sup> is the basic building block of all living things and is critical to soil health and fertility. The Relative Soil Organic Carbon (RSOC) Indicator estimates soil organic carbon (SOC) levels across the country relative to a soil-specific baseline level, while the Soil Organic Carbon Change (SOCC) Indicator assesses how organic carbon levels in Canadian agricultural soils are changing over time. Together, they provide a useful picture of soil health and an estimate of how much **carbon dioxide (CO<sub>2</sub>)** has been removed from the atmosphere by plants and **sequestered** as SOC in agricultural soils. They assess both the state and the trend of organic carbon levels in Canadian agricultural soils.

In 2021, the average SOC content of farmland soils in Canada was increasing. Canadian agricultural soils removed 22.4<sup>2</sup> million tonnes of CO<sub>2</sub> from the atmosphere in 2021 as the result of changes to cropland management. In Western Canada, SOC is increasing due to a reduction in tillage intensity and higher levels of carbon input to soils from increases in crop yields and subsequent crop residue carbon input, reduction in summerfallow usage and application of livestock manure. This increase has compensated for past practices that caused soil degradation and left many soils with very low SOC levels. In recent years, however, carbon gains have been partially offset by losses in SOC due to the conversion of **tame pastures** and hayland to annual crops. In Eastern Canada, the conversion of perennial forage land is largely responsible for decreasing levels of SOC in this region. These losses are partially offset by carbon inputs from **crop residues** and the application of manure, and through a reduction in tillage intensity.

## The issue and why it matters

Carbon is the basic building block of life and the main component of **soil organic matter**. It is captured from the air as CO<sub>2</sub> by plants during **photosynthesis**. Some of this C is stored in plant tissues and in the tissues of animals that directly or indirectly consume the plants. After the death and subsequent **decomposition** of these plants and animals, most of this carbon is quickly lost to the atmosphere; however, a small

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<sup>1</sup> Words included in the glossary (at the end of this publication) are bolded in the first instance.

<sup>2</sup> The sink of -22.4 Mt CO<sub>2</sub>e in 2021 is strictly the amount of carbon (in CO<sub>2</sub>e) lost or sequestered in soil. This figure does not include changes in carbon stocks associated with changes in living biomass and dead organic matter resulting from the conversion of forestland to cropland and changes in other perennial woody biomass on cropland with the exception of perennial wood crops (Christmas Trees, Fruit Orchards and Grapes). When these other changes are included, the net sink for 2021 is approximately -17.6 Mt CO<sub>2</sub>e respectively (Environment Canada, 2021)

portion of organic C is transformed into soil organic materials that are less easily decomposed. Over time, soil organic matter builds up in the soil until a **steady-state** level of soil organic matter (SOM) is reached. At this point, new organic C additions from decayed plant and animal tissues are balanced by losses of organic C as a result of decomposition. Note that, in this text, the terms SOC and SOM are used somewhat interchangeably, as SOM is typically estimated to contain 58% carbon by mass ( $SOC=0.58*SOM$ ).

Soil organic matter strongly influences many important aspects of soil quality and is a key component of good soil health. Along with plant roots, it holds soil particles together and stabilizes the **soil structure**, making the soil less prone to erosion and improving the ability of the soil to store and convey air and water. Good soil structure is important for maintaining soil tilth (workability) and permeability. SOM stores and supplies many **nutrients** needed for the growth of plants and soil organisms. SOM also binds potentially harmful substances, such as heavy metals and **pesticides**, thereby reducing their adverse environmental effects. Lastly, it acts as a storage reservoir (**sink**) for CO<sub>2</sub> captured from the atmosphere.

Losses of SOM contribute to degraded soil structure, increased soil vulnerability to erosion and lower fertility, ultimately leading to lower crop yields and reduced sustainability of the soil.

The health of Canada's soil resources is closely tied to the management practices that are used in crop and livestock production. The SOCC and the RSOC are key indicators of soil health. By assessing SOC trends in Canada, we can improve our understanding of the key drivers of soil health and the associated risks and opportunities. This knowledge is important for maintaining the land's productive capacity now and into the future, therefore ensuring the profitability and sustainability of the agriculture sector.

The SOCC and RSOC indicators are essential tools which are used to understand trends in agricultural **greenhouse gas (GHG)** emissions in Canada and to support Canada's annual GHG reporting efforts under the United Nations Framework Convention on Climate Change (see the Greenhouse Gas Indicator for Canadian Agriculture). Canada's National Inventory Report tracks total GHG emissions and removals of carbon resulting from changes in agricultural and forestry land-use activities in the land use, land-use change and forestry sectors (Environment Canada, 2020). The SOCC and RSOC indicators highlight the linkages between changes in crop production, changes in land management practices, such as conversion to **no-till**, reduction in **summerfallow**, conversion of annual crops to **perennial forages**, the application of livestock manure and the subsequent sequestration or release of carbon dioxide in agricultural soils.

Agri-environmental indicator (AEI) data on SOC and erosion are being used by agriculture industry stakeholders to meet requirements for demonstrating sustainability criteria to buyers, including those for international market access. The growing trend among retailers, such as Walmart and General Mills, to assess and report on the sustainability of their agricultural supply chains, including the effect of their practices on soil health and GHG emissions, highlights the importance of the SOCC and RSOC indicators.

## The Indicator

The SOCC Indicator has been developed to assess how organic carbon levels in Canadian agricultural soils are changing over time. The indicator is based on the methods used for Canada's National Inventory Report (Environment Canada, 2020). The indicator uses the Century model (NREL, 2007) to predict the rate of change in organic C content in Canada's agricultural soils associated with the effects of land management changes since 1951. These include changes in tillage and shifts between annual crops and perennial hay or pasture. The Intergovernmental Panel on Climate Change (IPCC) Tier 2 Steady State method (IPCC, 2019) is used to estimate the impact of crop production and subsequent crop residue C input on soil C storage. This also accounts for changes in fallow frequency over time by accounting for the effect that the absence or presence of summerfallow has on organic carbon input within a region. The impact of livestock manure application on SOC stocks in annual cropland is estimated using manure induced C retention factors. Defined as the proportion of manure C added to a soil that is retained in the soil over time (Liang et al., 2020), factors are specific to livestock type and type of manure applied (solid, liquid and composted). The indicator also includes the impact of land-use changes on SOC stocks, specifically the conversion of native grassland to **cropland** and the clearing of forests for agriculture; however, it does not include the loss of C from above and below-ground forest **biomass**. Where there were no changes in land use or land management, it was assumed that SOC did not change.

The change in SOC is a useful indicator of long-term, generalized trends in soil health. The indicator also serves to estimate how much CO<sub>2</sub> is removed from the atmosphere by plants and stored (or sequestered) as SOC in agricultural soils. Thus, in addition to indicating changes in soil health, the change in SOC provides an indication of potential reductions in atmospheric CO<sub>2</sub>, which can offset greenhouse gas emissions.

The SOCC Indicator results are given as the percentage of total cropland that falls into each of five SOC change classes expressed in kilograms per hectare per year (kg ha<sup>-1</sup> yr<sup>-1</sup>). Negative values represent a loss of SOC and positive values, a gain of SOC. The five classes are defined as follows: large increase (gain of more than 90 kg ha<sup>-1</sup> yr<sup>-1</sup>),

moderate increase (25 to 90 kg ha<sup>-1</sup> yr<sup>-1</sup>), negligible to small change (-25 to 25 kg ha<sup>-1</sup> yr<sup>-1</sup>), moderate decrease (-25 to -90 kg ha<sup>-1</sup> yr<sup>-1</sup>) and large decrease (loss of more than -90 kg ha<sup>-1</sup> yr<sup>-1</sup>).

If soil is well managed over a long period of time, the SOM content will stabilize and essentially remain constant over time. An increase in SOC is not necessarily better than a stable situation. However, if soil degradation has occurred in the past, a significant increase in SOC is clearly desirable, as it is indicative of improvements in soil health and function. A loss of SOC represents a release of CO<sub>2</sub> into the atmosphere and so is not desirable. Therefore, the preferred values for this indicator range from no loss of SOC from agricultural soils having high organic matter to C accumulation in soils that are currently low in organic matter.

In addition to knowing how quickly C is accumulating in the soil, it is useful to have a means of assessing soil health and function, which varies across different climates and soil types. A complementary indicator, the Relative Soil Organic Carbon (RSOC) Indicator, was developed as a measure which can be used to compare the current SOC level across different climates and soil types. This indicator is calculated using the Century model with data from the Canadian Soil Information Service (CANSIS) (Soil Landscapes of Canada Working Group, 2010) and changes estimated by the SOCC Indicator. Relative Soil Organic Carbon is expressed as the ratio of the current SOC level to a modelled baseline SOC value for an extensively grazed permanent grass pasture. This baseline SOC level is consistent with good soil health and function; however, it cannot be assumed to represent an attainable level of SOC for the wide diversity of cropping systems and management practices that exist within the agricultural sector. For many cropping systems, achieving the baseline SOC level is neither feasible nor necessary.

The resultant RSOC values are ranked as very low (<0.55), low (0.55 to 0.7), moderate (0.7 to 0.85), high (0.85 to 1.0) and very high (>1.0). Since farmland planted to annual crops generally has lower SOC levels than cropland under continuous pasture, the RSOC values are expected to fall into the moderate class when few periods of **forages** or pasture are included in the cropping cycle and when there are no organic matter additions from **cover crops**, green manures or animal manures. Areas with low or very low RSOC values represent opportunities to increase C sequestration through the adoption of appropriate management practices. Areas that have low RSOC values combined with a decline in SOC present the greatest risk of soil degradation.

## Limitations

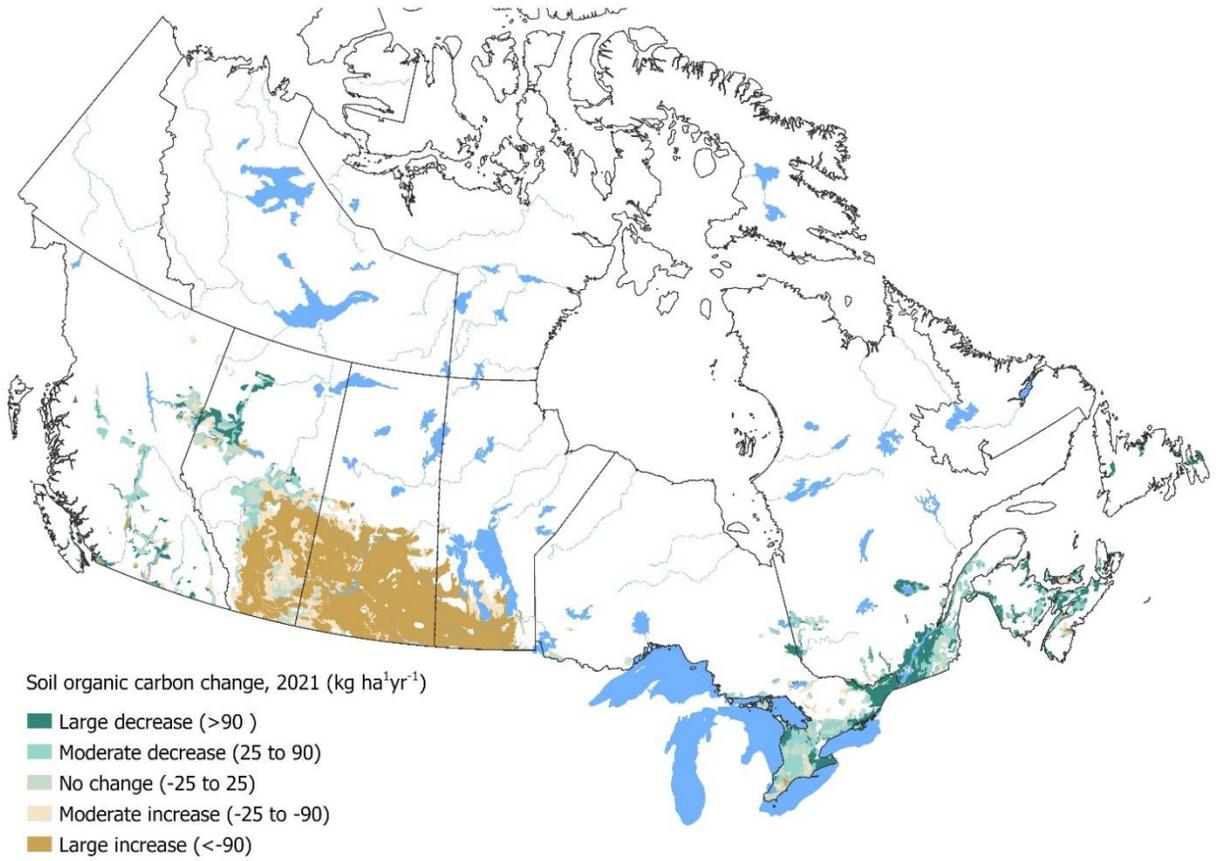
The SOCC Indicator does not take soil erosion into consideration. Soil erosion causes a decline in SOC because it removes part of the surface layer of soil which is enriched in SOC. Therefore, even relatively low rates of soil erosion can have significant effects on SOC status. As a result, when considered at the field-level, SOC change in this report is biased toward smaller losses and larger gains.

The RSOC Indicator should be considered more uncertain than the SOCC Indicator because of uncertainties related to the SOC values in the CANSIS database.

## Results and interpretation

For Canada as a whole, improvements in crop productivity and farm management have resulted in a dramatic shift from SOC levels that were relatively stable (additions=losses) during the early to mid-1980s to a situation where the majority of cropland had increasing SOC levels in the early-1990s and through to 2021 (Figure 1, Table 1).

Across Canada, 76% of the agricultural land is in the large or moderate increase class in 2021. Thanks to crop yield increases, which are reflected in higher C input to soils from crop residues and the enhanced management practices adopted during this period, cropland soils have become a larger sink for atmospheric CO<sub>2</sub>. Canadian agricultural soils represented a net source of 4.2 mega tonnes (Mt) of CO<sub>2</sub> per year in 1981. By 2006, agricultural soils were a sink of 30 Mt of CO<sub>2</sub> per year, and in 2021, a sink of 22.4 MtCO<sub>2</sub> per year. Over this time period, the interannual variability in soil carbon change was high due to weather-related impacts on crop production and subsequent C input to soils from crop residue (Figure 2).

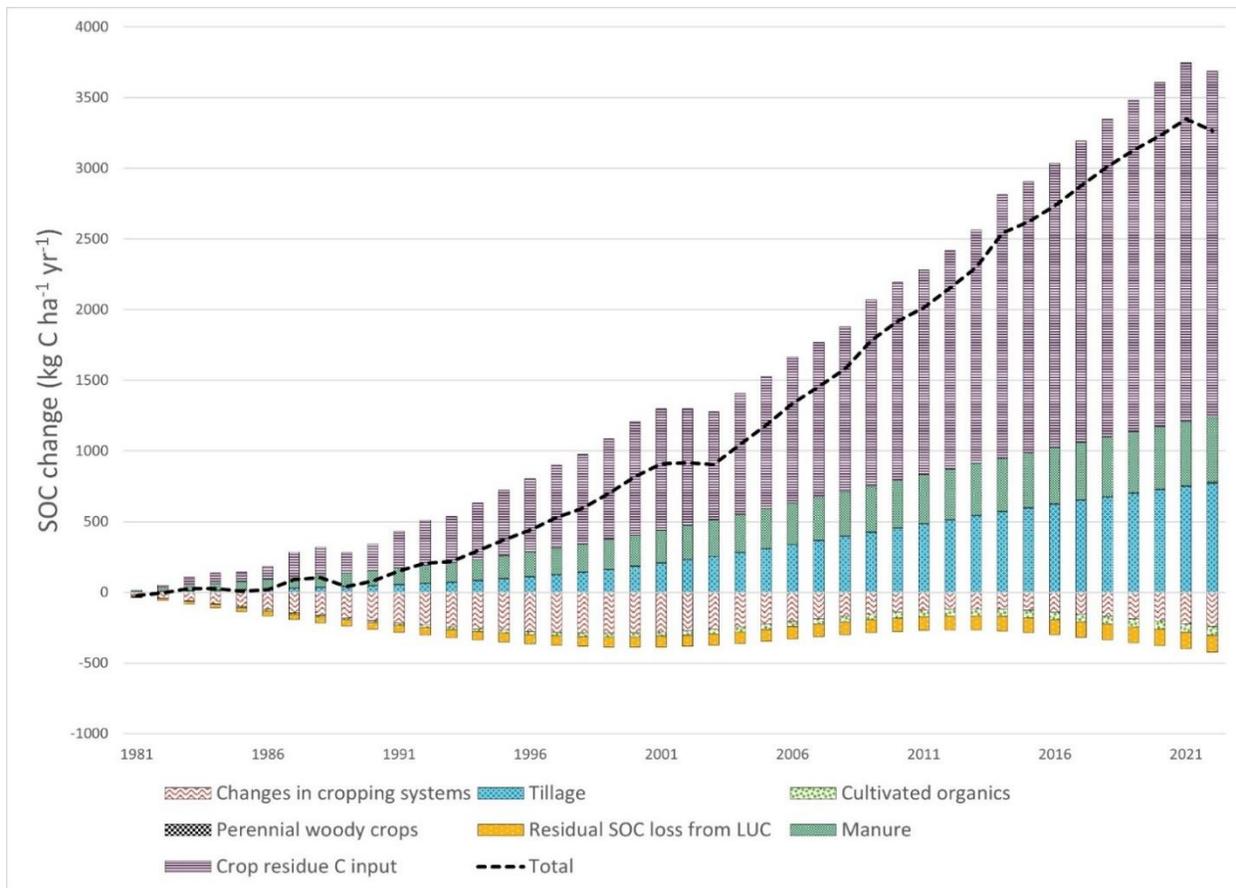


**Figure 1: Soil Organic Carbon (SOC) change (kg ha<sup>-1</sup> yr<sup>-1</sup>) in Canada, 2021**

**Table 1: Percentage of land in Soil Organic Carbon (SOC) change classes (Note: formatted for a tabloid layout)**

	Large Increase more than 90 kg ha <sup>-1</sup> yr <sup>-1</sup>										Moderate Increase 25 to 90 kg ha <sup>-1</sup> yr <sup>-1</sup>								Negligible to small change C3 -(25 to 25 kg ha <sup>-1</sup> yr <sup>-1</sup> )									
	1981	1986	1991	1996	2001	2006	2011	2016	2021		1981	1986	1991	1996	2001	2006	2011	2016	2021		1981	1986	1991	1996	2001	2006	2011	2016
BC	12	5	11	33	26	35	7	28	6	35	23	24	24	30	16	28	25	18	40	36	39	27	28	29	39	35	34	
<b>PRAIRIE MEAN</b>	1	14	50	48	64	76	69	70	74	13	27	25	37	24	11	21	17	15	46	39	20	14	10	6	7	9	6	
AB	3	4	8	50	30	76	72	40	51	33	21	41	35	44	16	19	30	24	41	50	40	13	22	8	7	20	14	
MB	0	69	92	41	97	16	53	94	93	0	11	5	36	3	14	26	6	6	5	10	2	20	0	14	7	0	1	
SK	0	9	70	48	82	91	70	87	87	1	35	19	39	14	7	22	9	11	59	37	9	13	4	2	7	3	2	
<b>CENTRAL CANADA MEAN</b>	1	1	2	1	0	1	1	1	1	12	24	16	17	4	9	9	6	5	31	39	30	29	18	26	31	16	22	
ON	0	1	3	1	0	1	2	1	2	4	18	13	18	5	11	10	6	6	31	38	27	27	19	26	33	14	27	
QC	2	2	1	1	0	0	0	0	1	27	37	22	15	1	4	7	8	3	32	41	38	33	16	27	28	20	12	
<b>ATLANTIC MEAN</b>	8	4	2	2	2	2	2	1	1	22	11	12	8	6	13	12	11	12	28	39	23	24	37	41	29	32	16	
NB	7	11	5	2	3	3	5	2	0	32	26	29	15	11	12	27	20	1	46	46	34	37	45	44	28	24	9	
NL	1	1	1	1	1	0	0	0	0	4	2	4	0	2	1	0	1	1	8	10	0	3	1	2	2	2	0	
NS	18	2	1	5	4	2	2	1	3	36	7	7	11	6	13	8	8	3	31	32	23	28	18	27	16	22	11	
PE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	0	4	32	7	39	12	8	47	52	43	51	29	
<b>CANADA MEAN</b>	1	12	42	41	54	65	58	60	62	13	26	24	34	21	11	20	16	14	43	39	22	16	12	9	11	11	9	

	Moderate Decrease C4 (-25 to -90 kg ha <sup>-1</sup> yr <sup>-1</sup> )										Large Decrease more than -90 kg ha <sup>-1</sup> yr <sup>-1</sup>																
	1981	1986	1991	1996	2001	2006	2011	2016	2021		1981	1986	1991	1996	2001	2006	2011	2016	2021								
BC	10	26	21	11	10	12	17	7	25	3	11	4	6	7	8	10	5	17	33	19	4	1	1	4	1	3	2
<b>PRAIRIE MEAN</b>	33	19	4	1	1	4	1	3	2	7	2	1	0	1	3	2	1	2	7	2	1	0	1	3	2	1	2
AB	20	21	9	1	3	0	1	7	6	3	3	3	0	1	0	1	3	5	3	3	3	0	1	0	1	3	5
MB	68	10	0	3	0	34	3	0	0	27	0	0	0	0	21	11	0	0	27	0	0	0	0	21	11	0	0
SK	35	18	1	1	0	0	1	0	0	5	1	0	0	0	0	0	0	0	5	1	0	0	0	0	0	0	0
<b>CENTRAL CANADA MEAN</b>	31	27	25	23	18	32	29	34	33	26	8	26	30	60	33	30	43	38	26	8	26	30	60	33	30	43	38
ON	33	35	30	27	18	37	35	39	37	32	8	27	27	59	26	21	40	28	32	8	27	27	59	26	21	40	28
QC	25	10	14	16	20	21	19	23	25	14	9	25	35	63	47	46	49	59	14	9	25	35	63	47	46	49	59
<b>ATLANTIC MEAN</b>	35	37	45	43	34	25	31	30	27	7	9	18	22	22	19	25	26	43	7	9	18	22	22	19	25	26	43
NB	13	11	18	29	27	27	23	26	25	2	6	13	16	14	15	17	28	64	2	6	13	16	14	15	17	28	64
NL	24	21	32	3	3	2	1	2	4	64	67	63	93	93	95	96	95	96	64	67	63	93	93	95	96	95	96
NS	8	41	38	37	41	33	38	39	40	7	18	31	20	32	25	34	30	43	7	18	31	20	32	25	34	30	43
PE	83	59	80	66	36	18	34	28	20	10	2	8	26	17	14	23	17	18	10	2	8	26	17	14	23	17	18
<b>CANADA MEAN</b>	32	20	8	5	4	8	5	7	7	9	3	5	4	9	7	6	7	7	9	3	5	4	9	7	6	7	7



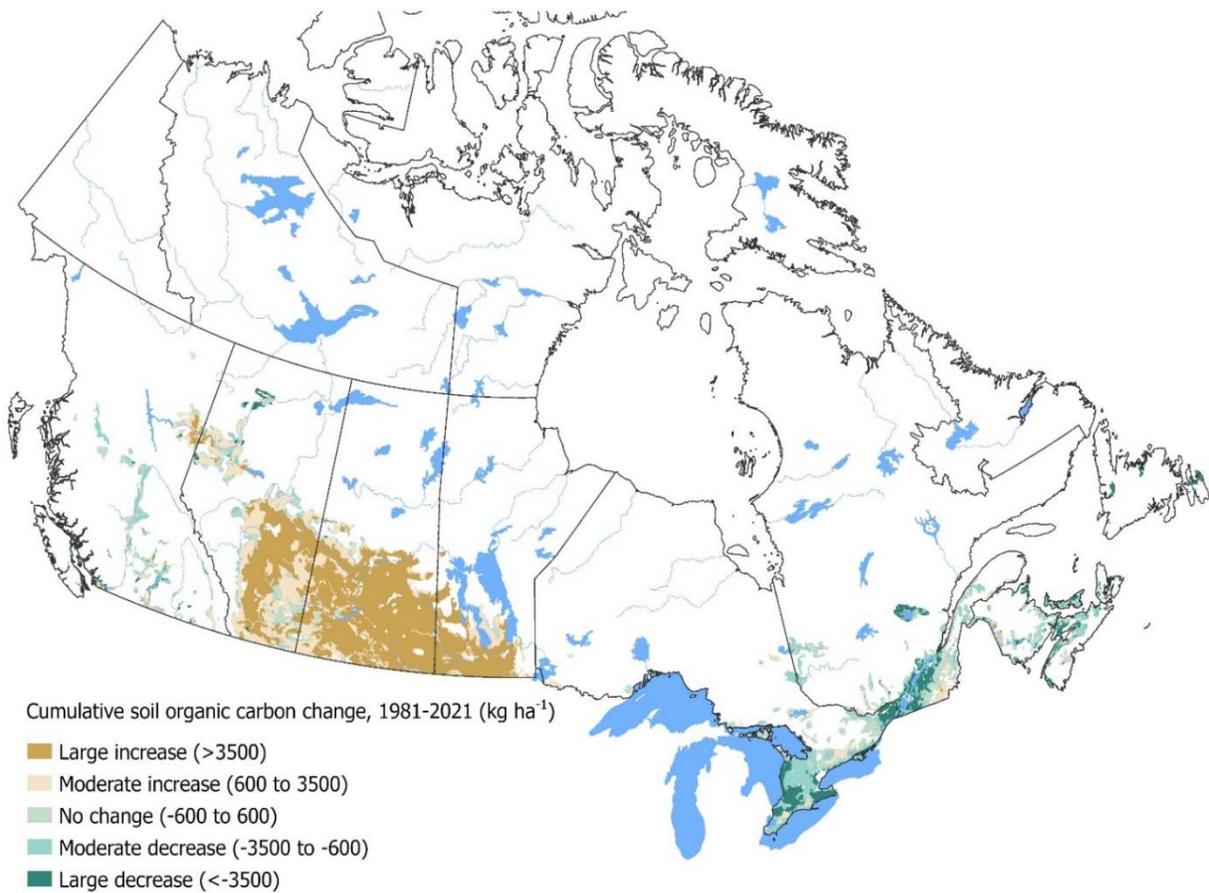
**Figure 2: Soil Organic Carbon change on agricultural land**

Changes in SOC vary among different regions of the county. From Ontario eastward, there was an overall loss of SOC from 1981 to 2021 due to the reduction in hayland and pasture and a corresponding increase in land seeded to annual crops (Figure 3). This shift in land use is due in part to declining cattle populations in those provinces and an associated reduction in the demand for feed (Statistics Canada 2017). Partially offsetting these emissions, there have been moderate gains in SOC as a result of higher levels of crop residue C input, application of livestock manure, and adoption of **conservation tillage** (Figure 8).

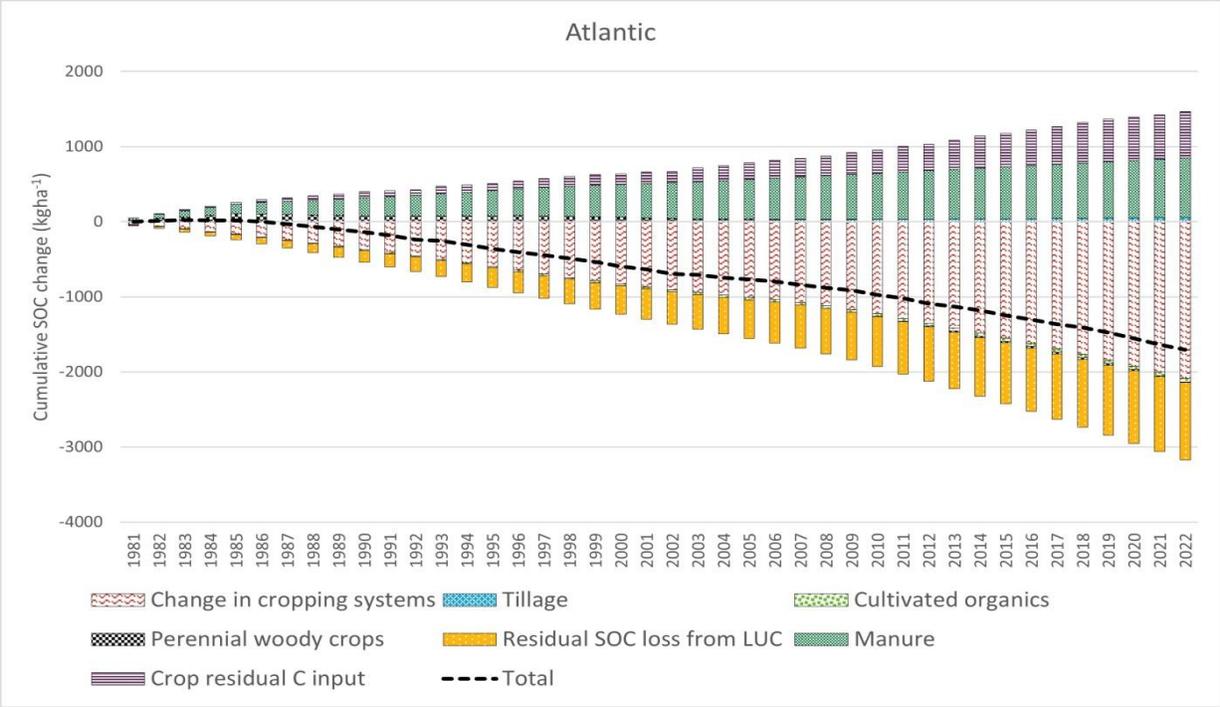
In Eastern Canada, carbon gains from the adoption of conservation tillage have been highest in Ontario and Quebec, while Atlantic Canada has shown limited increases because conservation tillage has not been implemented to the same extent, owing to the cooler and wetter climatic conditions.

The Prairie provinces and BC have seen increases in SOC due to a reduction in tillage intensity, higher levels of carbon input from crop residue as a consequence of crop yield

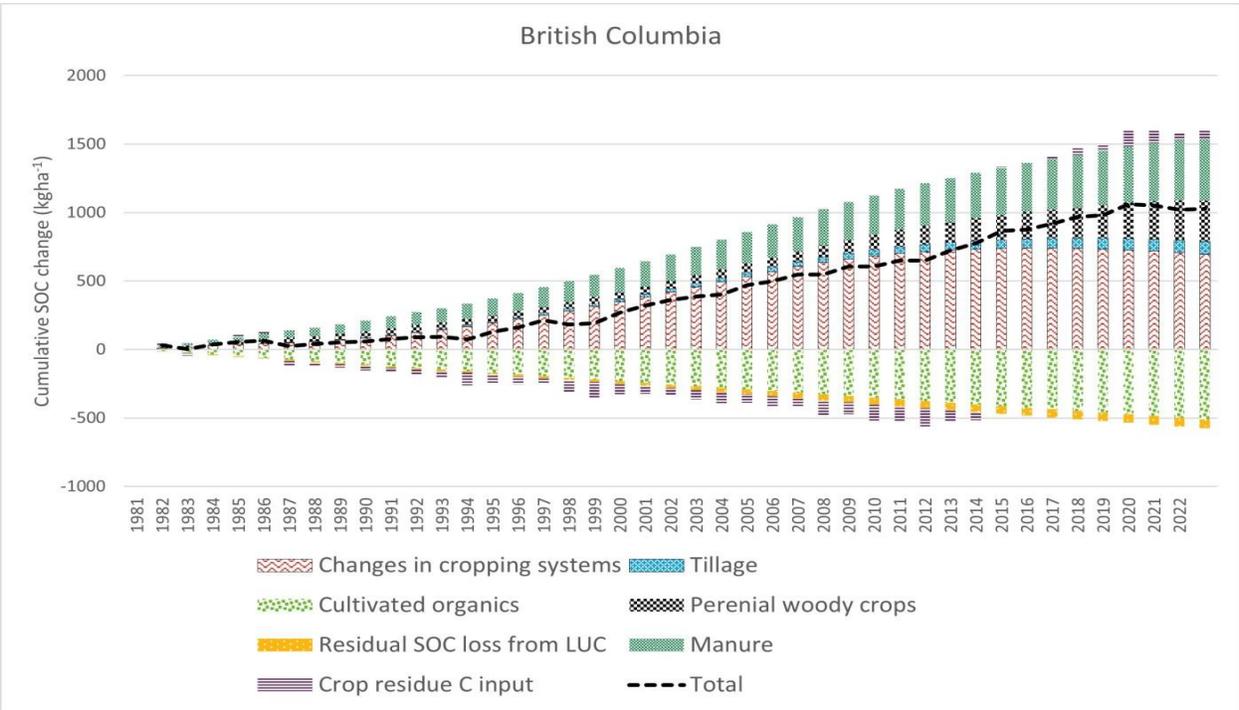
increases, reduced use of summerfallow over time, and from application of livestock manure (Table 1, Figure 3). An increase in land under perennial hay crops through the 1980s and early 2000s also contributed to higher levels of SOC. Since 2006, however, there has been a loss of hay and pasture land as a greater proportion of crop production is shifted to annual crops. The loss of hay and pasture land can be attributed in part to declining cattle populations over this time period and an associated reduction in the demand for feed.



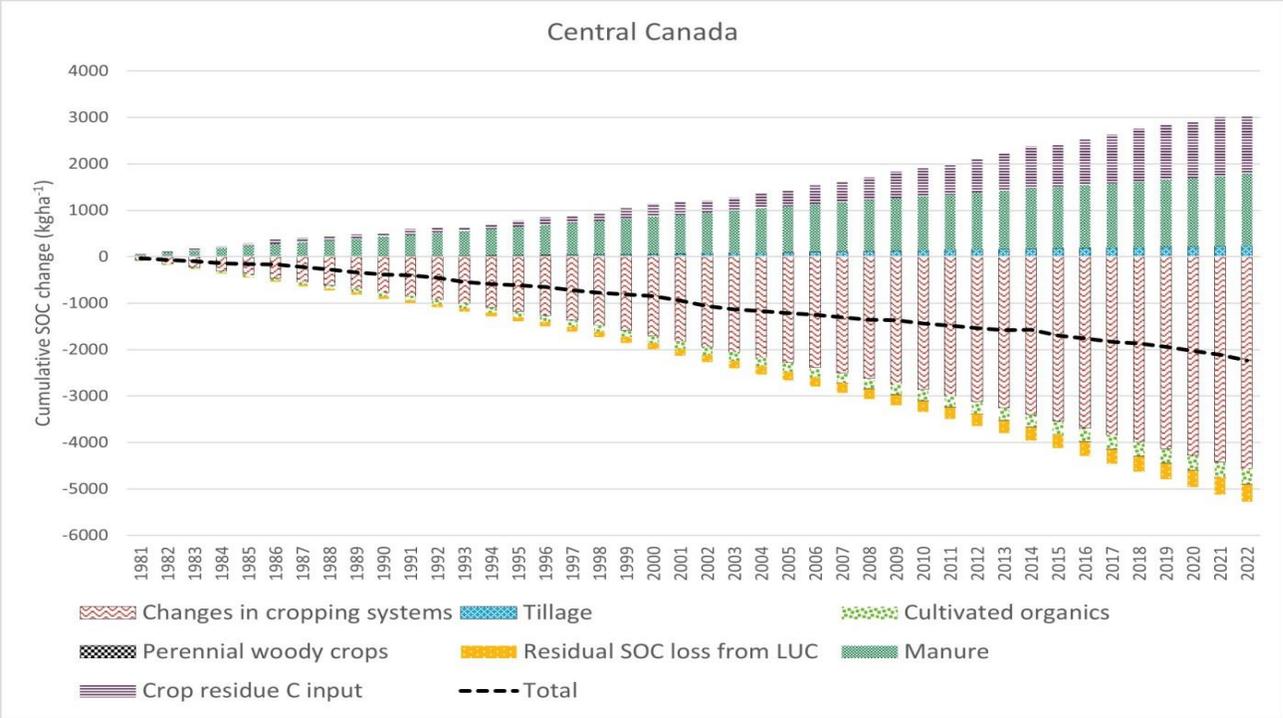
**Figure 3: Cumulative Soil Organic Carbon change ( $\text{kg ha}^{-1}$ ) from 1981 to 2021**



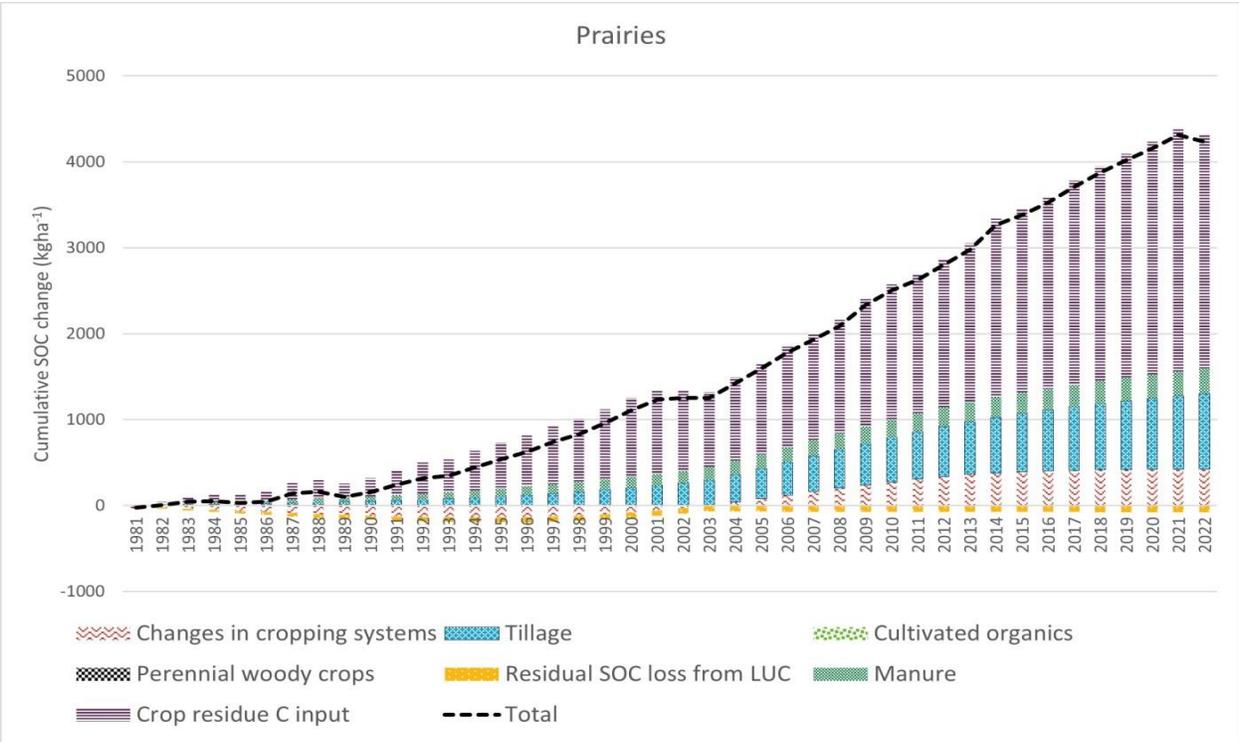
**Figure 4: Cumulative Soil Organic Carbon change (kg ha<sup>-1</sup>) by management type, 1981 to 2021 (Atlantic region)**



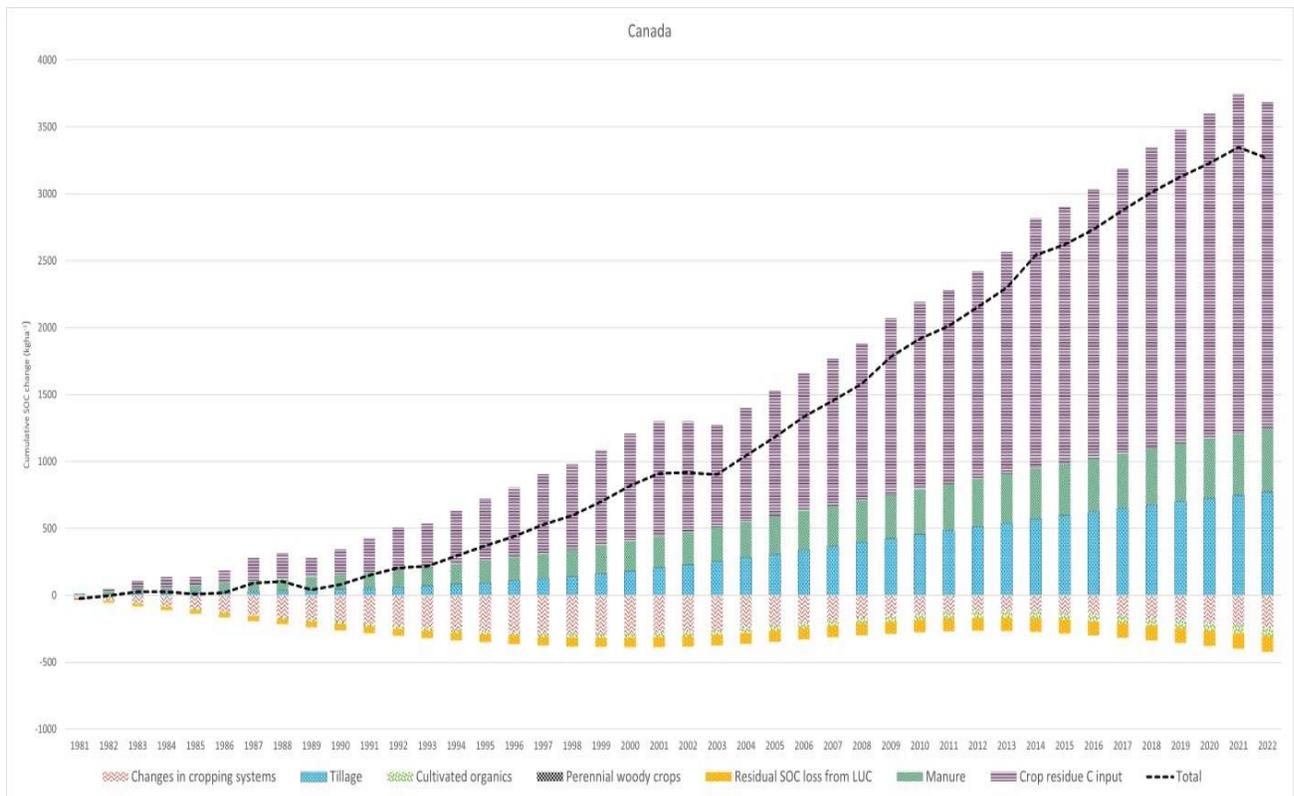
**Figure 5: Cumulative Soil Organic Carbon change (kg ha<sup>-1</sup>) by management type, 1981 to 2021 (British Columbia)**



**Figure 6: Cumulative Soil Organic Carbon change (kg ha<sup>-1</sup>) by management type, 1981 to 2021 (Central Canada)**



**Figure 7: Cumulative Soil Organic Carbon change (kg ha<sup>-1</sup>) by management type, 1981 to 2021 (Prairies)**



**Figure 8: Cumulative Soil Organic Carbon change (kg ha<sup>-1</sup>) by management type, 1981 to 2021 (Canada)**

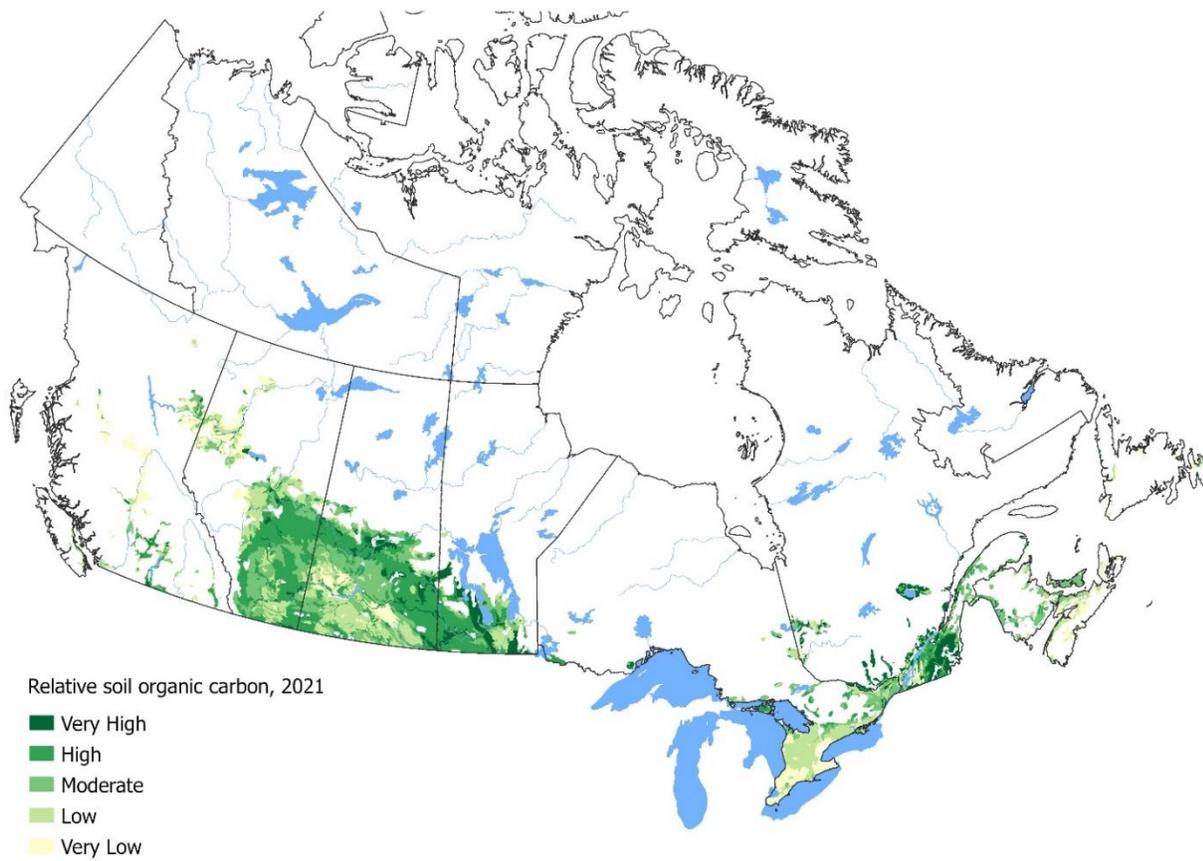
The mean RSOC Indicator value for Canada’s agricultural land in 2021 was 0.79 (Table 2). While the majority of agricultural land in the Prairies, Quebec, and Atlantic Canada has RSOC values in the moderate to high range (Table 3), significant areas with low or very low RSOC ratios (<0.7) are present in southwestern Ontario, the south-central Prairies, large portions of northern Alberta and British Columbia, and parts of the Atlantic provinces (Figure 9).

**Table 2: Average rates of SOC change and RSOC levels for the provinces and for Canada**

	Soil Organic Carbon Change									Relative Organic Carbon	
	(kg ha <sup>-1</sup> yr <sup>-1</sup> )									(Current SOC/modelled baseline SOC)	
	1981	1986	1991	1996	2001	2006	2011	2016	2021	1981	2021
BC	29	-14	8	61	40	50	-1	45	-25	0.68	0.69
<b>Prairie mean</b>	-18	23	86	84	124	186	128	143	148	0.77	0.81
AB	6	0	24	92	61	170	165	64	81	0.77	0.79
MB	-74	114	195	70	212	-54	73	204	210	0.86	0.91
SK	-23	19	107	82	149	255	113	187	183	0.75	0.80
<b>Central Canada mean</b>	-44	-11	-45	-49	-143	-64	-58	-89	-93	0.74	0.71
ON	-58	-18	-52	-43	-116	-46	-41	-84	-65	0.64	0.61
QC	-18	5	-31	-61	-198	-102	-92	-98	-148	0.94	0.91
<b>Atlantic mean</b>	-6	-24	-49	-55	-56	-41	-55	-61	-89	0.73	0.70
NB	24	11	-12	-32	-35	-32	-35	-60	-140	0.79	0.77
NS	35	-47	-72	-48	-85	-58	-75	-69	-92	0.63	0.59
PE	-65	-31	-58	-75	-40	-20	-42	-39	-16	0.75	0.73
NL	-167	-188	-203	-295	-322	-396	-425	-416	-451	0.75	0.60
	-21	17	66	65	85	148	99	108	110	0.76	0.79

**Table 3: Share of land (percentage) in each RSOC class in 2021**

Region	Very high	High	Moderate	Low	Very low
BC	3	25	20	12	39
<b>Prairies</b>	6	39	27	21	7
AB	2	41	28	21	8
SK	5	36	29	22	7
MB	21	44	17	16	1
<b>Central Canada</b>	12	8	16	33	31
ON	1	4	14	43	38
QC	34	17	19	15	15
<b>Atlantic Canada</b>	1	3	55	26	15
NB	2	9	65	23	1
NS	3	0	14	38	45
PE	0	0	84	16	0
NL	9	2	2	51	36
<b>Canada</b>	6	35	26	22	11



**Figure 9: Relative Soil Organic Carbon (RSOC) values for Canada in 2021**

Together, the RSOC and SOCC indicators provide information on the overall risk of SOC degradation. The combination of SOCC and RSOC classes used to define the SOC degradation risk classes is shown in Table 4. Areas having RSOC values in the low to very low classes combined with declining SOC (i.e., those cells highlighted in red) are considered to be at high risk of soil degradation and raise the greatest concern about soil quality in terms of SOC. These areas are listed in Table 5 and can be seen in Figure 10.

**Table 4: SOCC/RSOC class combinations used to define SOC degradation risk**

		Soil organic carbon degradation risk						
		ROC					Legend	
SOCC		Very low	Low	Moderate	High	Very high	Soil degradation risk	
Large decrease							High	
Moderate decrease							Moderate	
No change							Low	
Moderate increase							Very Low	
Large increase								

In 2021, more than half the cropland in Central and Atlantic Canada could be considered to be at a high risk of degradation (Table 5). In the Prairies, the majority of cropland is considered to be at very low to low risk of soil degradation owing to increases in SOC levels in most years since 1981. In BC, almost half of the cropland is considered to be at very low to low risk of soil degradation with the remainder at a moderate to high risk.

Degradation of soil structure, as reflected in poor soil tilth and infiltration, is likely to be the first sign that SOC levels are lower than desired. The effects of degradation are most noticeable on sandy and clayey soils. Soils with low RSOC have the greatest potential for improvement through the adoption of enhanced management practices that increase SOC levels. In the Prairie provinces, 28% of the land was in the very low and low RSOC classes in 2021, and the majority of this land had increasing SOC levels. Fourteen percent of the land with low to very low RSOC values on the Prairies had decreasing SOC levels.

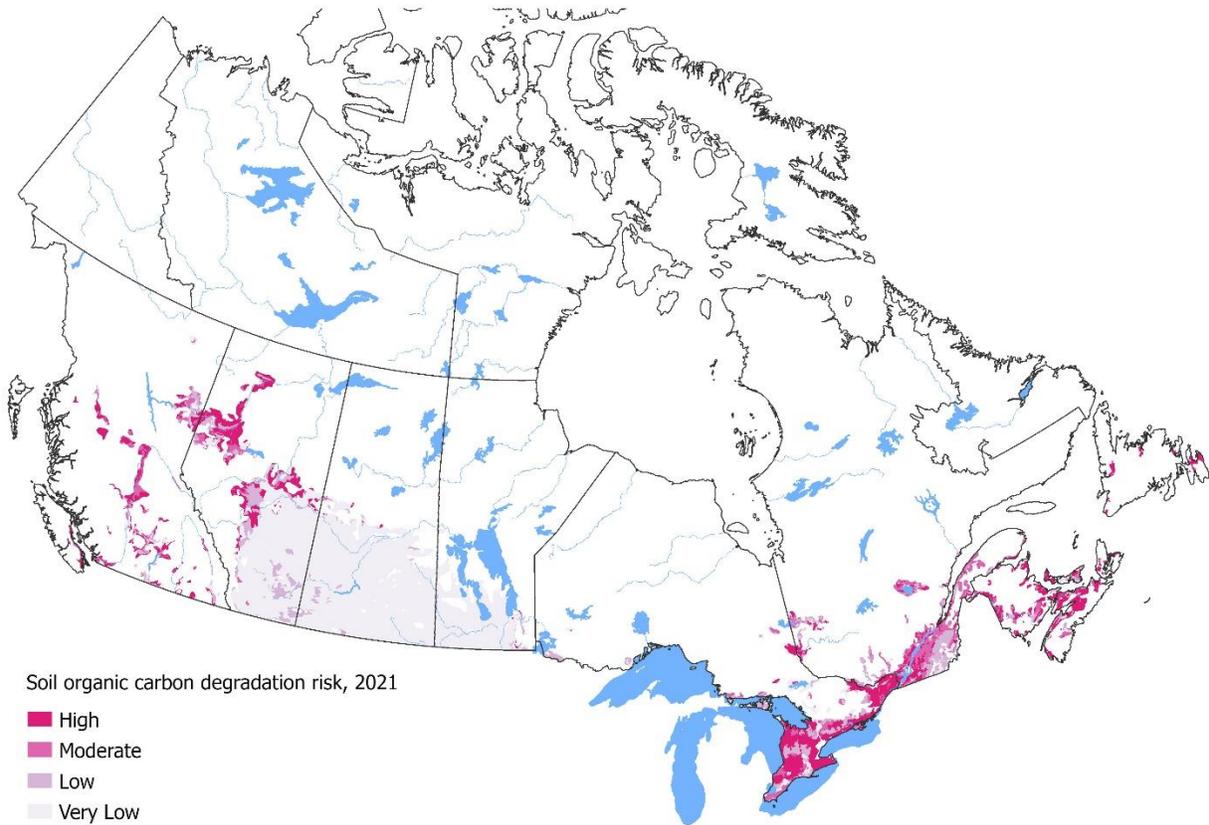
In eastern Canada, the majority of land with high and very high RSOC values is also losing SOC. This situation is not as worrisome from a soil health standpoint as is the loss of SOC combined with low RSOC values. In 2021, 45% and 35% of the land in Central and Atlantic Canada respectively, had low and very low RSOC values and decreasing SOC levels. The loss of SOC from soils with high RSOC values is associated with shifts in farming from a cattle- and forage-based system to grains and **oilseeds**.

**Table 5: Share of land (percentage) in each RSOC class/SOCC combination in 2021 (Note: formatted for a tabloid layout)**

	More than 90 kg ha <sup>-1</sup> yr <sup>-1</sup> RSOC class					25 to 90 kg ha <sup>-1</sup> yr <sup>-1</sup> RSOC class					-25 to 25 kg ha <sup>-1</sup> yr <sup>-1</sup> RSOC class					-25 to -90 kg ha <sup>-1</sup> yr <sup>-1</sup> RSOC class					Loss of more than -90 kg ha <sup>-1</sup> yr <sup>-1</sup> RSOC class				
	Very Low	Low	Mod	High	Very High	Very Low	Low	Mod	High	Very High	Very Low	Low	Mod	High	Very High	Very Low	Low	Mod	High	Very High	Very Low	Low	Mod	High	Very High
BC	1	2	1	2	0	6	2	3	6	1	10	2	6	15	1	14	3	6	2	0	8	3	5	1	0
PRAIRIE	4	15	23	27	5	0	2	4	9	0	1	2	0	3	0	1	2	0	0	0	1	1	0	0	0
AB	0	8	22	20	0	1	3	5	15	0	2	4	1	6	1	2	4	0	0	0	3	2	0	0	0
SK	7	21	26	28	5	0	1	3	7	0	0	0	0	2	0	nil	0	0	nil	nil	0	0	0	nil	nil
MB	1	15	15	43	19	nil	1	2	1	2	0	1	0	0	0	nil	nil	nil	nil	nil	0	0	0	nil	nil
CENTRAL CANADA	0	1	0	0	0	1	2	1	1	0	6	9	1	2	3	12	10	6	2	4	12	11	7	4	5
ON	0	1	1	0	0	1	4	1	1	0	9	13	1	3	0	17	15	5	0	0	11	10	7	0	0
QC	0	0	0	0	0	0	0	1	1	1	0	1	1	1	9	0	1	9	5	10	14	12	8	11	13
ATLANTIC	0	0	0	0	0	0	0	11	nil	0	1	3	13	0	0	6	11	8	2	1	8	10	23	1	1
NB	0	0	0	nil	nil	nil	0	1	nil	nil	nil	1	8	0	0	0	9	9	6	0	1	13	46	3	1
NS	2	1	0	nil	0	1	1	0	nil	0	2	7	2	nil	nil	18	14	6	nil	2	23	15	6	nil	nil
PE	nil	nil	0	0	nil	nil	nil	32	nil	nil	nil	2	27	nil	nil	nil	11	8	nil	nil	nil	2	16	nil	nil
NL	nil	nil	nil	nil	nil	nil	nil	nil	nil	1	nil	nil	nil	nil	nil	nil	2	nil	nil	2	36	49	2	2	6
CANADA	3	13	19	22	4	1	2	3	8	0	2	3	1	3	1	2	3	1	0	0	3	2	1	1	1

**Note:** Row totals may not add up to 100% due to rounding

0 indicates <0.5 % of agricultural land area



**Figure 10: Soil Organic Carbon degradation risk in 2021**

### Response options

Soil health with respect to SOC is generally improving. The adoption of practices such as reduced summerfallow and **reduced tillage** are valuable ways to correct low SOC levels. Some significant declines in SOC have occurred. The decline in SOC in regions east of the Prairies is the inevitable result of the conversion of pastures and hay-land to more intensive annual crops. As this trend has persisted for at least five decades, a continual loss of SOC has occurred.

In cases where low-residue horticultural or root crops are grown on farmland with relatively low SOC levels, it is important to include crops that produce abundant residues in the rotation. Spreading manure on soils with very low SOC is an approach that can increase SOC and improve soil health and productivity quickly.

The clearing of trees and shrubs to add land for farming continues to a limited extent and causes losses of carbon in all provinces. Similarly, conversion of native grassland or long-term perennial hay-land to cropland causes SOC loss and is evident in Alberta and Saskatchewan. The long-term merits of breaking this often marginal land for crops

needs to be considered carefully. Actively planting trees in riparian areas and restoring lost shelterbelts, or incorporating new shelterbelts, are all measures that farmers can implement to increase carbon sequestration and provide other co-benefits such as reduced soil erosion, habitat for pollinators and improved resilience to flooding.

Approaches for managing SOC need to be tailored to the SOC status of the area concerned. In the case of soils with relatively low SOC levels due to past management practices, a comprehensive analysis should be carried out to identify the methods that can be used to increase SOC levels. Slowing or reversing the loss of SOC is particularly important for soils that have low RSOC values. Minimizing erosion is a prerequisite for increasing SOC on these soils. Other suitable methods may include using cover crops, periodic use of perennial forages, incorporation of manure, and reducing tillage. Consideration should also be given to retiring highly eroded marginal lands from crop production entirely.

In soils with relatively high SOC, there is a need to prevent detrimental losses of SOC. Minimizing soil erosion on these soils is the most effective way to maintain SOC levels. Returning crop residues to the soil and having high residue crops in the rotation are also important for maintaining SOC levels.

## Glossary

**Agri-environmental indicator:** A measure of a key environmental condition, risk or change resulting from agriculture; or a measure of management practices used by producers.

**Biomass:** Total mass of a species or group of species per unit area; or the total mass of all the species in a community.

**Carbon (C):** Element present in all materials of biological origin.

**Carbon dioxide (CO<sub>2</sub>):** Major greenhouse gas produced through the decomposition of organic matter in soils under oxidizing conditions; also produced by the burning of fossil fuels. It is one of the three main agricultural greenhouse gases (with CH<sub>4</sub> and N<sub>2</sub>O).

**Conservation tillage:** Any tillage sequence designed to minimize or reduce the loss of soil and water; operationally, a tillage or tillage and planting system that leaves 30% or more crop residue cover on the soil surface.

**Cover crop:** Secondary crop grown after a primary crop or between rows of the primary crop to provide a protective soil cover that will minimize soil erosion and leaching of nutrients.

**Crop residue:** Plant material remaining after harvesting, including leaves, stalks and roots.

**Cropland:** Census of Agriculture category of agricultural land use denoting the total area on which field crops, fruits, vegetables, nursery crops and sod are grown.

**Decomposition:** Breakdown of complex organic matter into simpler materials by micro-organisms.

**Forage:** Grass or legume crop grown to provide livestock feed; may be stored dry as hay or under moist conditions as silage, ploughed into the soil as green manure, or grazed.

**Greenhouse gas (GHG):** Greenhouse gases absorb and trap heat in the atmosphere and cause a warming effect on earth. Some occur naturally in the atmosphere, while others result from human activities. Greenhouse gases include carbon dioxide, water vapour, methane, nitrous oxide, ozone, chlorofluorocarbons, hydrofluorocarbons and perfluorocarbons.

**No-till:** Procedure by which a crop is planted directly into the soil using a special planter, with no primary or secondary tillage after harvest of the previous crop.

**Nutrient:** Substance required by a living organism for proper growth and development. Nitrogen, phosphorus and potassium are key crop nutrients.

**Oilseeds:** Seeds or crops grown mainly for oil, including flaxseed, canola and rapeseed, soybeans, safflower and sunflower seed.

**Perennial forage:** Grasses and legumes that re-grow each spring from the rootstock of plants from the previous growing season.

**Pesticide:** A substance, usually a chemical, that is used to kill or control pests. Pesticides include herbicides, insecticides, fungicides, nematicides, rodenticides and miticides.

**Photosynthesis:** Process by which plants transform carbon dioxide and water into carbohydrates and other compounds using energy from the sun captured by the plants' chlorophyll.

**Reduced tillage:** Tillage operations that involve less soil disturbance than conventional tillage, either through the use of fewer passes or special equipment. Includes minimum tillage.

**Sequestered:** Stored separately. Carbon that is removed from the atmosphere and stored in soil in the form of soil organic matter is said to be sequestered carbon.

**Sink:** In soils, the capacity to assimilate substances and retain them or subsequently provide them as a source for above- and below-ground vegetative growth.

**Soil organic matter:** Carbon-containing material in the soil that derives from living organisms.

**Soil structure:** Physical properties of a soil relating to the arrangements and stability of soil particles, aggregates and pores.

**Steady-state:** A stable condition that does not change over time or in which change in one direction is continually balanced by change in another.

**Summerfallow:** Census of Agriculture category of agricultural land use and general term denoting cropland that is not cropped for at least one year, primarily for the purpose of conserving soil moisture, but is instead managed by cultivating or spraying to control weeds.

**Tame pasture:** Census of Agriculture category of agricultural land use denoting pasture that has been improved by management such as cultivation, drainage, irrigation, fertilization, seeding or spraying. Also referred to as "improved pasture" and "seeded pasture."

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