

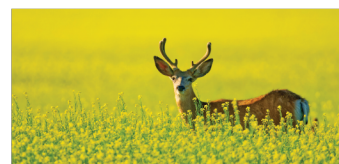


Soil Erosion Risk Indicator

Agri-Environmental Indicators Report

The Environmental Sustainability of Canadian Agriculture

Census Year 2021



Agriculture and
Agri-Food Canada

Agriculture et
Agroalimentaire Canada

Canada

Soil Erosion Risk Indicator

Agri-Environmental Indicators Report, Census Year 2021

Status: National Coverage, 1981-2021

Authors: D.A. Lobb, S. Li, B.G. McConkey and T.C. Martin and L. Eidsness

© His Majesty the King in Right of Canada, represented by the Minister of Agriculture and Agri-Food, 2026

Electronic version available at publications.gc.ca

AAFC no.: 13347E

Catalogue no.: A59-126/2026E-PDF

ISBN: 978-0-660-98499-5

Paru également en français sous le titre : Indicateur de risque d'érosion du sol

See [Agri-environmental indicators - agriculture.canada.ca](https://agriculture.canada.ca) for information on this and other agri-environmental indicators.

For more information, reach us at www.agriculture.canada.ca or call us toll-free at 1-855-773-0241.

Table of Contents

Summary.....	1
The issue and why it matters	2
The indicator	4
Limitations.....	5
Results and interpretation.....	6
Response options	24
Acknowledgments.....	26
Related indicators	26
References	28

List of Figures

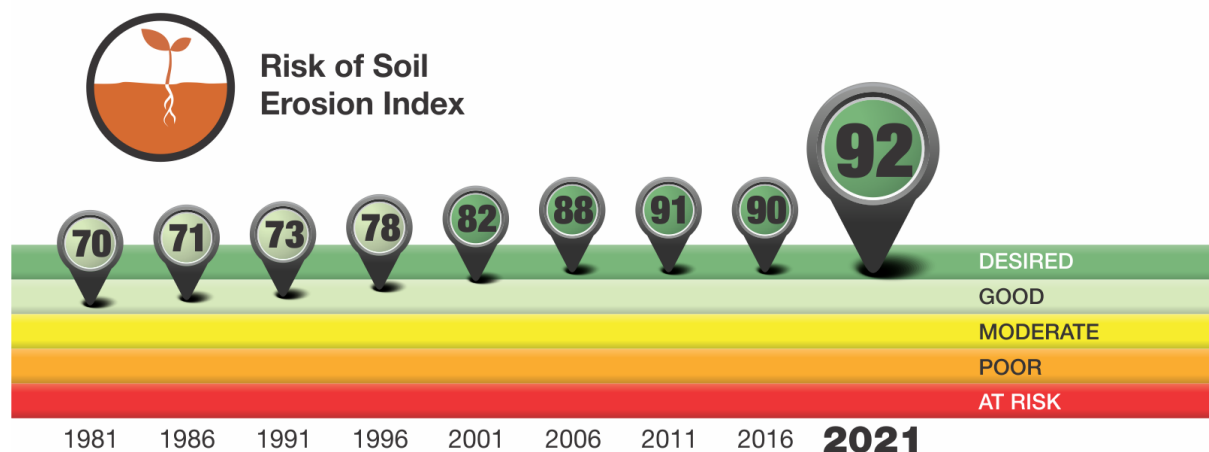
Figure 1: Integrated risk of soil erosion (water, wind and tillage erosion combined) in Canada, 2021.	7
Figure 2: Change in integrated risk of soil erosion (water, wind and tillage erosion combined) in Canada, 1981 to 2021.....	8
Figure 3: Risk of soil erosion by water in Canada, 2021.	9
Figure 4: Risk of soil erosion by wind in Canada, 2021.....	10
Figure 5: Risk of soil erosion by tillage in Canada, 2021.....	11
Figure 6a: Percentage of land undergoing intensive tillage by province and year.	20
Figure 6b: Percentage of land under reduced tillage by province and year.....	21
Figure 6c: Percentage of land undergoing zero tillage by province and year.....	22
Figure 7: Percentage of cropland in summerfallow, by province and year.....	23

List of Tables

Table 1: Percentage of cropland in Canada in overall Soil Erosion (water, wind and tillage erosion combined) risk classes, 1981 to 2021.	12
Table 2: Percentage of cropland in Canada in Water Erosion risk classes, 1981 to 2021.	14
Table 3: Percentage of cropland in Canada in Wind Erosion risk classes, 1981 to 2021.	16
Table 4: Percentage of cropland in Canada in Tillage Erosion risk classes, 1981 to 2021.	18

State and Trend

In 2021, the state of the environment from the standpoint of the risk of soil erosion on farmland in Canada fell within the desired category. The index has been moving upwards, from an index value of 71 in 1981 to a value of 92 in 2021, representing a declining risk of soil erosion across the country. These improvements came about primarily as a result of widespread adoption of conservation tillage, as well as decreases in the use of summerfallow in the Prairie provinces, making soils less vulnerable to the effects of tillage and wind erosion in particular. The index tends to aggregate and generalize trends. Specific findings, regional variations and interpretations are more explicitly discussed in the Results and interpretation section of this chapter.



Summary

Soil erosion—the movement of soil from one area to another, resulting in losses and accumulations—occurs through three main processes: wind, water and tillage erosion. It occurs naturally on cropland through the erosive action of wind and water, erosion that can be accelerated by some farming activities (for example, summerfallow or row cropping). It is also caused directly by tillage, which results in the progressive downslope movement of soil from hilltops to accumulate at the base of hills.

Soil erosion is a major threat to the sustainability of agriculture in Canada. Erosion removes topsoil, reduces soil organic matter and contributes to the breakdown of soil structure. This adversely affects soil fertility, movement of air and water into and from the soil surface, and, ultimately, crop yields and profitability. Yields from severely eroded soil may be substantially lower than those from non-eroded soil in the same

field. Erosion can also have significant adverse environmental and economic impacts off farm through the physical transport and deposition of soil particles and through the release and transport of nutrients, pesticides and pathogens from agricultural lands. Management of the combined effects of wind, water, and tillage erosion is required to maintain soil health.

The Soil Erosion Risk Indicator (SoilERI) is an indicator for the combined risk of water, wind, and tillage erosion when climate, soil, topography, and farming practices are considered. The SoilERI was calculated for each Soil Landscape of Canada (SLC) polygon as the sum of wind, water and tillage erosion rates.

Soil loss from the combined effects of wind, water and tillage decreased in most provinces of Canada between 1981 and 2021. Over that period, the proportion of cropland in the very low risk class increased from 37% to 78%. Much of this change is due to a reduction in wind and tillage erosion in the Prairie provinces. In 2021, 8.6% of cropland remained in the moderate to very high-risk classes, reflecting high levels of water and tillage erosion in other provinces. This slight decreases from 12% in 2016 continues the preceding 35-year trend of decreasing soil erosion risk.

The issue and why it matters

Soil erosion poses a serious threat to the sustainability of agriculture in Canada without the adoption of adequate management practices for erosion control. The loss of soil from current and past management is a major cause of decreased soil health, lower crop productivity, inefficient use of cropping inputs, and increases in risk to water quality through sedimentation, release and transport of nutrients, pesticides and other substances. Soil erosion occurs through three main processes: wind, water, and tillage erosion. The combined effects of wind, water, and tillage erosion pose a more serious threat than individual erosion processes.

Water erosion

Rainfall and runoff are the driving forces behind water erosion. In addition to the degradation caused by the loss of topsoil, eroded soil is carried in runoff to agricultural drains, ditches and other waterways where suspended soil particles increase the turbidity (cloudiness) of the water, add to sediment build-up in the waterways and reservoirs, and deliver nutrients and pesticides that are carried with the eroded soil and runoff into the surface waterways and water bodies.

Wind erosion

Wind erosion is a concern in many areas of Canada, from the sandy soils along the Fraser River in British Columbia to the coastal areas of the Atlantic provinces, but it is the Prairie region that has the greatest potential for wind erosion. This stems from the region's dry climate and vast expanses of cultivated land with little protection from the wind.

Tillage erosion

Many farm implements move soil, and on sloping land this movement is influenced by gravity, which causes more soil to be moved when soil is tilled downslope than when tilled upslope. Even when tilling is done across the slope, more soil will be moved downslope than upslope. The resulting progressive downslope movement of soil from hilltops and soil accumulation at the base of hills is called tillage erosion.

Evidence of tillage erosion is found on hilly land across Canada. This form of erosion is most severe on land that has many short, steep slopes and in areas where intensive cropping and tillage practices are used. Although distinct from wind and water erosion, tillage erosion influences wind and water erosion by exposing the subsoil that is often more sensitive to these erosion processes, and by delivering soil to the areas of the landscape where water erosion is most intense. As such, tillage erosion also contributes to the off-site environmental impacts of soil erosion by wind and water.

Reducing all forms of soil erosion is a challenge, as some practices are effective in reducing soil loss by more than one form of erosion and other practices reduce one form of erosion while increasing another form. Tillage practices that are effective in reducing wind and water erosion are not necessarily effective in reducing tillage erosion. For example, the chisel plough leaves more crop residues on the soil surface than the moldboard plough, providing more protection against wind and water erosion. However, the chisel plough can move soil over a much greater distance and cause more tillage erosion. Shelterbelts and water diversion terraces reduce wind and water erosion, but the addition of any field boundaries or obstacles within a landscape results in more widespread soil losses associated with tillage erosion. High disturbance direct seeding used in some no-till cropping systems can cause as much tillage erosion as the moldboard plough because it moves soil great distances and with great variability. Clearly, management practices to reduce soil erosion require integrated approaches that target the combined effects of soil loss by all forms of erosion.

The indicator

The SoilERI was used to assess the risk of soil erosion from the combined effects of wind, water, and tillage erosion on cultivated agricultural lands. Calculated at the Soil Landscapes of Canada (SLC) polygon scale, this indicator and its component indicators for wind, water and tillage erosion reflect the characteristics of the climate, soil and topography and respond to changes in farming practices over the 40-year period from 1981 to 2021. Reporting takes place with each new Census of Agriculture, with current census data providing the basis for the backward-looking analysis. As such, the farms and lands included in the reported data and used in the analysis vary slightly, reflecting changes in the Canadian agricultural footprint over the years.

Soil erosion was calculated using landform data and the associated soil and topographic data in the National Soil Database. Each SLC polygon is characterized by one or more representative landforms, and each landform is characterized by hillslope segments (upper, mid and lower slopes and depression). Each hillslope segment is characterized by a slope gradient and slope length. Hillslope segment data was revised to better reflect the topographically complex nature of landforms (for example, differences between convergent, divergent and irregular slopes) and the influence of landform on erosion processes.

Soil erosion risk by wind, water and tillage was calculated as soil loss on all segments of a landform. However, soil losses by wind and tillage erosion are greatest on the upper slopes, and soil losses by water erosion are greatest on the mid slopes. The SoilERI was assessed as the cumulative soil loss rate for the slope segment with the greatest rate of loss—since the slope segment with the greatest rate of loss will largely determine changes in management. For analysis and reporting purposes, the erosion rates were summed across areas to SLC polygon, provincial, regional and national levels.

The erosion indicator calculation estimates the average annual rate of soil loss for each census year. These values are reported in five classes: very low (less than 6 tonnes per hectare per year, which can also be expressed as $6 \text{ t ha}^{-1} \text{ yr}^{-1}$), low (6 to 11 $\text{t ha}^{-1} \text{ yr}^{-1}$), moderate (11 to 22 $\text{t ha}^{-1} \text{ yr}^{-1}$), high (22 to 33 $\text{t ha}^{-1} \text{ yr}^{-1}$) and very high (greater than 33 $\text{t ha}^{-1} \text{ yr}^{-1}$). Areas in the very low risk class are considered capable of sustaining long-term crop production and maintaining agri-environmental health under current conditions. The other four classes represent the risk of unsustainable conditions that call for soil conservation practices to support crop production over the long term and to reduce risk to soil health and productivity.

Limitations

Results from the soil erosion indicators, when interpreted at provincial and national scales and over the eight census years, are considered to provide reasonably accurate spatial and temporal trends. However, they are subject to limitations that affect their accuracy and uncertainty. These limitations include the following:

- Soil erosion models estimate current average annual rates of soil loss. They do not provide an assessment of the cumulative level of past soil losses, which impacts crop production and environmental performance. As such, the adoption of no-till represents a dramatic reduction in the current rate of soil loss, but it does not reflect the historical soil erosion and its current impacts.
- Landforms are represented in the National Soil Database by simple, two-dimensional hillslopes. As such, the landform data reflect neither the topographic variety and complexity that exist in real landscapes nor the effect of manmade features such as fence lines, tree lines, roadways, ditches and drainage ways on the slope. For many landforms, these missing data cause overestimates of soil loss by water erosion and underestimates of soil loss by tillage erosion.
- The SoilERI represents the slope position with the greatest soil loss, the upper or mid-slope areas of a landscape. Values are averaged for slope segments of representative landforms; thus, specific areas may be at greater risk than indicated by the risk class assessment.
- The SoilERI is a simple sum of the soil losses by wind, water and tillage erosion; it does not allow for interactions that occur over time among erosion processes.
- Wind and water erosion indicators do not account for some erosion control practices: grassed waterways, strip cropping, terracing, contour tillage and contour cropping, winter cover crops and shelter belts.
- The water erosion indicator does not include gully erosion—the deep-cutting, severe erosion that occurs where runoff concentrates. Water erosion risk should also be considered less accurate for locations in which significant erosion occurs when soils are frozen. In particular, the erosion risk from rainfall occurring on a thawed soil layer overlying frozen soil is likely underestimated.
- The tillage erosion indicator only accounts for soil erosion that occurs along the lengths of hillslopes (the primary or downslope gradient, which defines the slopes used in modeling). It does not include soil erosion that occurs across hillslopes (secondary or cross-slope gradient), and it does not include planning or scalping caused by tillage equipment operated over uneven or irregular slopes.
- Wind erosion may be significant in some years on exposed sandy and peaty soils outside of the Prairie provinces, but these situations were not considered.
- The nature of what constitutes conventional, conservation, and no-till tillage systems has evolved significantly since 1981. Generally, conventional tillage has

become less intensive, and no-till includes some tillage, narrowing the differences in intensity between tillage systems. This is in part due to a broadening of the definition of tillage to include tertiary tillage operations (that is, soil disturbance during seeding through to harvest operations) in addition to primary and secondary tillage operations.

Results and interpretation

The risk of soil erosion on Canadian cropland declined steadily between 1981 and 2011, but increased slightly again in 2016 (Figure 2, Table 1). Most changes and improvement occurred between 1991 and 2006. In 2021, 78% of the cropland area was in the very low risk class versus 38% in 1981, marking a considerable improvement. The slight increase in erosion risk in 2016 and drop again in 2021 suggests that reductions in erosion risk due to ongoing practice change maybe have plateaued. New approaches will be required if we are to see continued reductions in erosion risk in Canada.

The integrated erosion risk indicator results (Figure 1) show a trend that is less positive than the results from the individual component indicators for water, wind and tillage erosion (Figures 3, 4 and 5, respectively), but they better reflect the actual risk of soil degradation by erosion. The improvement in soil erosion risk reflects reduction in wind and tillage erosion risk, with percentage share increases of 13% and 21% in the very low risk class, respectively, compared to a decrease of 1.5% for water erosion (Tables 1, 2, 3 and 4).

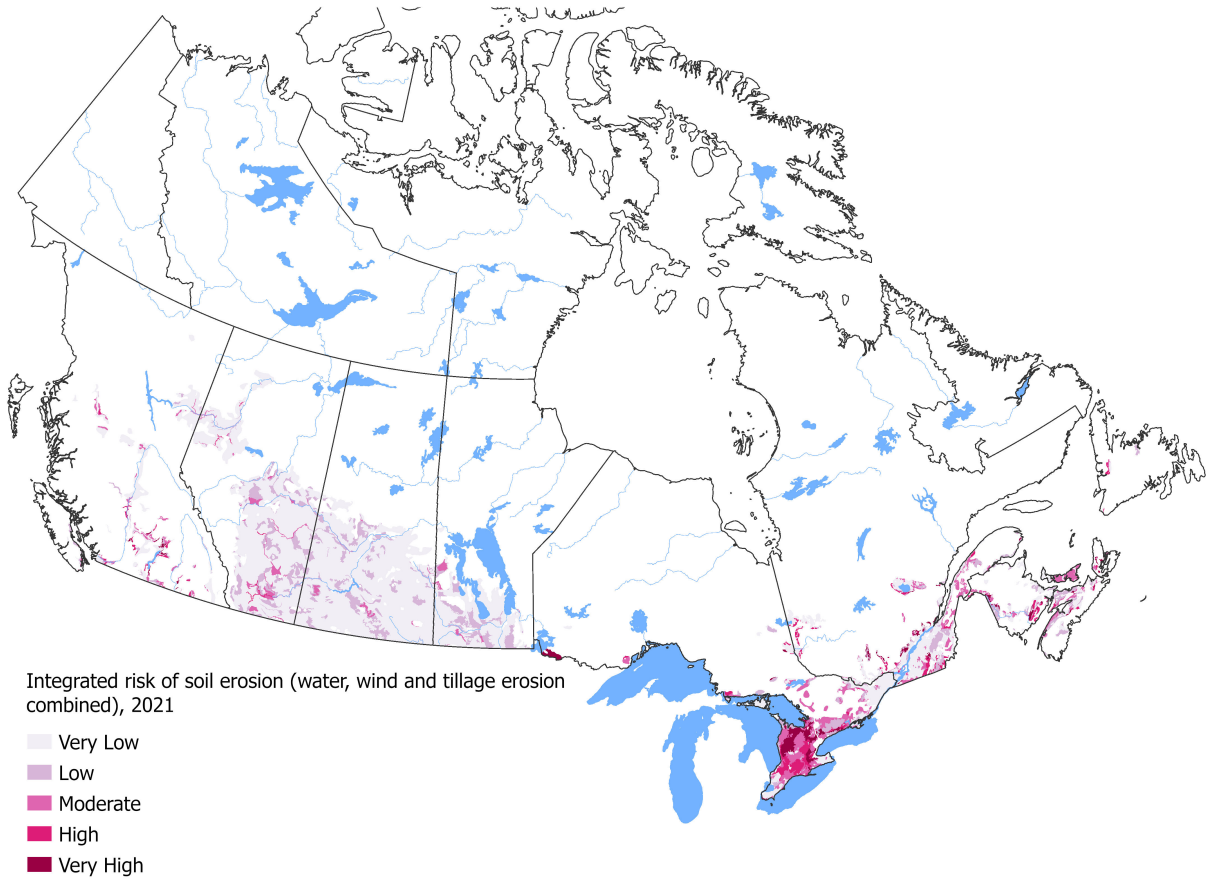


Figure 1: Integrated risk of soil erosion (water, wind and tillage erosion combined) in Canada, 2021.

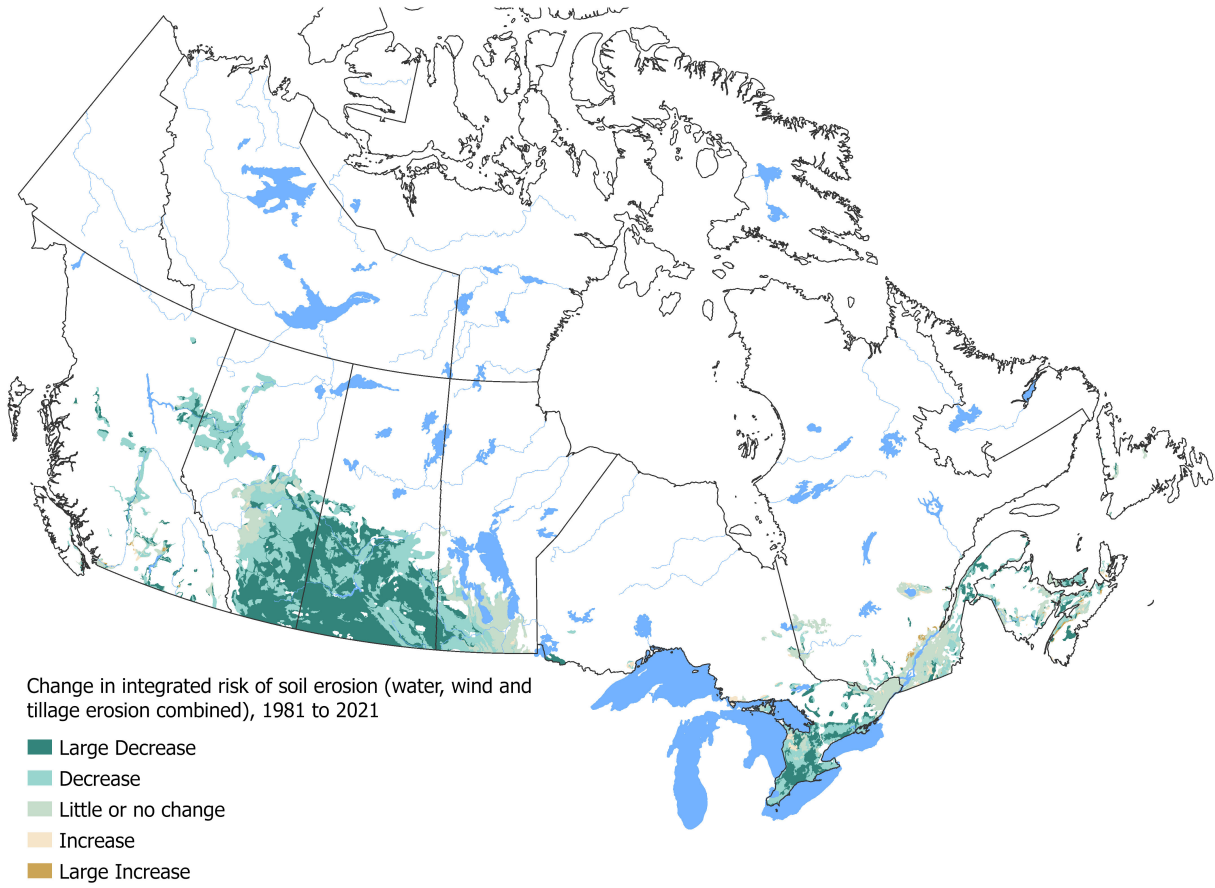


Figure 2: Change in integrated risk of soil erosion (water, wind and tillage erosion combined) in Canada, 1981 to 2021.

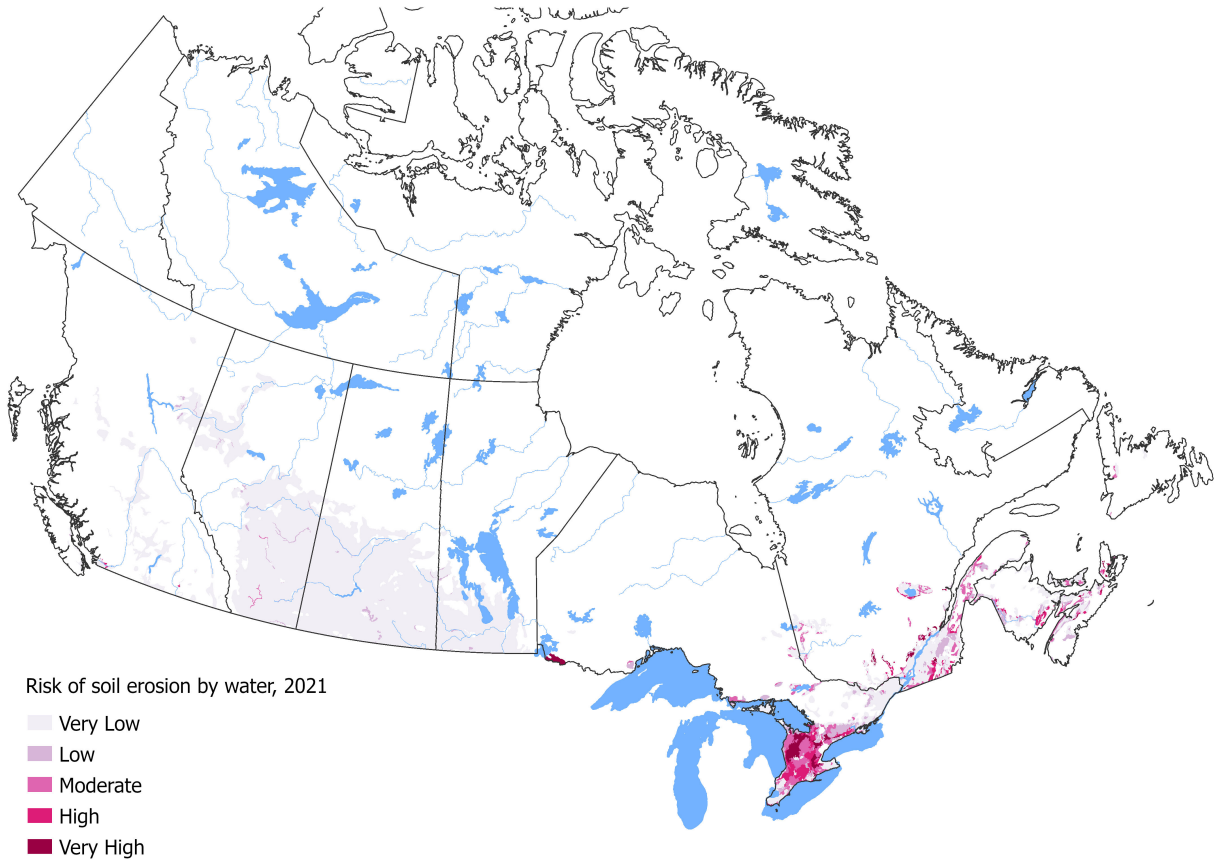


Figure 3: Risk of soil erosion by water in Canada, 2021.

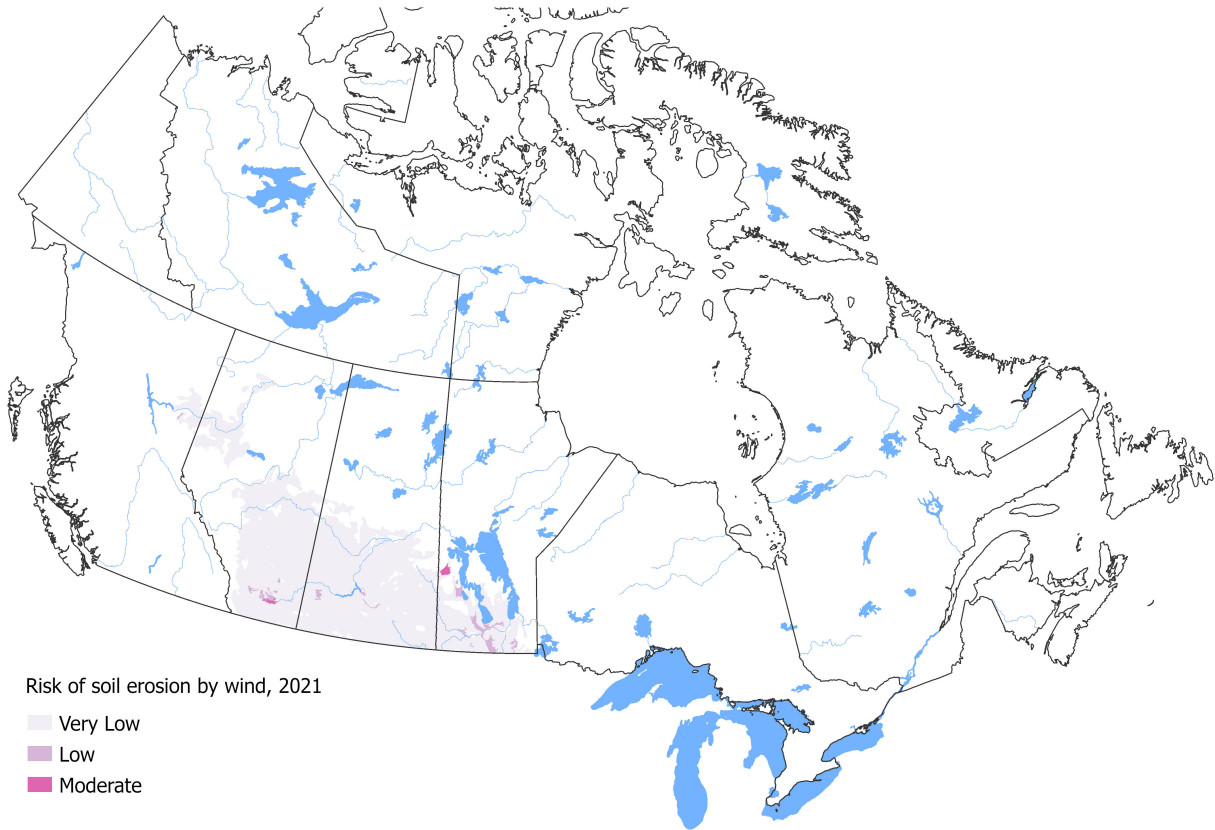


Figure 4: Risk of soil erosion by wind in Canada, 2021.

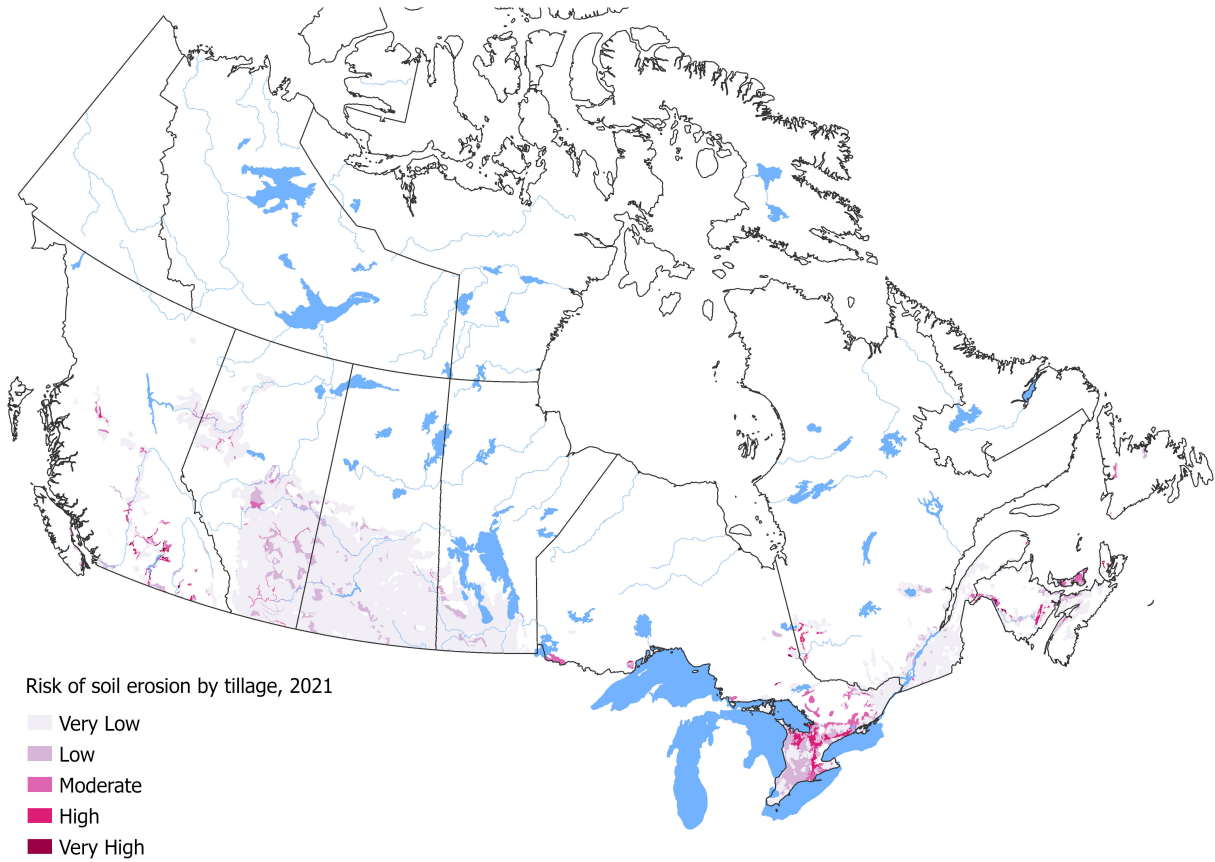


Figure 5: Risk of soil erosion by tillage in Canada, 2021.

Table 1: Percentage of cropland in Canada in overall Soil Erosion (water, wind and tillage erosion combined) risk classes, 1981 to 2021.

Class	Very Low (<6 t/ha/yr)									Low (6 to 11 t/ha/yr)									Moderate (22 to 33 t/ha/yr)								
	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	2021
Alberta	56.6	57.2	57.8	61.4	73.0	80.3	86.1	87.0	86.4	14.6	14.4	17.7	20.1	13.9	10.5	10.3	10.1	10.8	18.8	18.0	14.9	10.6	11.8	8.5	3.3	2.3	2.2
British Columbia	47.0	46.6	51.1	65.3	75.3	77.1	85.7	85.6	82.5	40.1	41.2	37.8	24.8	18.8	17.2	8.9	8.6	9.9	8.3	7.7	6.0	5.5	1.6	1.5	2.1	2.6	5.0
Manitoba	50.1	49.3	53.8	54.1	55.2	53.1	68.1	51.1	74.2	29.3	31.6	30.8	31.9	30.2	41.2	22.5	37.4	21.0	19.5	18.1	14.6	13.2	13.8	5.3	8.9	11.0	4.9
New Brunswick	41.4	45.3	42.9	44.5	43.9	44.2	40.8	40.2	34.4	33.8	29.5	31.4	31.4	31.3	31.4	35.9	37.3	42.2	7.3	7.3	8.5	6.3	7.1	9.0	12.7	12.0	8.7
Newfoundland and Labrador	33.6	29.2	27.1	38.8	37.0	40.3	34.7	34.3	27.3	10.4	9.9	10.4	10.7	7.2	3.8	4.4	21.8	7.9	13.9	32.9	43.8	34.3	36.2	34.8	41.3	22.5	50.0
Nova Scotia	20.8	25.2	33.3	35.3	37.3	41.2	46.5	41.7	34.5	39.2	46.5	42.0	43.5	43.8	46.3	35.5	39.4	42.0	34.7	24.1	18.2	18.0	16.4	10.0	15.8	17.0	19.9
Ontario	24.1	26.6	23.1	28.3	28.7	29.5	28.7	28.4	28.4	8.6	6.4	11.4	10.6	11.3	12.8	14.4	10.9	10.8	21.7	23.6	23.4	23.3	22.2	28.2	28.6	28.6	30.7
Prince Edward Island	18.2	18.8	19.0	19.2	19.5	19.8	20.1	20.3	25.4	4.3	4.4	4.3	4.2	4.1	4.2	4.0	4.1	0.1	65.8	64.6	65.3	64.6	72.2	75.9	75.9	75.5	74.6
Quebec	73.8	75.4	75.4	73.0	70.8	74.2	75.2	74.0	75.5	11.1	11.1	11.1	13.6	12.2	10.8	11.6	11.3	11.2	10.3	9.8	9.6	10.5	11.8	10.5	9.8	10.3	8.9
Saskatchewan	22.6	26.3	29.9	47.5	57.8	68.9	77.5	80.0	86.7	38.8	37.1	35.6	20.1	16.9	25.7	20.7	18.6	12.5	25.9	28.9	28.6	27.9	23.7	5.3	1.8	1.4	0.8
Canada	37.7	39.9	41.9	51.5	59.6	66.4	73.6	72.9	78.4	27.2	26.5	27.1	20.5	17.1	21.5	16.8	17.5	12.9	22.0	23.1	21.7	20.1	18.4	8.8	6.5	6.2	5.3

Class	High (22 to 33 t/ha/yr)									Very High (>33 t/ha/yr)								
	1981	1986	1991	1996	2001	2006	2011	2016	2021	1981	1986	1991	1996	2001	2006	2011	2016	2021
Alberta	6.4	8.1	8.1	6.8	0.6	0.5	0.3	0.5	0.6	3.6	2.4	1.6	1.1	0.7	0.2	0.0	0.0	0.0
British Columbia	1.2	0.7	1.4	1.1	0.7	0.8	0.4	2.4	1.9	3.4	3.8	3.7	3.3	3.6	3.5	2.9	0.7	0.6
Manitoba	0.6	0.6	0.5	0.7	0.8	0.4	0.4	0.4	0.0	0.5	0.4	0.4	0.2	0.0	0.0	0.0	0.0	0.0
New Brunswick	7.1	7.3	8.7	9.7	8.2	7.4	3.0	2.9	5.2	10.4	10.6	8.5	8.2	9.5	7.9	7.6	7.6	9.4
Newfoundland and Labrador	31.4	12.4	9.8	9.5	9.3	5.9	18.6	20.3	13.0	10.8	15.6	8.9	6.7	10.3	15.2	1.0	1.1	1.8
Nova Scotia	3.7	3.4	5.4	2.7	1.5	1.9	1.3	1.6	1.2	1.6	0.8	1.1	0.5	1.0	0.5	0.8	0.3	2.4
Ontario	21.0	19.6	18.4	21.9	22.7	17.3	15.4	17.4	16.3	24.6	23.8	23.6	15.8	15.2	12.3	12.9	14.7	13.8
Prince Edward Island	11.7	12.2	11.5	12.0	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Quebec	2.7	2.0	2.0	1.3	3.3	3.0	1.7	2.8	2.8	2.0	1.6	1.8	1.6	1.8	1.5	1.6	1.6	1.6
Saskatchewan	8.2	3.8	2.8	4.1	1.5	0.0	0.0	0.0	0.0	4.5	3.8	3.1	0.4	0.1	0.0	0.0	0.0	0.0
Canada	7.6	5.9	5.3	5.8	3.2	2.0	1.7	2.0	1.9	5.5	4.6	4.0	2.0	1.8	1.3	1.4	1.5	1.4

Table 2: Percentage of cropland in Canada in Water Erosion risk classes, 1981 to 2021.

Class	Very Low (<6 t/ha/yr)									Low (6 to 11 t/ha/yr)									Moderate (22 to 33 t/ha/yr)								
	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	2021
Alberta	97.1	98.0	98.0	97.9	98.4	98.6	99.2	99.2	99.2	2.2	1.3	1.3	1.4	0.9	0.8	0.3	0.2	0.3	0.4	0.3	0.5	0.7	0.6	0.6	0.5	0.5	0.5
British Columbia	98.7	98.5	99.1	99.0	99.5	99.6	99.5	99.5	99.2	0.9	1.1	0.3	0.7	0.5	0.4	0.5	0.5	0.8	0.4	0.3	0.5	0.3	0.0	0.0	0.0	0.0	0.0
Manitoba	98.6	98.6	98.9	98.9	98.9	99.3	98.8	98.5	98.5	0.9	0.9	0.6	0.9	0.9	0.6	1.1	1.2	1.2	0.5	0.5	0.5	0.3	0.3	0.1	0.1	0.3	0.3
New Brunswick	62.5	64.7	64.5	61.5	60.5	61.1	55.6	57.5	48.0	23.3	20.9	21.8	25.2	25.2	24.9	30.8	28.7	37.6	8.9	9.1	9.3	9.2	9.7	8.6	8.4	9.0	7.9
Newfoundland and Labrador	76.1	77.2	74.7	78.1	75.1	74.2	76.9	75.4	85.2	0.6	0.0	2.5	3.2	1.6	5.2	5.9	3.2	0.0	6.1	10.7	11.3	14.3	11.8	12.6	6.5	12.9	13.0
Nova Scotia	56.3	61.2	67.0	74.0	75.0	77.8	77.7	75.7	70.5	24.1	24.3	18.2	13.4	14.8	14.1	13.7	15.2	16.9	14.4	10.3	8.2	9.4	7.7	5.6	6.4	7.2	9.1
Ontario	30.3	31.1	27.3	33.3	34.0	35.9	33.7	32.2	32.2	11.4	10.6	16.9	12.6	11.5	12.6	13.0	12.9	13.1	17.6	18.5	16.8	17.5	17.7	24.5	27.1	23.7	25.7
Prince Edward Island	35.7	40.0	60.3	67.4	72.9	83.9	76.3	71.8	87.4	52.6	47.8	28.2	20.6	15.6	4.6	11.4	16.0	0.4	0.0	0.0	0.0	0.0	7.3	11.5	12.3	12.2	12.2
Quebec	79.0	80.5	80.6	78.1	75.2	78.8	79.8	78.1	80.2	9.1	8.5	8.7	11.0	12.3	9.0	9.2	9.5	8.7	7.9	8.0	7.4	8.7	8.1	8.4	8.2	8.7	7.2
Saskatchewan	97.4	97.5	97.5	98.2	98.3	99.1	99.3	99.3	99.4	1.9	1.8	1.8	1.5	1.4	0.9	0.7	0.6	0.6	0.7	0.7	0.7	0.4	0.3	0.0	0.0	0.0	0.0
Canada	90.2	91.1	91.1	91.5	91.5	91.9	91.7	91.7	91.7	3.3	2.9	3.2	2.9	2.7	2.4	2.4	2.3	2.3	2.5	2.4	2.3	2.3	2.3	2.9	3.2	2.9	3.1

Class	High (22 to 33 t/ha/yr)									Very High (>33 t/ha/yr)								
	1981	1986	1991	1996	2001	2006	2011	2016	2021	1981	1986	1991	1996	2001	2006	2011	2016	2021
Alberta	0.2	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
British Columbia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Manitoba	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
New Brunswick	5.1	5.0	3.8	3.8	3.6	5.1	4.6	4.4	5.9	0.2	0.2	0.6	0.3	1.0	0.4	0.6	0.3	0.6
Newfoundland and Labrador	15.0	7.7	9.9	3.6	11.5	0.0	10.2	7.4	0.0	2.3	4.5	1.6	0.8	0.0	8.0	0.6	1.1	1.8
Nova Scotia	3.6	3.4	5.6	2.7	1.6	2.0	1.3	1.5	1.2	1.6	0.8	1.0	0.5	0.9	0.5	0.8	0.3	2.4
Ontario	19.3	18.5	18.2	24.2	25.0	16.5	15.9	18.8	17.2	21.2	21.3	20.8	12.4	11.9	10.5	10.4	12.4	11.7
Prince Edward Island	11.7	12.2	11.5	12.0	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Quebec	2.2	1.4	1.6	0.6	2.7	2.4	1.3	2.2	2.3	1.8	1.5	1.6	1.6	1.8	1.5	1.5	1.5	1.6
Saskatchewan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Canada	2.0	1.8	1.7	2.2	2.4	1.7	1.6	1.9	1.8	2.0	1.9	1.8	1.1	1.1	1.0	1.1	1.2	1.2

Table 3: Percentage of cropland in Canada in Wind Erosion risk classes, 1981 to 2021.

Class	Very Low (<6 t/ha/yr)									Low (6 to 11 t/ha/yr)									Moderate (22 to 33 t/ha/yr)								
	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	2021
Alberta	83.1	83.3	88.2	91.3	95.2	96.5	98.1	98.3	98.6	12.0	10.6	7.7	5.0	3.6	2.4	1.4	1.4	1.1	3.7	4.9	3.1	3.0	1.3	1.1	0.5	0.3	0.2
British Columbia	99.7	99.6	100.0	100.0	100.0	100.0	100.0	99.9	99.9	0.3	0.4	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Manitoba	82.3	83.3	87.1	87.1	87.5	88.7	87.3	85.2	88.9	13.8	13.9	10.5	10.9	10.7	9.6	9.9	12.1	9.3	3.9	2.8	2.4	2.1	1.8	1.6	2.7	2.6	1.8
New Brunswick	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Newfoundland and Labrador	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nova Scotia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ontario	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Prince Edward Island	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Quebec	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Saskatchewan	86.3	87.5	89.0	93.3	96.1	99.0	99.5	99.5	99.7	10.9	10.1	9.5	5.9	3.5	1.0	0.5	0.5	0.3	2.5	2.2	1.4	0.8	0.4	0.1	0.0	0.0	0.0
Canada	84.9	85.7	88.6	91.8	94.6	96.7	97.4	97.3	97.9	11.6	10.7	9.0	6.3	4.5	2.6	2.1	2.3	1.8	3.0	3.1	2.1	1.7	0.9	0.6	0.5	0.4	0.3

Class	High (22 to 33 t/ha/yr)									Very High (>33 t/ha/yr)								
	1981	1986	1991	1996	2001	2006	2011	2016	2021	1981	1986	1991	1996	2001	2006	2011	2016	2021
Alberta	0.9	0.8	1.0	0.8	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
British Columbia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Manitoba	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
New Brunswick	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Newfoundland and Labrador	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nova Scotia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ontario	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Prince Edward Island	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Quebec	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Saskatchewan	0.2	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Canada	0.4	0.4	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 4: Percentage of cropland in Canada in Tillage Erosion risk classes, 1981 to 2021.

Class	Very Low (<6 t/ha/yr)									Low (6 to 11 t/ha/yr)									Moderate (22 to 33 t/ha/yr)								
	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	2021
Alberta	73.6	73.9	74.2	76.8	84.6	87.7	92.1	93.4	92.1	13.8	13.5	13.2	10.9	6.9	7.9	6.4	5.5	6.8	6.3	6.5	6.5	8.3	7.7	3.7	1.4	1.1	1.1
British Columbia	55.2	56.7	58.9	75.8	77.7	79.1	85.9	86.9	85.6	33.3	32.9	30.8	14.0	16.3	15.0	8.7	7.8	9.5	6.7	5.8	5.2	5.9	1.6	1.5	1.9	2.0	2.3
Manitoba	75.5	75.2	75.2	75.4	89.3	90.4	93.5	92.6	93.9	15.2	15.2	15.4	15.2	5.2	7.4	4.3	5.4	5.0	8.5	8.8	8.6	8.7	5.5	2.2	2.2	2.0	1.1
New Brunswick	56.4	65.9	65.0	68.3	66.2	66.7	72.0	72.0	69.0	22.8	12.4	13.7	11.9	13.2	13.5	10.5	10.8	12.3	4.3	4.8	5.2	7.0	3.2	9.8	9.4	8.4	5.7
Newfoundland and Labrador	54.6	55.4	51.6	63.8	63.5	63.2	58.3	59.1	36.5	8.8	9.2	9.1	7.0	17.7	1.9	5.5	13.3	9.6	13.1	28.6	29.3	22.6	12.2	22.5	28.7	23.8	52.4
Nova Scotia	59.4	60.6	60.9	59.9	63.1	66.1	77.6	75.4	62.3	30.1	33.1	31.2	33.5	31.5	31.7	15.9	19.2	30.8	10.1	5.9	7.4	6.3	5.3	1.9	6.2	5.1	6.4
Ontario	41.6	41.7	42.3	44.3	47.9	48.7	48.5	47.9	48.4	8.1	9.0	12.4	22.1	26.9	37.0	38.9	38.1	36.6	38.2	37.6	35.2	24.7	16.9	6.3	5.0	5.9	6.6
Prince Edward Island	22.3	23.0	23.2	23.3	23.6	31.9	24.0	32.8	34.0	12.7	13.2	12.4	12.9	12.4	4.5	13.3	4.8	11.2	65.1	63.8	64.4	63.7	64.0	63.6	62.7	62.4	54.8
Quebec	87.5	88.7	88.8	89.1	89.0	89.7	91.1	90.8	93.0	9.0	7.7	7.7	7.3	6.9	7.3	6.0	7.4	5.5	2.7	2.8	2.9	3.3	3.4	2.3	2.8	1.3	1.1
Saskatchewan	64.7	64.4	64.4	66.8	71.2	75.1	88.9	91.0	93.3	7.3	7.5	7.4	5.9	19.4	23.1	11.0	9.0	6.6	23.5	23.6	23.8	25.0	9.3	1.8	0.1	0.1	0.0
Canada	67.0	67.1	67.3	69.5	75.6	78.5	86.2	87.5	88.4	10.6	10.6	10.7	10.0	14.3	17.4	11.3	10.2	9.3	17.4	17.2	17.2	17.4	8.9	3.1	1.6	1.5	1.4

Class	High (22 to 33 t/ha/yr)									Very High (>33 t/ha/yr)								
	1981	1986	1991	1996	2001	2006	2011	2016	2021	1981	1986	1991	1996	2001	2006	2011	2016	2021
Alberta	5.6	5.5	5.4	3.3	0.2	0.6	0.1	0.0	0.1	0.7	0.7	0.7	0.7	0.5	0.1	0.0	0.0	0.0
British Columbia	1.3	0.6	1.3	0.8	0.7	1.1	0.5	2.5	2.0	3.6	4.0	3.8	3.4	3.7	3.4	3.0	0.8	0.7
Manitoba	0.8	0.8	0.8	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
New Brunswick	9.0	10.1	9.4	6.2	10.4	3.5	1.5	2.9	5.7	7.5	6.8	6.7	6.6	7.0	6.5	6.6	5.9	7.3
Newfoundland and Labrador	17.3	3.7	9.6	2.6	6.5	8.0	7.2	3.8	1.5	6.2	3.1	0.3	3.9	0.2	4.3	0.2	0.0	0.0
Nova Scotia	0.2	0.1	0.1	0.1	0.0	0.0	0.1	0.0	0.0	0.2	0.3	0.3	0.2	0.1	0.2	0.2	0.3	0.5
Ontario	3.5	4.2	4.1	5.0	6.3	6.6	6.9	6.7	8.4	8.7	7.5	6.1	3.9	2.0	1.3	0.8	1.5	0.1
Prince Edward Island	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Quebec	0.7	0.7	0.6	0.2	0.7	0.7	0.1	0.5	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Saskatchewan	3.6	4.5	4.4	2.2	0.1	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Canada	3.6	4.1	4.0	2.5	0.8	0.8	0.7	0.7	0.9	1.4	0.9	0.8	0.6	0.4	0.2	0.1	0.2	0.0

The decrease in all forms of erosion across Canada has been largely attributable to the widespread adoption of conservation tillage, particularly no-till systems, which increased from less than 2% to 30% of cropland between 1981 and 2021. No-till is now the most common tillage practice used for cereal crops in the Prairies, in particular Saskatchewan (76%) and Alberta (66%) (Figure 6), which account for the majority of Canada's total agricultural land. Changes in soil erosion from the ratio of crops grown were less of a contributing factor. Crops normally produced using more intensive tillage (increasing the risk of erosion) such as corn, potatoes and beans increased in area from 5% of cropland in 1981 to 22% in 2021. This uptrend was offset by a decrease in summerfallow (a practice which increased erosion risk), from 13% in 1981 to less than 1% in 2021 (Figure 7). Although most crops have seen a reduction in tillage intensity, the adoption of no-till in cereals has had the greatest influence on soil erosion owing to the large share of cropland devoted to cereals.

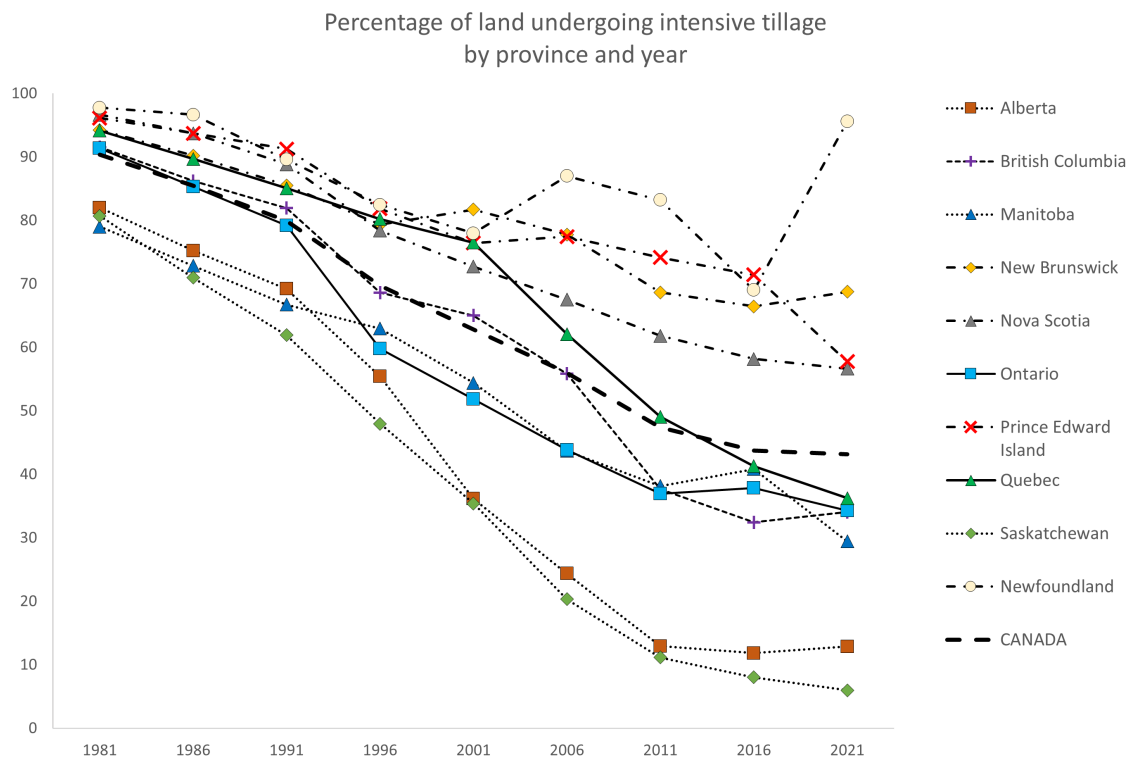


Figure 6a: Percentage of land undergoing intensive tillage by province and year.

Among the cropping systems found across Canada, the highest risk of soil erosion is associated with potato production in the Atlantic Maritimes, which requires intensive tillage and is not conducive to the adoption of conservation tillage practices. The cropping system that presents the next highest risk of erosion is corn and soybeans produced with conventional tillage. However, in this case there is considerable potential

to reduce the erosion risk through conservation tillage. On landscapes across Canada, the highest risk of soil erosion is associated with slopes of 10% or more, especially in

Eastern Canada, where there is an inherently high risk of water erosion owing to the climatic conditions. Soil erosion is of particular concern in situations where cropping systems involving a high erosion risk are paired with soil landscapes with high erosion risks. This is the case for a significant proportion of the cropland in southern Ontario and in Atlantic Canada. However, there are areas in every province that present risks of unsustainable soil erosion, including the steep slopes of the Hand Hills region of southern Alberta, the very dry and loamy soils of windy southern Saskatchewan, and the steep slopes along the Manitoba escarpment.

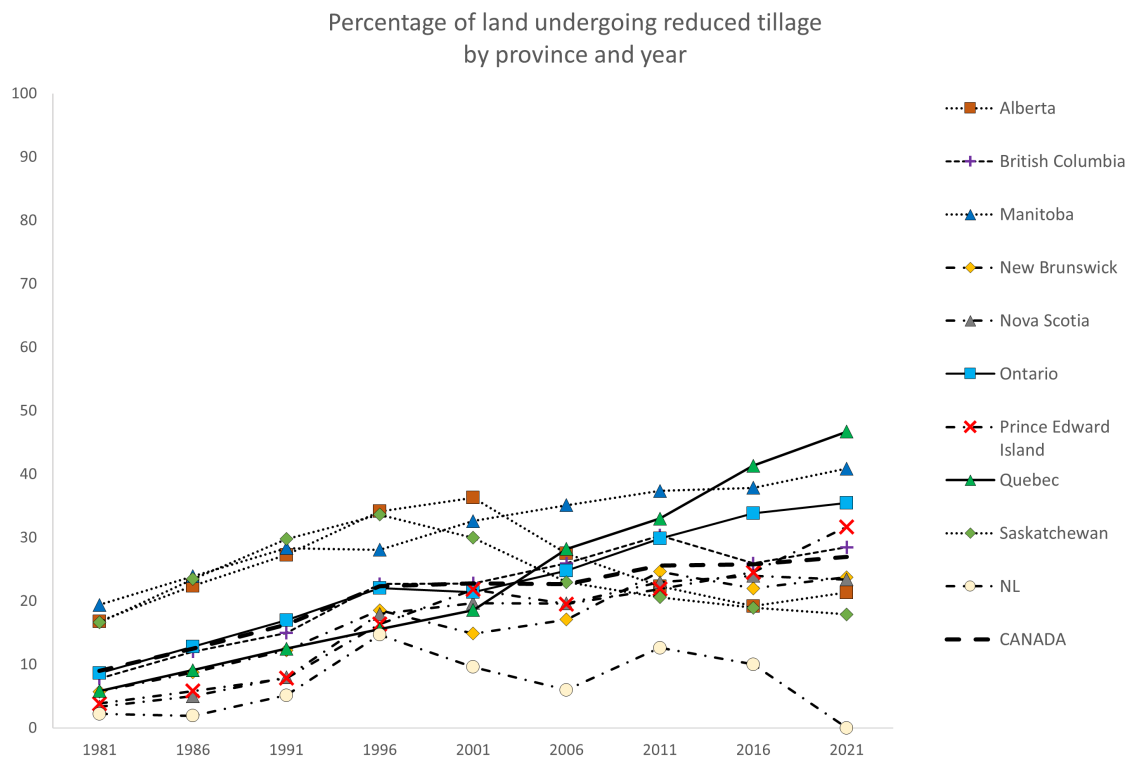


Figure 6b: Percentage of land under reduced tillage by province and year.

Percentage of land undergoing zero tillage, by province and year

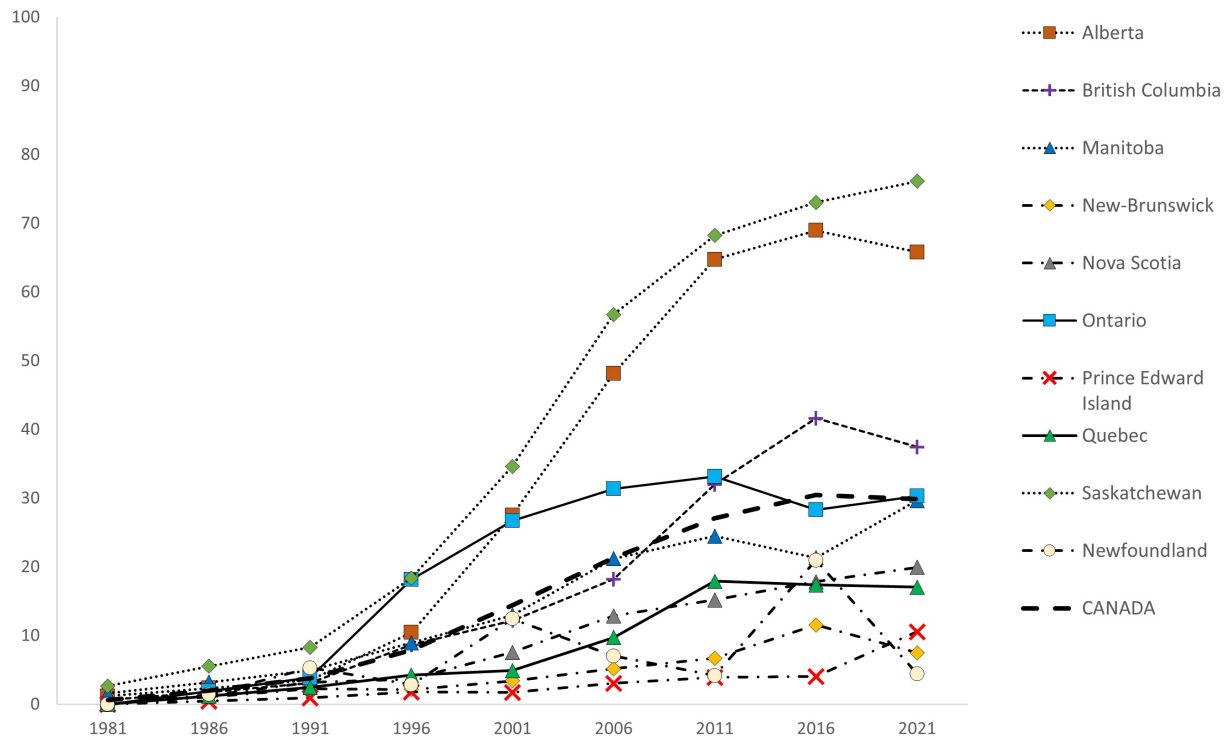


Figure 6c: Percentage of land undergoing zero tillage by province and year.

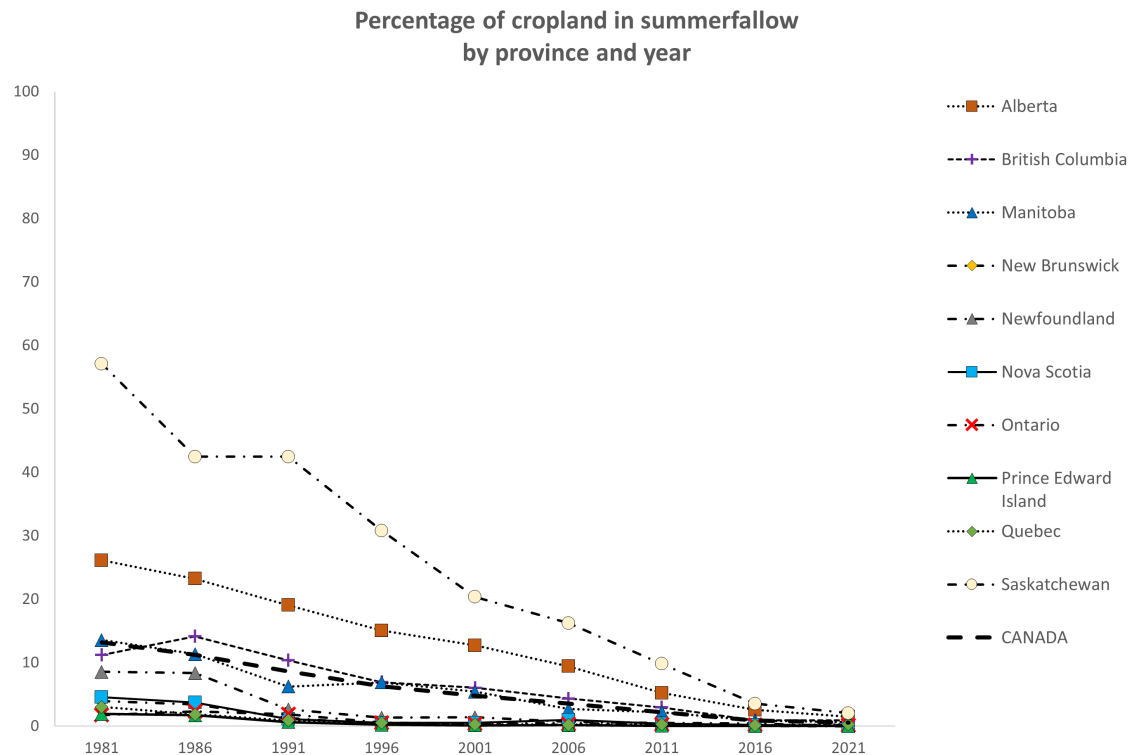


Figure 7: Percentage of cropland in summerfallow, by province and year.

Economic impact

Reductions in the productivity of historically eroded soils have a significant economic impact. A study was conducted to estimate these impacts by combining SoilERI model results with a model of the response of soil organic carbon to soil loss and a model of the response of crop yield to soil organic carbon content. The cost of soil erosion, simply in terms of lost crop yield (expressed in 2021 dollar values), increased from \$1B per year in 1971 to \$3B per year in 2011. This represents 7% of the total value of crop production in 1971 and 10% in 2011 (Badreldin and Lobb, 2019). Similar work in the corn-belt region of the midwestern United States estimated annual economic losses of \$US2.8B due to tillage erosion (Thaler et al., 2021).

Though the annual erosion rate has been decreasing in Canada, the annual impact of erosion on productivity is cumulative, and thus the annual economic impact has continued to increase over time. This effect is compounded by market value increases and by the introduction of higher yielding varieties of crops. Annual economic losses will continue until the eroded soil is restored and can be expected to continue to increase with each additional year of erosion.

Response options

An integrated approach is needed to reduce the combined effects of soil loss to sustainable levels by all forms of erosion. This is critical to maintaining soil health. While there are many practices that farmers can implement to reduce soil erosion, the appropriateness of a practice depends upon the type of the farming system, the climate and characteristics of the land, such as soil texture and whether the land is level or hilly. In general, all forms of soil erosion can be reduced by using less intensive tillage. This reduces the amount and extent of soil movement and, therefore, reduces tillage erosion. It also reduces the degree of incorporation of crop residue, an effective protection measure against the erosive forces of wind and water.

Water erosion

Water erosion can be controlled by improving the soil's structure and protecting the soil against the impact of rainfall and flowing water, and by managing the land to reduce the amount and erosiveness of flowing water. Management practices that aid in controlling water erosion include:

- using conservation tillage, including forages in rotations,
- planting row crops across the slope,
- strip cropping,
- inter-seeding row crops with other crops, and
- growing cover crops.

More research needs to be done on alternatives to no-till for areas where this practice is not viable, such as areas of intensive horticultural or potato production. Where water erosion is very high, conservation tillage and cropping systems might be inadequate to control erosion and run-off. In these areas alternative practices to control erosion include establishing terraces, or steps, to reduce slope steepness and length, establishing permanent small earthen berms or diversions running along the contours and converting back into perennial cover (for example, forages and trees) in the most sensitive areas. Addressing gully erosion usually requires engineering solutions such as constructing grassed waterways or, where grassed waterways would be inadequate, installing erosion control structures. In areas of higher precipitation and inherently greater risk of water erosion, low residue or high soil exposure crops such as potato, horticulture and row crops (corn and soybean) are particularly prone to water erosion and need to be targeted for policy and conservation programs to reduce that risk.

Wind erosion

Wind erosion is most effectively controlled by keeping the soil covered with crops and crop residues in all areas of the country. In the Prairies, soils with surface textures of loamy sand and sand have the greatest inherent erosion risk and planting perennial forages is the most practical response option. For sandy loam soils in this region, forages are also appropriate. If sandy loam soils are cropped to annual crops, complete no-till is necessary to achieve very low erosion risk. Windbreaks should also be considered for these soils. For other soil textures, conservation tillage or no-till are sensible ways to reduce erosion risk. Applying solid manure will also help control erosion.

Following potatoes and sugar beets, crop residue management is essential to protecting the soil. Planting a cover crop of spring or winter cereals can help control wind erosion, but on the Prairies, where wind erosion is of greatest risk, the cover crop will consume valuable water needed for the primary crops. This leaves crop residue management, windbreaks and solid manure application the only viable solutions for wind erosion control where water availability is a limiting factor.

Tillage erosion

Tillage erosion is controlled by modifying tillage practices. Only by eliminating tillage can this form of erosion be completely stopped. Using no-till practices to grow crops or growing crops (such as forage) that require no tillage are the most effective means of reducing tillage erosion. However, even no-till seeding and fertilizer injection can cause significant levels of soil disturbance and tillage erosion. Many cropping systems, such as potato production, will always entail some form of soil disturbance, leading to soil movement and tillage erosion. In these production systems, it is important to select tillage implements and carry out tillage operations in a way that minimizes tillage erosion. Implements that move less soil and move it over a shorter distance will generate less tillage erosion. Also, more uniform speed and depth of operation will lessen tillage erosion. In landscapes where contour tillage is practical, this approach may result in less tillage erosion than tilling up and down hillslopes, particularly if greater uniformity of tillage depth and speed can be achieved by tilling along the contours. With contour tillage, the rollover moldboard plough can be used as a conservation tool when the furrow is thrown upslope. The upslope movement of soil by the mold-board plough may offset the downslope movement by other tillage operations. Efforts to reduce tillage erosion should be focused on landscapes that are hilly and therefore more susceptible to such erosion.

Soil landscape restorations

Reducing or stopping soil erosion does not immediately restore soil health and productivity. The impact of erosion on the agricultural landscape is cumulative, so even a low annual rate of erosion, after years, can continue to reduce productivity. It can take decades to centuries to return a moderately to severely eroded soil to a productive and profitable state, because biomass accumulation (for example, crop residue, soil organic matter) is the driving process of soil restoration, and the eroded soils have reduced rates of biomass production precisely because they are eroded.

One practice that farmers use to quickly improve eroded soils is the collection of organic-rich topsoil from the base of the hills where it has accumulated through historical tillage erosion, and its placement on the upslope areas of severe soil loss. This practice is referred to as soil-landscape restoration, and it has great potential impacts on hilly lands that have been eroded by tillage erosion. A recent Farm Environmental Management Survey (FEMS) reports 7% of farmers surveyed across Canada use some form of this practice (Statistics Canada, 2021). Research into this practice has demonstrated dramatic improvements in Minnesota and the Dakotas, with yield increases of 20% to 50% and biomass production increases up to 95% (Schneider et al., 2021; Papiernik et al., 2009). Canadian research into this practice is ongoing.

Acknowledgments

Several individuals contributed to the production of this document. Bob MacMillan, Scott Smith, Walter Fraser, Tony Brierley and Alan Moulin contributed to the development of revised landform data within the National Soil Database (NSDB). Carolyn Baldwin, Murray Lewis, Phil Owens, Qiang Huang and several others assisted with the validation of the wind erosion risk indicator model. Qiang Huang undertook the study of uncertainty analysis for the erosion indicators. Genevieve Ali, Carolyn Baldwin and Carolyn English carried out a case study on scaling the erosion indicator results from hillslopes to a watershed. We greatly appreciate Zisheng Xing, Nasem Badreldin, Fan-Rui Meng and Darrel Cerkowniak, and Liz Eidsness for their technical assistance in the indicator programming and analysis, as well as Nasem Badreldin and Marita Loro for their contribution to economic assessment of crop yield losses associated with soil erosion.

Related indicators

- The Soil Organic Matter Indicator tracks the health of Canadian agricultural soils as it relates to soil carbon content.
- The Soil Salinization Indicator examines salinization risk to Prairie soils.

- The Soil Cover Indicator assesses the number of days in a given that soils are protected by crops or snow.

References

- Ali, G., C. Baldwin and C. English, 2013. Upscaling of soil erosion indicator models in a Canadian prairie watershed. A case study on the applicability of the NAHARP erosion indicator models at the watershed level – Final report. Ottawa, ON, Canada: Agriculture and Agri- Food Canada. 22 p.
- Badreldin, N., and D.A. Lobb, 2019. *Assessment of the cost of soil erosion to crop production in Canada*. Global Symposium on Soil Erosion. Food and Agriculture Organization of the United Nations. UN-FAO. Rome, Italy, May 2019. Proceedings of the Global Symposium on Soil Erosion. UN-FAO. pp. 633-637.
- Baldwin, C. and D.A. Lobb, 2012. *Field assessment of soil erosion and validation of WindERI. Technical supplement*. Ottawa, ON, Canada: Agriculture and Agri-Food Canada.
- Huang, Q., and D.A. Lobb, 2013. *Uncertainty analysis for the soil erosion risk indicators. Technical supplement*. Ottawa, ON, Canada: Agriculture and Agri-Food Canada.
- Li, S., D.A. Lobb and B.G. McConkey, 2008. Soil erosion risk indicator (SoilERI) methodology in *Soil erosion risk indicators: Technical supplement*. Ottawa, ON, Canada: Agriculture and Agri-Food Canada.
- Li, S., and D.A. Lobb, 2009. Role of Topographic Data on the Accuracy and Uncertainty of NAHARP Indicators. Technical supplement. Ottawa, ON, Canada: Agriculture and Agri-Food Canada.
- Li, S., B.G. McConkey, M.W. Black, and D.A. Lobb, 2008. Water Erosion Risk Indicator (WatERI) Methodology in *Soil erosion risk indicators: Technical supplement*. Ottawa, ON, Canada: Agriculture and Agri-Food Canada.
- Lobb, D.A., S. Li, K.H.D. Tiessen, G.R. Mehuys, T.E. Schumacher, J.A. Schumacher, J. Mollinedo, D.J. Pennock, J. Liu and T. Yates, 2008. *Tillage Erosion Risk Indicator (TillERI) Methodology in Soil erosion risk indicators: Technical supplement*. Ottawa, ON, Canada: Agriculture and Agri-Food Canada.
- McConkey, B.G., S. Li and M.W. Black, 2008. *Wind Erosion Risk Indicator (WindERI) Methodology in Soil erosion risk indicators: Technical supplement*. Ottawa, ON, Canada: Agriculture and Agri- Food Canada.
- Papiernik, S.K., T.E. Schumacher, D.A. Lobb, M.J. Lindstrom, M.L. Lieser, A. Eynard, and J.A. Schumacher. 2009. *Soil properties and productivity as affected by topsoil movement within an eroded landform*. Soil Tillage Research, 102: 67-77.

Schneider, S.K., C. Cavers, S. Duke, J.A. Schumacher, T.E. Schumacher, and D.A. Lobb. 2021. *Crop responses to topsoil replacement within eroded landscapes*. *Agronomy J*, 113: 2938-2949.

Statistics Canada, 2019 *Farm Environmental Management Survey*, special tabulation. <https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&Id=118847>

Statistics Canada. Table 32-10-0208-01 Land management improvements on farms. <https://doi.org/10.25318/3210020801-eng>

Thaler, E.A., I.J. Larsen and Q. Yu. 2021. *The extent of soil loss across the US Corn Belt*. *PNAS* 2021 Vol. 118 No. 8. 8 pages.