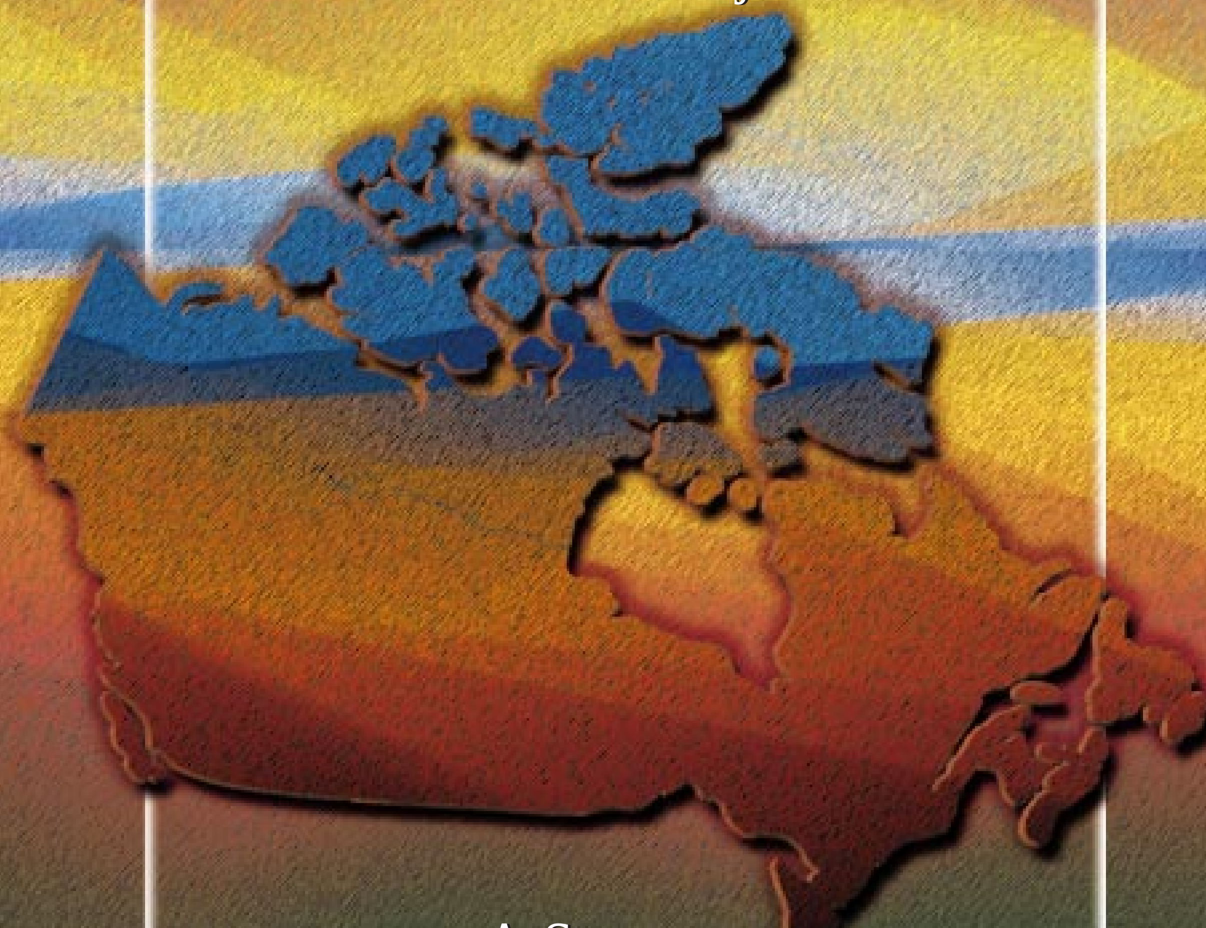
Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada

Environmental Sustainability of Canadian Agriculture: Report of the Agri-Environmental Indicator Project



A Summary

T. McRae, C.A.S. Smith, and L.J. Gregorich (editors)

Research Branch, Policy Branch, Prairie Farm Rehabilitation Administration
Agriculture and Agri-Food Canada, 2000

Canada

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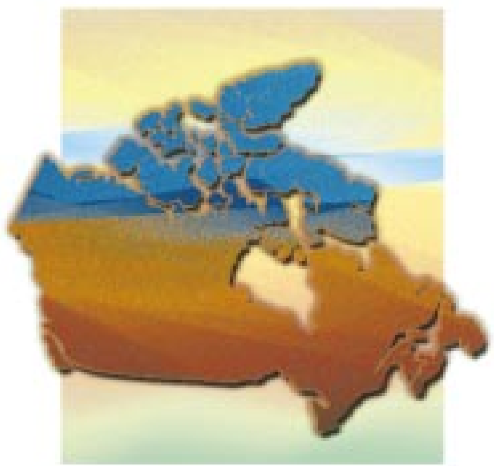

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Contents

Minister
of Agriculture and
Agri-Food

Ministre
de l'Agriculture et de
l'Agroalimentaire

Ottawa, Canada K1A 0C5

A word from

The Minister

on Sustainable Development

The sustainable production of food is crucial for us all. As Minister of Agriculture and Agri-Food Canada, I am pleased to present *Environmental Sustainability of Canadian Agriculture: Report of the Agri-Environmental Indicator Project*. In this report, we introduce a new set of tools, agri-environmental indicators, to help guide and assess the environmental performance of our primary agriculture sector.

Agriculture and Agri-Food Canada is pleased to have lead the development of these indicators, which are based on our best understanding of agricultural ecosystems and their interactions with the economy and surrounding environment. Our scientists have worked together with the invaluable assistance of an external Advisory Committee to develop the methods and information, and also to analyze the results. We can now begin to use the indicators to assess the environmental implications of our actions, and we will draw on this and related information as we engage our partners in a dialogue aimed at developing a new Sustainable Development Strategy. Many of the underlying concepts and methods may well be used by others to track the environmental performance of primary agriculture elsewhere, such as in other countries.

Environmental Sustainability of Canadian Agriculture: *Report of the Agri-Environmental Indicator Project* is another important contribution toward our goal of increasing understanding of linkages between the environment and the agricultural economy. The results clearly demonstrate the progress Canadian agriculture has made in conserving the environment, and alsofocus our attention on where we need to work harder. This publication compliments andintegrates the information presented in related publications from Agriculture and Agri-Food Canada: *The Health of Our Soil(1995)*, *The Health of Our Air (1999)* and *The Health of Our Water (2000)*.

Agriculture and Agri-Food Canada will continue to work with its partners to encourage sustainable development through basic research, and by developing and transferring the tools producers and other decision-makers need to improve environmental management in agriculture.

Lyle Vanclief

Minister of Agriculture and Agri-Food Canada
and Minister Coordinating Rural Affairs

Canada

A word from the Agri-Environmental Indicator Project Advisory Committee

Agriculture is integral to Canadian society, making significant contributions to our economy, rural communities, and food security. It is also intimately connected to the environment. Not only are resources such as soil and water vital to agricultural productivity, but agriculture both affects and is affected by the local, regional, and global environment.

In recent years, Canadians have made significant commitments toward a more sustainable society. The government of Canada has signed international conventions; federal and provincial governments have implemented environmental legislation, policies, and programs; and municipalities have adopted environmental bylaws. Citizens and industry have also contributed through numerous actions. The challenge of achieving a more environmentally sound agriculture has been taken up by farmers, and the agriculture industry has undertaken many initiatives to ensure its sustainability. If more-sustainable agriculture is to become a reality, objectives and indicators of progress are needed to guide these efforts.

Recognizing the need for indicators, and in response to recommendations made by several groups, Agriculture and Agri-Food Canada (AAFC) initiated the Agri-Environmental Indicator Project in 1993. The department's Environment Bureau and Research Branch carried out most of the work. Many AAFC scientists and analysts from across the country were involved in developing and using the indicators to generate the findings presented in this report. Many scientists outside of AAFC also contributed to this work.

An advisory committee was established in 1995 to provide input from agencies other than AAFC. Several farm and farm input-supply organizations, conservation groups, universities, scientific bodies, provincial agriculture ministries, and federal departments were represented on this advisory body, which played a significant role in the process of developing the indicators and shaping this report. As a result of the advisory committee's efforts, many indicators were modified, some were dropped, and others were added.

The advisory committee regards the indicator project as a success. The findings of this report confirm that the agricultural industry's efforts to address environmental challenges have yielded many positive results, and also that much remains to be done. This study represents a major step forward in our ability to provide national assessments of the environmental performance of agriculture, based on available information and resources.

We encourage all users to exercise caution in interpreting and using this report. The indicators provide first approximations; their limitations are explained in Chapter 2 of the full report (*Environmental Sustainability of Canadian Agriculture: Report of the Agri-Environmental Indicator Project*), as well as for each individual indicator. More research and effort will be needed to increase the accuracy and scope of the indicators. Also, the utility of the indicators has yet to be fully tested, and this will be the ultimate measure of their success.

We are confident that the indicators will contribute to a more informed debate in Canada regarding the establishment and pursuit of environmental sustainability goals for agriculture, and that this work will contribute to similar initiatives underway elsewhere within Canada and abroad. We urge Agriculture and Agri-Food Canada to ensure the continuous improvement and periodic reporting of the agri-environmental indicators in the future.

David Lobb, Marie Boehm, and Jim Farrell
Co-chairs, Agri-Environmental Indicator Project Advisory Committee

1 Introduction

T. McRae

Need for environmentally sustainable agriculture

Agriculture today must balance a wide array of demands and environmental challenges that are continually evolving in their nature and complexity. A major challenge is achieving long term environmental sustainability of production. At the same time, agriculture is increasingly valued by Canadians for its environmental benefits, including its provision of some wildlife habitat; the visual beauty of farmland; and environmental services, such as nutrient cycling and the storage and filtering of water. Governments, farmers, and others have worked together for many years to promote research, programming, and related actions to address environmental concerns. However, an environmentally sustainable form of agriculture is now more urgently needed. The policy challenge in agriculture — to ensure optimal and sustainable social, economic, and environmental benefits — has become more pressing and complex than ever.

Need for information

If we genuinely want to practise environmentally sustainable agriculture, we must have some idea of whether the path we are on is headed toward or away from this goal. Information is one of the common needs of all decision makers concerned with sustainability. Decision makers at all levels need information on the performance of a given system, why that system is behaving as it is, whether that performance is satisfactory, and how it is likely to behave in the future in response to potential changes in policies and other driving forces. Decision makers who rely solely on economic indicators risk achieving economic goals at the expense of environmental and other objectives. Over the past 15 years, considerable effort has gone into developing new ways of measuring and valuing environmental assets and services, and understanding the links between the environment and the economy. Environmental indicators are one result of such efforts.

Benefits of agri-environmental indicators

Environmental Sustainability of Canadian Agriculture: Report of the Agri-Environmental Indicator Project presents the results of Agriculture and Agri-Food Canada's work on agri-environmental indicators. Agri-environmental indicators are measures of key environmental conditions, risks, and changes resulting from agriculture, and of management practices used by producers. They are expected to be useful in

- informing agricultural and other decision makers about environmental performance in agriculture
- demonstrating the progress being made by the agriculture sector in adopting stewardship principles and using environmentally sound practices
- supporting the development of strategies and actions targeted at areas and resources that remain at environmental risk
- facilitating the environmental analysis of policies and programs in agriculture and providing a means of monitoring their performance
- contributing to international efforts to develop agri-environmental indicators.

Report's audience and focus

Environmental Sustainability of Canadian Agriculture: Report of the Agri-Environmental Indicator Project is targeted at farmers and farm leaders, government policy makers, environmentalists, and the interested public. The report offers an overall assessment of agroecosystem sustainability and considers the major environmental conditions within agroecosystems, as well as relationships between agroecosystems and the broader natural ecosystems and driving forces with which they interact. Indicators are presented for six main areas: farm management, soil, water, air, biodiversity, and production intensity.

2 Understanding and Assessing the Environmental Sustainability of Agriculture

C.A.S. Smith and T. McRae

Two criteria

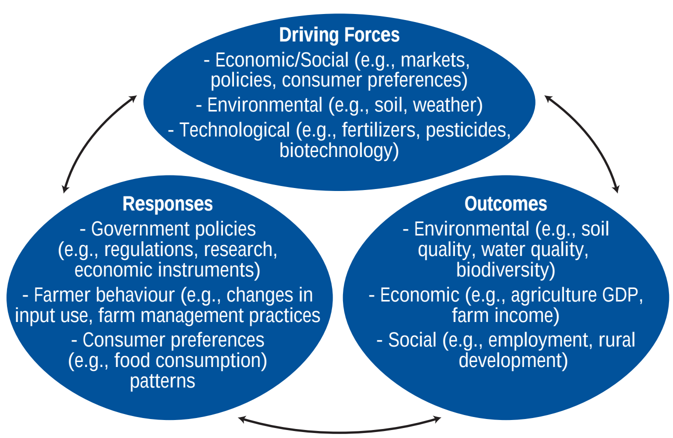
Agroecosystems begin as natural ecosystems and develop under human manipulation. Even under this manipulation they have much in common with natural systems, sharing soils, water resources, natural nutrient supplies, and solar radiation and other aspects of climate. The two main criteria used to judge the environmental sustainability of Canada's agriculture are how well it manages and conserves natural resources that support agricultural production, and how compatible agricultural systems are with natural systems and processes.

Conceptual framework

Agri-environmental indicators were selected using a Driving Force–Outcome–Response framework, which recognizes three broad areas that sustainability assessments must consider:

- driving forces that influence agricultural activities
- environmental outcomes of these activities, both beneficial and adverse
- societal responses to actual and perceived changes in outcomes and driving forces, including producer behaviour, consumer reactions, technological development, and government action.

Driving Force–Outcome–Response Framework for agriculture



Agri-environmental indicators

Fourteen agri-environmental indicators were developed within six categories: environmental farm management, soil quality, water quality, greenhouse gas emissions, agroecosystem biodiversity, and production intensity. Some indicators are summaries of national *Census of Agriculture* data, survey data, or provincial data. Others were calculated using existing or newly developed mathematical models or formulas and an integration of census data, *Soil Landscapes of Canada* information, and, in some cases, custom data sets.

Indicator limitations

All indicators are subject to various limitations, including those related to gaps in data and our knowledge base, the quality of the data, and geographical limits. These limitations confine the use of the indicators to depicting trends over time in certain areas and providing a basis for comparison between areas.

Conclusion

The results of this work are encouraging. The indicators appear sensitive to changing farm practices and show patterns of environmental risk that reflect the intensity of agricultural production in some areas. They establish a baseline against which future assessments can be compared. And they will be useful in developing and evaluating agricultural policy, directing future research, and providing producers with a report card on broad trends in agriculture's environmental performance.

3 Driving Forces Affecting the Environmental Sustainability of Agriculture

R.J. MacGregor and T. McRae

Key driving forces

Agriculture is situated within the broader economic, social, and environmental systems of the world. These systems are inextricably linked to one another, interacting and giving rise to various driving forces that influence the nature and direction of agricultural production, as well as environmental and other outcomes of agriculture. Key driving forces are the economic and social signals received from the marketplace, government policy, and technology. Over time these have evolved considerably and in recent years have become more complex.

Market demand and social preferences

Global demand for agricultural products has grown and will continue to do so. The nature of that demand has also changed. Growth and evolution in demand has been accompanied by globalization of markets, increased trade liberalization, and competition among countries. Canada's agriculture has responded by increasing output and adopting new production methods and technologies to improve its productivity and competitiveness. Structural changes have also occurred, such as greater farm size and specialization, and more intensive use of land and other resource inputs. Many of these changes have increased the potential environmental risks from agriculture. At the same time, society's environmental expectations and preferences have evolved. New environmental regulations and agreements have been enacted, placing additional demands on agriculture to meet environmental as well as economic goals.

Technology

At the farm level, it is changing technology that has principally altered the way in which producers have used resources over the last 200 years. This has been particularly true during the technology explosion of the last part of the twentieth century. The environmental effects of technological change are the subject of considerable debate. Some technologies have had unanticipated, adverse effects on the environment. On the other hand, the use of technology has allowed farmers to produce more food on a limited land base. Canadian agriculture today is a product of technological change, and further developments will affect decisions made by producers and environmental outcomes from agriculture.

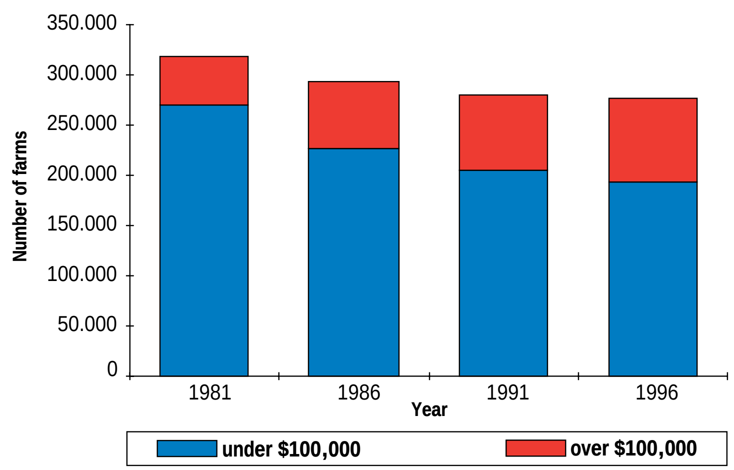
Responses

Government agricultural policy has traditionally focussed on economic and production objectives. More recently, policy reform has been guided by environmental considerations, along with more traditional social and economic criteria. The sector has also responded to driving forces with a wide array of voluntary initiatives and changes in management practices.

Conclusion

Driving forces will continue to evolve and influence environmental outcomes in agriculture. Potential risks to the environment will continue to increase as output expands. Ongoing responses will be required by industry, governments, and Canadians so that social, economic, and environmental objectives for agriculture are achieved.

Number of farms and proportion of small versus large farms based on gross farm receipts



Source: Statistics Canada,1997. Catalogue no. 93-358 XPB.

4 Indicator: Soil Cover by Crops and Residue

E. Huffman

Geographic scope: National, provincial
Time series: 1981, 1991, 1996

Issue

Soil left exposed by various cropping practices is vulnerable to erosion. The canopy of the crop and crop residues protect the soil from wind and water erosion and the resulting conditions of soil degradation. The less soil that is left exposed, the smaller the risk of erosion.

Indicator description

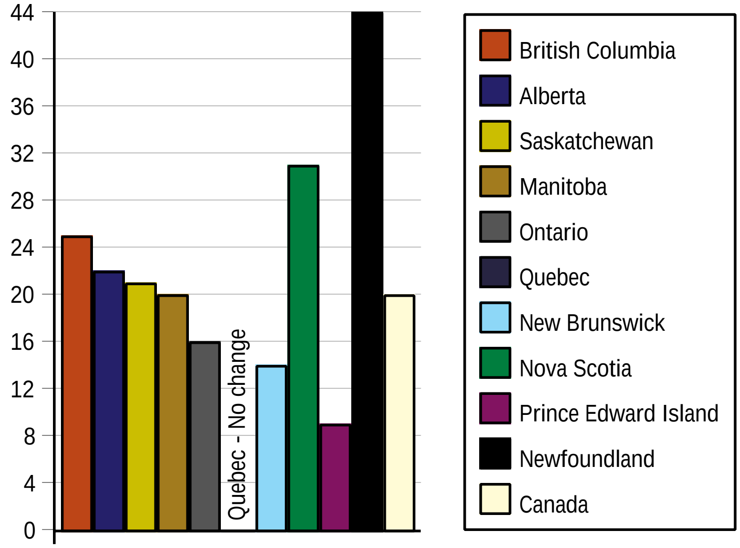
The indicator was based on an index of bare-soil days that accounted for the number of days in a year that soil would be bare under specific cropping and tillage practices in various regions of Canada. The performance objective is to have a steady trend toward fewer bare-soil days, while aiming for zero bare-soil days, under all cropping systems.

Key results

Between 1981 and 1996 the average number of bare-soil days in Canada's agricultural regions dropped by 20%, from 98 to 78. All provinces and all ecoregions except the St. Lawrence Lowlands showed a drop in the number of bare-soil days, indicating an improvement in soil cover during this period.

Most areas associated with improvements in soil cover of greater than 20% have less land under agriculture and less intense agriculture. Areas showing less than 10% improvement in soil cover were the St. Lawrence Lowlands of Central Canada, New Brunswick's Uplands and St. John River Valley, and Prince Edward Island. These regions have large areas in row crops, such as silage corn, soybeans, potatoes, and vegetables, which are associated with low levels of soil cover.

Percent reduction in the average number of bare-soil days between 1981–1996



Conclusion

Although the indicator shows considerable improvement in soil cover between 1981 and 1996, this trend could reverse as economic signals cause a shift to crops that provide less soil cover. More work is needed to promote the benefits of soil cover and to develop new methods and equipment to provide soil cover, especially in areas of intensive farming of row crops.

5 Indicator: Management of Farm Nutrient and Pesticide Inputs

R. Koroluk, D. Culver, A. Lefebvre, and T. McRae

Geographic scope: ecozones
Time Series: 1995

Issue

Crop nutrients and pesticides are added to agroecosystems to improve crop production. When not used wisely, these amendments can reduce the quality of soil, water, and air and affect biodiversity. Indicators are needed to assess how well these inputs are being managed in Canadian agriculture.

Indicator description

The following indicators were developed to evaluate the management of nutrient and pesticide inputs on farms. For fertilizer management: Method of Fertilizer Application, Timing of Nitrogen Application, Reduction of Fertilizers Applied to Offset Nutrient Content of Manure, and Use of Soil Testing; for manure management: Storage Method for Solid Manure, Storage Method for Liquid Manure, Liquid Manure Storage Capacity, and Manure Application Method; for pesticide management: Timing of Herbicide Applications, Timing of Insecticide and Fungicide Applications, Sprayer Calibration, and Use of Non-chemical Pest Control Methods. Indicators were calculated using data from a 1995 Statistics Canada survey, except for the indicator on manure application methods, for which data from a new *Census of Agriculture* question were used. The performance objective is to have all Canadian farmers using best management practices with respect to nutrient and pesticide management.

Key results

Nationally, fertilizer application methods that reduce nutrient losses were quite prevalent, although room for improvement exists. Injection was used on 22% of cropland receiving fertilizer, banding on 43%, and application with seed on 55%. Broadcasting, the most environmentally risky application method, was still widely used, except in the Prairies and Boreal Plains ecozones. The national figure for the timing of nitrogen fertilizer application on cropland was largely driven by the situation in the Boreal Plains and Prairies, where nitrogen fertilizer is applied before planting on 70% and 61% of cropland, respectively. Farmers are more likely to apply nitrogen after planting in ecozones where leaching is a problem. Better account should be taken of the nutrient content of manure when it is applied along with mineral fertilizer. Soil testing, a useful tool for managing nutrient inputs, was carried out by 60% of Canadian farmers in 1995. Results suggest that manure is the nutrient source most needing improved management. In general, both liquid and solid storage methods are less than optimal, and improvements are needed now and as the industry expands.

Herbicide application was prompted by the level of economic injury to the crop on about 20% of cropland receiving these treatments. Farmers were more likely to apply herbicides at a certain stage of crop growth or to use the first sign of pests (weeds, insects, disease) to time pesticide applications. About 68% of farmers using their own sprayers calibrated them only at the beginning of the crop season. Crop rotation was used as a non-chemical control of pests on 56% of Canadian cropland, and tillage on 27%. No alternatives to chemical controls were used on about 33% of cropland treated for pests.

Conclusion

Although many good farm input management practices are being applied across Canada, there is also room for improvement when viewed in terms of environmental protection. As agriculture continues to move to larger and more intensive operations, sound input management practices will be critical for both environmental protection and farm profitability. In most cases, improving input management goes hand in hand with enhancing farm profitability.

6 Indicator: Risk of Water Erosion

I.J. Shelton, G.J. Wall, J.-M. Cossette, R. Eilers, B. Grant, D. King, G. Padbury, H. Rees, J. Tajek, and L. van Vliet

Geographic scope: National, provincial
Times series: 1981, 1991, 1996

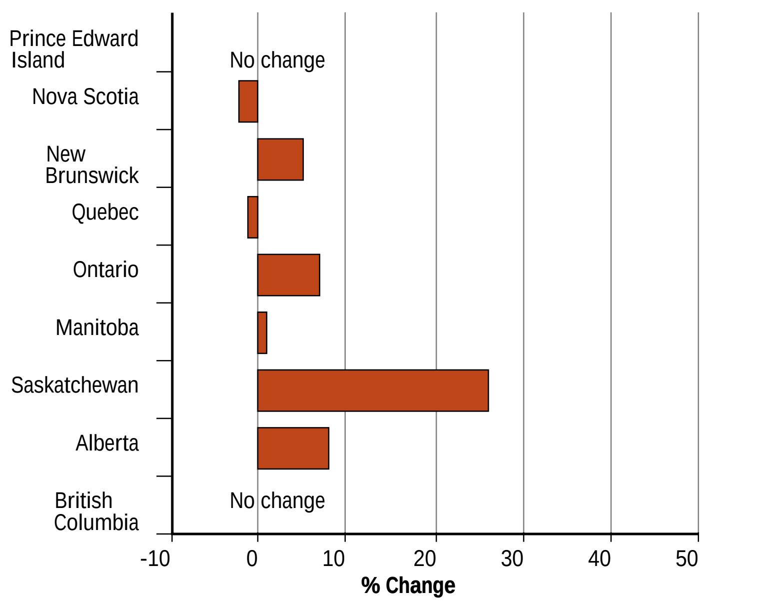
Issue

Water erosion is a natural process that is accelerated by various agricultural management practices. Erosion results in the loss or redistribution of topsoil in a landscape, usually causing soil degradation and reducing crop quality and yield on-site. If the eroded sediment is transported off-site into waterways, it can cause an increase in turbidity and sedimentation. Attached to the eroded soil particles may be nutrients, pesticides, and bacteria, which also contribute to declining water quality. Thus, controlling erosion helps to protect both soil quality and water quality.

Indicator description

The indicator expresses the degree to which Canada's cropland was at risk of water erosion in 1981, 1991, and 1996. It does not reflect the use of some erosion control practices such as grassed waterways and terraces, cross-slope cultivation, strip and contour cropping, and winter cover cropping, because the land base on which these practices are used is not reported in the *Census of Agriculture*. The risk was expressed in five classes: tolerable (associated with erosion that is offset by soil building and is thus sustainable), low, moderate, high, and severe (all of which are considered unsustainable). The change in risk between 1981 and 1996 was calculated to evaluate the effects of prevailing land use and management practices. The performance objective is to have all cropland in the tolerable risk class.

Change in the area of cropland at risk of tolerable levels of water erosion between 1981 and 1996



Key results

Between 1981 and 1996, cropping measures and increased use of conservation tillage were responsible for decreases in the risk of water erosion in Alberta, Saskatchewan, Manitoba, Ontario, and New Brunswick. The risk remained the same in British Columbia and Prince Edward Island, where the benefits of conservation tillage and other conservation measures were offset by intensified agricultural production in some areas. The risk rose in Quebec, mainly because of the intensification of cropping practices, and in Nova Scotia, mainly because of expanded potato production.

By 1996, Alberta, Saskatchewan, Manitoba, Quebec, and Nova Scotia had more than 70% of cropland in the tolerable risk class, while the share of cropland in this risk class ranged from about 50 to 70% in British Columbia, Ontario, Prince Edward Island, and New Brunswick.

Conclusion

The overall reduced risk of water erosion on Canadian cropland is a positive trend resulting primarily from shifts in tillage and cropping practice. However, a large share of Canadian cropland is still at risk of unsustainable loss of soil by water erosion, especially areas used for intensive row crop or horticultural crop production and smaller areas of vulnerable topography or soil. Improved land management is needed here.

7 Indicator: Risk of Wind Erosion

G. Padbury and C. Stushnoff

Geographic scope: Prairie Provinces
Time series: 1981, 1991, 1996

Issue

Wind erosion is a natural process that removes topsoil from cultivated agricultural lands, contributing to an overall decline in soil health, including a breakdown of soil structure and reduced soil fertility.

Indicator description

The indicator monitors the extent of cultivated land at risk of wind erosion. It is based on soil, climate, and management factors. Five classes of risk were identified: negligible, low, moderate, high, and severe. The indicator was applied to the Prairie Provinces, the Canadian region most prone to wind erosion. The performance objective is to have all agricultural soils in the negligible or low risk classes.

Key results

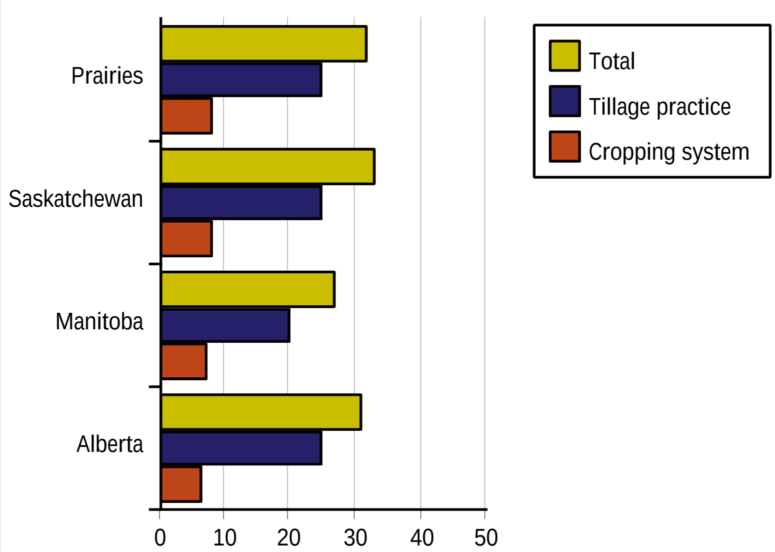
Two-thirds of cultivated land in the Prairies is at moderate to severe risk of wind erosion without the use of any soil conservation practices.

Between 1981 and 1996, the share of cultivated land at high to severe risk of wind erosion dropped from 15% (5 million hectares) to 6% (2 million hectares) because of changes in management practices. Implementation of reduced tillage technologies coupled with a decline in the use of summerfallow in the Prairies resulted in an overall decline of 30% in the risk of wind erosion during this period. The share of cultivated prairie land at negligible risk of wind erosion grew from 41% to 64% in this period. Improvements were greatest where sandy, highly erodible lands were converted from annual crops to perennial forages. Most of the land still at risk is located in the Brown and Dark Brown soil zones of southern Alberta and Saskatchewan.

Conclusion

If the trend toward reduced tillage and less summerfallow continues in the Brown and Dark Brown soil zones, the risk of wind erosion is expected to decline even further. Further reduction in this risk is less likely in the Black and Gray soil zones, where summerfallow area is already relatively small and the inherent risk of soil erosion is less.

Reduction (%) in the risk of wind erosion in the Prairie Provinces between 1981 and 1996



8 Indicator: Risk of Tillage Erosion

D.J. King, J.-M. Cossette, R.G. Eilers, B.A. Grant, D.A. Lobb, G.A. Padbury, H.W. Rees, I.J. Shelton, J. Tajek, L.J.P. van Vliet, and G.J. Wall

Geographic scope: Provincial, ecoregion
Time series: 1981, 1996

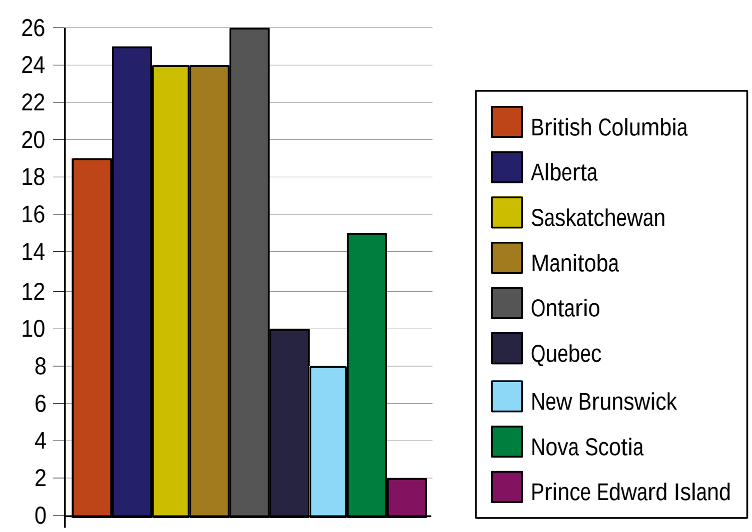
Issue

Tillage erosion is caused when tillage implements loosen soil and move it downslope with the help of gravity. Over time, this movement results in large losses of soil from the tops of hills and knolls and accumulation of soil downslope. Tillage erosion is a measure of the amount of soil lost from these upper slope areas.

Indicator description

The indicator estimates the risk of tillage erosion on Canada's cropland and assesses how this risk changed between 1981 and 1996 as a result of changes in agricultural management practices. The risk of soil loss from hilltops was expressed in five classes: tolerable, low, moderate, high, and severe. The performance objective for this indicator is to have all cropland in the tolerable risk class.

Reduction (%) in the risk of tillage erosion between 1981 and 1996



Key results

The risk of tillage erosion dropped in all provinces between 1981 and 1996 by values ranging from a high of 26% in Ontario to a low of 2% in Prince Edward Island. During this period the amount of cropland at tolerable risk grew in all provinces except Prince Edward Island, which had little overall change. Quebec continued to have the largest share of cropland (75%) in the tolerable risk class in 1996, while Saskatchewan continued to have the smallest share (35%). Only New Brunswick (9%) and Prince Edward Island (10%) continued in 1996 to have a significant share of land at high to severe risk of tillage erosion.

Areas showing limited improvement or an increased risk of tillage erosion between 1981 and 1996 include British Columbia's South Coastal and Southern Interior regions; Alberta's Parkland and Mid Boreal Upland; Manitoba's Black soil zone; Ontario's Algonquin–Lake Nipissing region; the St. Lawrence Lowlands, Central Laurentians, Southern Laurentians, Lac Temiscamingue Lowlands, Abitibi Plains, and Rivière Rupert Plateau; New Brunswick; Nova Scotia; and Prince Edward Island. These areas were characterized by higher inherent erodibility, intensive cropping, or both.

Conclusion

Lower risk of tillage erosion is associated with conservation tillage and no-till practices, reduced area in summerfallow, increased area in forages, and the taking of marginal land out of production. In some cases, intensive cropping and inherent erodibility of the land offset the benefits of these practices. The risk of tillage erosion is expected to drop further in areas not limited by cropping options and complex topography, but may rise with market opportunities to intensify production of cash crops, especially on sloping land.

9 Indicator: Soil Organic Carbon

W.N. Smith, G. Wall, R. Desjardins, and B. Grant

Geographic scope: National, provincial
Time series: 1970 to 2010

Issue

Carbon (C) is the main component of soil organic matter, the presence of which is a major factor in soil quality. Loss of soil organic matter, and thus of soil organic carbon, results in the breakdown of soil structure, greater vulnerability of the soil to erosion, and reduced fertility, all leading to reductions in both yield and sustainability of the soil resource. Building up carbon stores in soils may help curb the accumulation of carbon dioxide, a greenhouse gas, in the atmosphere.

Indicator description

The indicator estimates the change in soil organic carbon levels in Canada's agricultural soils from 1970 to 2010. Indicator values were generated using the Century model, a computer simulation model that uses simplified soil–plant–climate interactions to describe the dynamics of soil carbon and nitrogen in various agroecological zones. The performance objective for this indicator is to stabilize the loss of soil organic carbon in all agricultural soils and to increase the amount of stored carbon in those soils for which this is feasible.

Key results

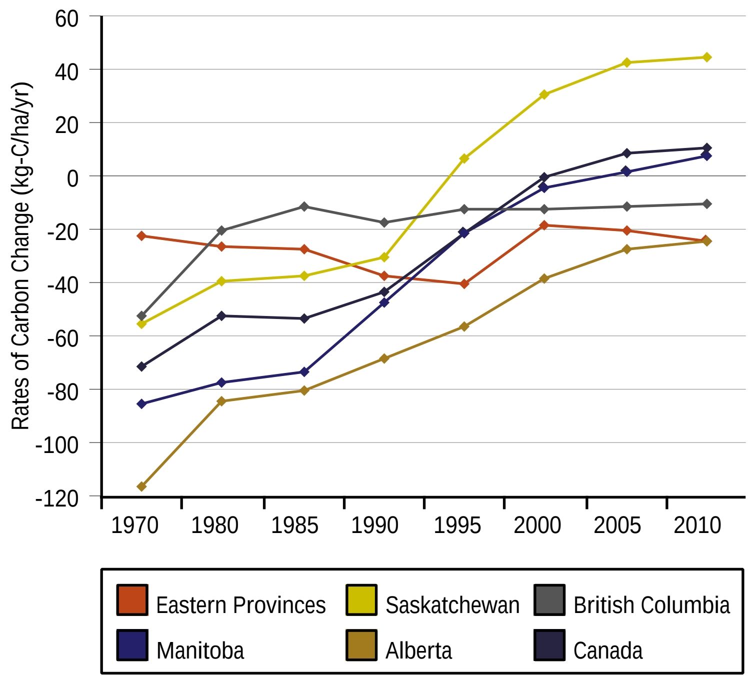
Canadian agricultural soils as a whole lost organic carbon at an estimated rate of 70 kilograms per hectare (kg/ha) in 1970 and 43 kg/ha in 1990. The declining rate of loss is mainly the result of greater adoption of no-till, reduced area in summerfallow, and increased crop residues due to greater crop yields. The model estimates that Saskatchewan has been accumulating soil organic carbon since about 1994, but the other provinces will continue to lose soil carbon at different rates for many years. Canadian soils as a whole will stop losing organic carbon in 2000 and will accumulate it at a rate of 11 kg/ha in 2020. Accumulation is predicted to continue beyond 2010, reaching a limit in about 2020. The share of Canadian farmland accumulating soil organic carbon is predicted to be 52% in 2010.

Erosion has a significant effect on the change in organic carbon in the soils of eastern Canada. Assuming that no soil is lost to waterways because of erosion, the model predicts that in 2000 eastern Canadian soils would gain 94 kilograms of soil organic carbon per hectare. In the same year, if 15% of eroded soil was lost to waterways, soils would lose 19 kg C/ha.

Conclusion

The accurate estimation of the rate of carbon change in Canada's agricultural soils is a difficult undertaking. Still, model predictions showed sensitivity to changes in agricultural management practices during the 1990s, particularly greater use of no-till, reduced area in summerfallow, and increased fertilizer application in some parts of the country.

Rate of change in organic carbon levels in Canada's agricultural soils



10 Indicator: Risk of Soil Compaction

R.A. McBride, P.J. Joosse, and G. Wall

Geographic scope: Ontario, Maritime Provinces
Time series: 1981, 1991, 1996

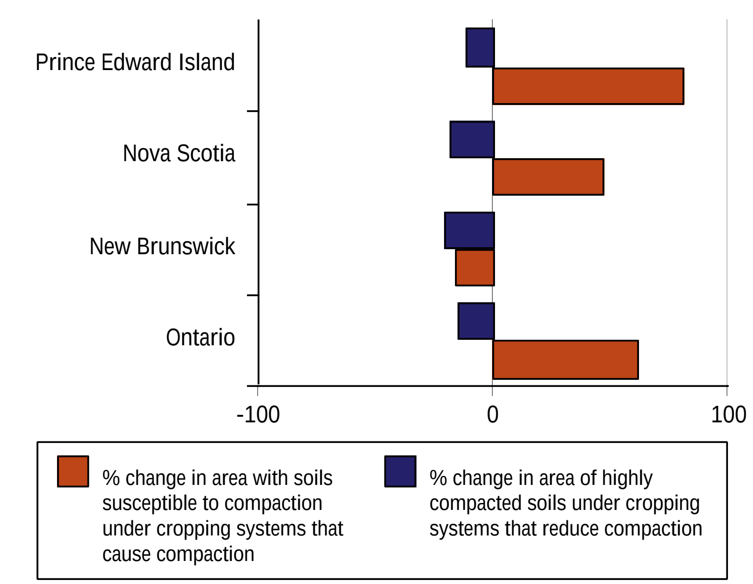
Issue

Soil compaction caused by wheel traffic and tillage is a form of soil degradation. This process leaves the soil denser, less permeable to air and water, slower to warm up in the spring, more difficult to till, and more resistant to the penetration of plant roots. Compaction is a particular problem in fine-textured soils and causes millions of dollars in lost crop yield each year.

Indicator description

The indicator assesses the likelihood that major agricultural soils in Ontario and the Maritimes will become less compacted, stay the same, or become more compacted under prevailing cropping systems in 1981, 1991, and 1996. It is based on estimates of the actual degree of compactness of these soils (low, moderate, or high). The performance objective for this indicator is to have a decrease over time in the area of row crops planted on soils susceptible to compaction, and an increase in the area of forage crops planted on highly compacted soils.

Change (%) in farmland area under cropping systems that cause and reduce risk of soil compaction between 1981 and 1996



Key results

Many of the study soils with fine-textured subsoils were estimated to be significantly compacted, especially in southern Ontario. The risk of further compaction in these subsoils is not as great as for many other soils in eastern Canada. Different cropping systems or other management practices may help to reduce the degree of compactness in these soils and improve crop yields.

Between 1981 and 1996, the area of farmland with both highly compacted subsoils and cropping systems capable of improving soil structure and reducing soil compactness (e.g., forage, pasture) shrank by 15% in Ontario, 21% in New Brunswick, 18% in Nova Scotia, and 11% in Prince Edward Island. There was little change in the distribution of these areas during this 15-year period.

Between 1981 and 1996, the area of farmland with both soils susceptible to compaction and cropping systems likely to degrade soil structure and induce further soil compaction (e.g., corn, soybeans, vegetable or root crops) grew by 61% in Ontario, 47% in Nova Scotia, and 81% in Prince Edward Island, and shrank by 16% in New Brunswick. Areas of particular concern were central and eastern Ontario, Nova Scotia's Annapolis Valley, and much of Prince Edward Island.

Conclusion

A comparison of the estimated degree of soil compactness used in calculating the indicator compares well with actual soil survey data, indicating that *Soil Landscapes of Canada* data are reliable for this use. The increased risk of further soil compaction in areas of eastern Canada is largely associated with the expansion of intensively cultivated cash crops. The distribution of areas where the degree of soil compactness is likely to improve over time has not changed significantly throughout eastern Canada during the past 15 years. The overall provincial-level decrease (11 to 21%) in the area under crops capable of improving soil structure is a troubling trend.

11 Indicator: Risk of Soil Salinization

R.G. Eilers, W.D. Eilers, and T. Brierley

Geographic scope: Prairie Provinces
Time series: 1981, 1991, 1996

Issue

Soil salinity is a state in which soil contains excess soluble salts in the root zone, hindering plant growth. Moderate to severe salinity reduces annual yields of most cereal and oilseed crops by about 50%.

Indicator description

The indicator assesses the risk of soil salinization under dryland agriculture in the Prairies. It is expressed in three risk classes: low, moderate, and high. Components of the indicator include long term average climate, soil and landscape characteristics, hydrology, and land use. Only land use is controlled by humans. The performance objective for the indicator is to have a declining share of land in the moderate and high risk classes.

Key results

In the Prairies as a whole, about 60% of cropland remained in the low risk class in all three census years. About 3% of cropland shifted from the high risk to the moderate risk class between 1981 and 1996, showing an overall positive trend for this indicator. Changes in agricultural practice, including adoption of conservation tillage and reduction of area under summerfallow, likely contributed to this gradually declining risk.

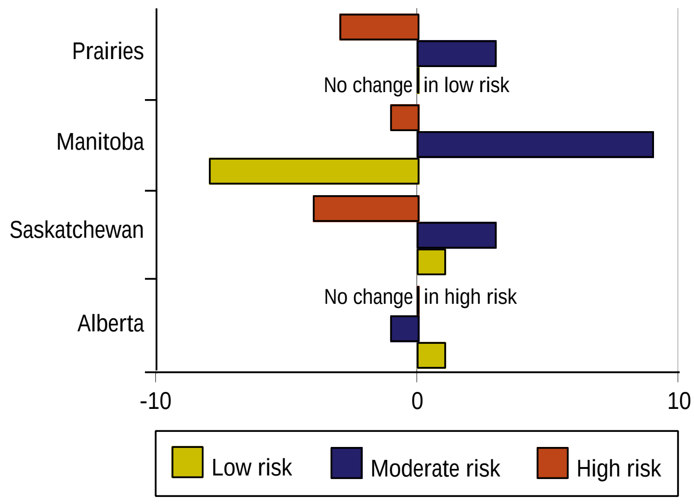
About 76% of Alberta's cropland was at low risk of increasing soil salinization during the census years, as was about 44% of Saskatchewan's cropland. Alberta had little change in the share of cropland at moderate or high risk between census years, but Saskatchewan had a shift of 4% of cropland out of the high risk class in 1991, maintained in 1996. In contrast, in Manitoba the improvement in risk between 1981 and 1991 was reversed between 1991 and 1996, and there was a sizeable shift of cropland from the low risk to moderate risk class.

Differences between the provinces in the distribution of cropland in the risk classes mainly reflect the extent to which summerfallow is practised. Alberta and Saskatchewan continue to show a downward trend for this land use, whereas Manitoba shows a slight increase in 1996.

Conclusion

The indicator gives a snapshot of the risk of soil salinization, reflecting annual variations in weather, markets, and local management decisions, as well as the timing of the census and reported land use. Periodic regional analysis of the indicator is a useful monitoring tool that can also be used to target areas where increasing salinization may be a problem under prevailing management practices.

Change (%) in the risk of soil salinization in the Prairie provinces between 1981 and 1996



12 Indicator: Risk of Water Contamination by Nitrogen

K.B. MacDonald

Geographic scope: Provincial
Time series: 1981, 1991, 1996

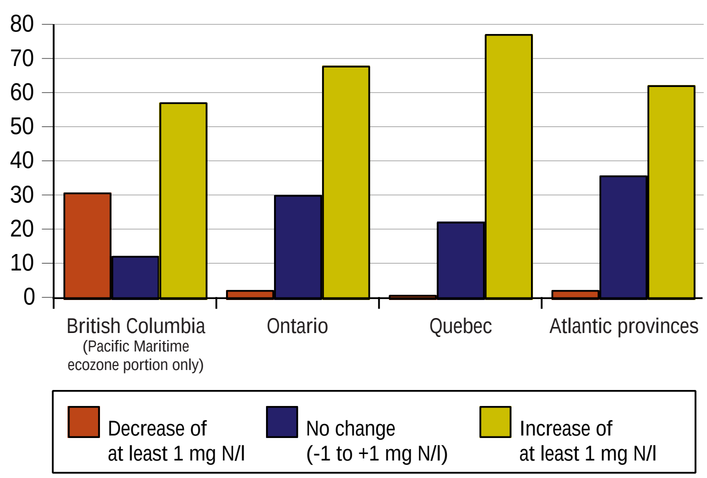
Issue

Nitrogen is an essential nutrient that becomes available for crop use when it is in soluble form, such as nitrate. Nitrate can be leached into groundwater, an important source of drinking water, where it may reach levels harmful to humans. Nitrate can also enter surface waters, contributing to nutrient loading and possible eutrophication.

Indicator description

The indicator assesses the risk of water contamination by nitrogen from farmland based on the *Canadian Water Quality Guidelines* safe limit for nitrate-nitrogen in drinking water (10 milligrams per litre, mg/L). The indicator was calculated by dividing the amount of nitrogen that could potentially move off farmland (residual nitrogen) by the amount of excess water. (Excess water exists only in the humid regions of Canada, so the indicator was calculated only for agricultural areas in British Columbia (humid portions only), Ontario, Quebec and the Atlantic provinces.) Risk was expressed in three classes: low, intermediate, and high. The performance objective for the agricultural industry is to ensure that the quality of water moving off agricultural land to groundwater and surface waters is not seriously impaired by agricultural activity.

Share (%) of assessed farmland for which the estimated nitrogen content of water changed between 1981 and 1996



Key results

In the coastal agricultural region of British Columbia, about 70% of farmland was in the high risk class. Measures are being taken to remedy this situation, possibly explaining the finding that British Columbia had the lowest share of farmland (57%) in the category showing increasing risk.

In central Canada, Ontario had the largest share (17%) and total area of farmland at the highest risk of water contamination by nitrogen. Between 1981 and 1996 the estimated nitrogen content of water increased by at least 1 mg/L on 68% of Ontario's farmland. Areas at high risk were southwestern Ontario, the areas around Lake Simcoe, and the South Nation watershed. In Quebec, 6% of farmland was in the high risk class, located mainly in the St. Lawrence Lowlands region and the area south of Quebec City. Between 1981 and 1996 the estimated nitrogen content of water increased by at least 1 mg/L on most (77%) of Quebec's farmland.

In the Atlantic Provinces, more than 80% of farmland was at low risk of water contamination by nitrogen in 1996, but the estimated nitrogen content of water increased by at least 1 mg/L on about 60% of farmland between 1981 and 1996.

Conclusion

The risk of water contamination by nitrogen is rising in many humid areas of Canada's cropland, particularly where agriculture is intensive. The indicator is subject to limitations of data but is still useful for making regional comparisons, highlighting areas where field testing is advisable, and providing an early warning that some areas may face greater risk of water contamination by nitrogen if appropriate management practices to curtail this risk are not put into place.

13 Indicator: Risk of Water Contamination by Phosphorus

M.A. Bolinder, R.R. Simard, S. Beauchemin, and K.B. MacDonald

Geographic scope: Quebec
Time Series: 1981, 1991, 1996

Issue

Phosphorus moving off farmland into surface waters can cause eutrophication; overgrowth of algae and aquatic plants; reduced oxygen levels in water; and subsequent changes in the species composition of the aquatic ecosystem.

Indicator description

The indicator rates sites based on the relative risk (compared to other sites) of phosphorus moving through them into neighbouring waters. In the preliminary stage of development, it was calculated only for agricultural areas of Quebec. The risk was first expressed in five classes: very low, low, medium, high, and very high. However, because no land was rated at very low or very high risk, these classes were dropped and the medium risk class was subdivided into medium low, medium, and medium high. A performance objective will be defined when the indicator has been further developed.

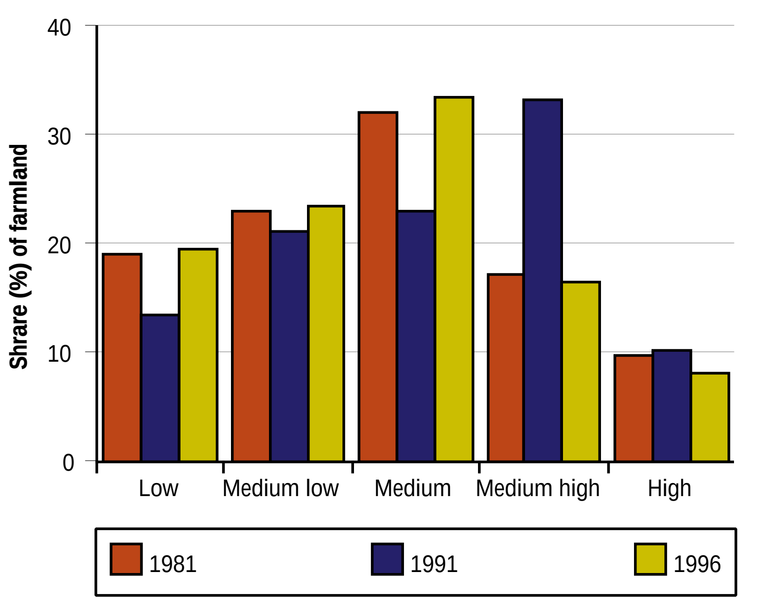
Key results

Ratings were very similar between 1981 and 1996, with about 19% of farmland area at low risk, 72 to 73% at medium risk, and 8 to 10% at high risk of water contamination by phosphorus. However, this similarity masks the distinct drop in the area at low risk (13%) and the jump in the areas at medium risk (77%), especially medium high risk, in 1991.

Conclusion

The indicator estimated that the relative risk of water contamination by phosphorus in Quebec rose between 1981 and 1991, and then dropped back to 1981 levels by 1996. The approach showed some sensitivity to variations over time in the census data, particularly related to the contribution of phosphorus from manure and mineral fertilizers. Further work is needed to gather better index data, account for specific management practices at the farm level, and refine the ratings.

Changes in the risk of water contamination by phosphorus on Quebec's farmland between 1981 and 1996



14 Indicator: Agricultural Greenhouse Gas Budget

R.L. Desjardins and R. Riznek

Geographic scope: National, provincial
Time series: 1981, 1986, 1991, 1996

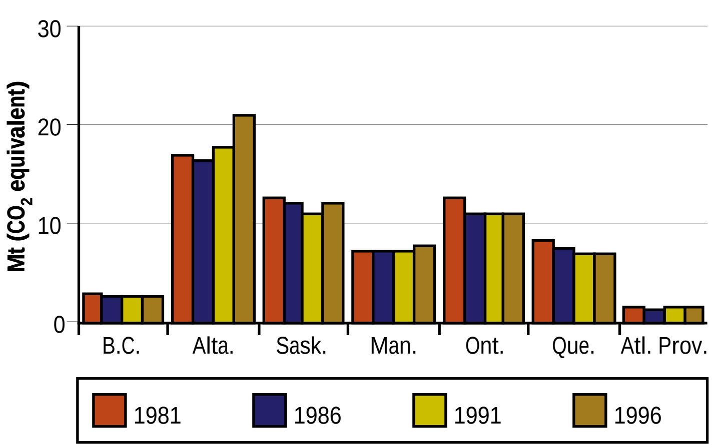
Issue

Atmospheric concentrations of greenhouse gases — particularly nitrous oxide, methane, and carbon dioxide — have been increasing dramatically in the past 20 years, enhancing the greenhouse effect by which the earth's atmosphere is warmed. Uncontrolled buildup of these gases in the atmosphere may cause global warming and other climate changes.

Indicator description

The indicator estimates the combined emissions of nitrous oxide, methane, and carbon dioxide as a result of agricultural activity. Emissions were estimated for nitrous oxide and methane using the Intergovernmental Panel on Climate Change methodology, and for carbon dioxide using the Century model. The performance objective for this indicator is to have declining net emissions of greenhouse gases over time (a specific reduction target has not been established for agriculture, but Canada's national goal is to reduce average annual emissions over the 2008–2012 period to 6% below 1990 emission levels).

Agricultural emissions of greenhouse gases, in carbon dioxide equivalents



Key results

Total estimated agricultural emissions of nitrous oxide, methane, and carbon dioxide (the first two expressed in carbon dioxide equivalents) in 1981, 1986, 1991, and 1996 were 83, 78, 77, and 86 megatonnes, respectively, representing about 13% of total 1996 Canadian emissions. These amounts include all sources associated with farming except food processing and transportation. Net emissions decreased by 7% between 1981 and 1991, and then rose 12% between 1991 and 1996. Overall, emissions rose by about 4% between 1981 and 1996.

Agricultural emissions of nitrous oxide in 1981, 1986, 1991, 1996 were 99, 96, 99, and 120 kilotonnes — stable between 1981 and 1991 and rising by 21% between 1991 and 1996. Agricultural emissions of methane were relatively constant, at 1045, 927, 949, and 1074 kilotonnes. Total agricultural emissions of carbon dioxide were 30, 28, 26, and 26 megatonnes, dropping by 13% between 1981 and 1996. This reduction in carbon dioxide emissions was mainly the result of adopting conservation farming practices. During this period, the increase in nitrous oxide and methane emissions was mainly the result of more intensive farming practices and growing use of nitrogen fertilizer.

Conclusion

Total agricultural emissions have increased from 83 megatonnes of carbon dioxide equivalent in 1981 to 86 megatonnes in 1996. Because agroecosystems are intensively managed, they present many opportunities to adopt measures that reduce greenhouse gas emissions. To quantify the benefits of these measures, better methods of measuring greenhouse gas emissions are needed.

15 Indicator: Availability of Wildlife Habitat on Farmland

P. Neave, E. Neave, T. Weins, and T. Riche

Geographic Scope: National, ecozones
Time series: 1981, 1991, 1996

Issue

Loss and alteration of habitat is the leading cause of depletion of the earth's wildlife species, and thus of biodiversity. Conversion of natural land to agriculture has contributed to declining wildlife habitat, but agriculture also offers better habitat than some other land uses by humans, such as urban development. Wildlife on farmland offer both advantages (e.g., aesthetic appeal, hunting, fishing) and disadvantages (e.g., reduced crop yields).

Indicator description

The indicator was developed for the seven main terrestrial ecozones in which agriculture is practised in Canada. It identifies the share (percentage) of habitat use units (each separate use of a specific habitat type by a species equals one habitat use unit) associated with agricultural habitat types that have increased, decreased, or remained constant in area between 1981 and 1996. The assessment is based on habitat use by mammals, birds, reptiles, and amphibians known to occur in the agricultural areas of each ecozone. The indicator also notes changes in the distribution of agricultural habitat types during this period. The five habitat types assessed correspond with the five main land use categories defined in the 1996 *Census of Agriculture* (Cropland, Summerfallow, Tame or Seeded Pasture, Natural Land for Pasture, and All Other Land). A national performance objective has not yet been established, but some objectives exist in specific habitat conservation programs throughout the country.

Key results

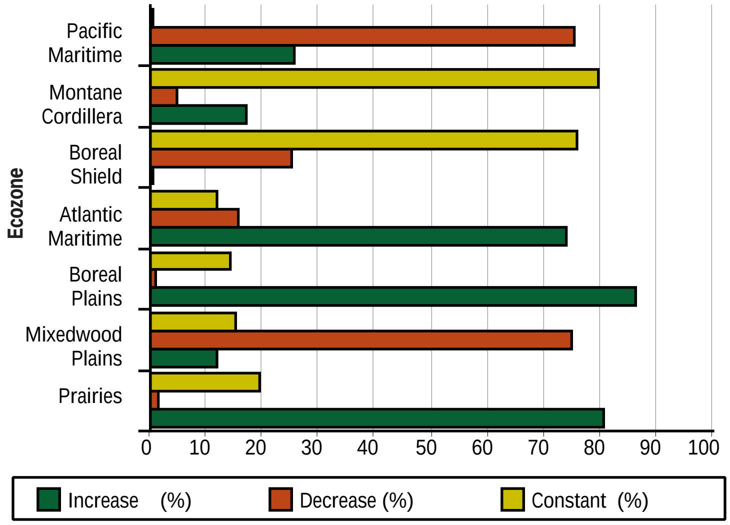
Between 1981 and 1996, habitat area increased for 86% of habitat use units in the Boreal Plains, 80% in the Prairies, and 73% in the Atlantic Maritime ecozones. In contrast, habitat area decreased for 74% of the habitat use units in the Mixedwood Plains and 75% in the Pacific Maritime ecozones. Habitat area remained relatively constant for 75% of habitat use units in the Boreal Shield and 79% of habitat use units in the Montane Cordillera.

Reduced area in Summerfallow and expanded area in All Other Land and Tame or Seeded Pasture account for most increases in habitat availability between 1981 and 1996. Decreases in habitat availability are mainly the result of the expansion of Cropland through the conversion of farmland more suited as wildlife habitat, such as Natural Land for Pasture and All Other Land.

Conclusion

Agricultural lands offer a variety of habitats for wildlife, but some types are superior to others, especially All Other Land and Natural Land for Pasture. Changes in agricultural land use from less intensive to more intensive practices create pressures on wildlife by making one or more of the habitat resources they depend on more scarce or otherwise unavailable. In general, from 1981 to 1996 agricultural habitat for wildlife shows positive or neutral trends for some species in all ecozones except the Pacific Maritime and Mixedwood Plains.

Share of habitat use units for which habitat area increased, decreased, or remained constant between 1981 and 1996



16 Indicator: Residual Nitrogen

K.B. MacDonald

Geographic Scope: Provincial
Time series: 1981, 1991, 1996

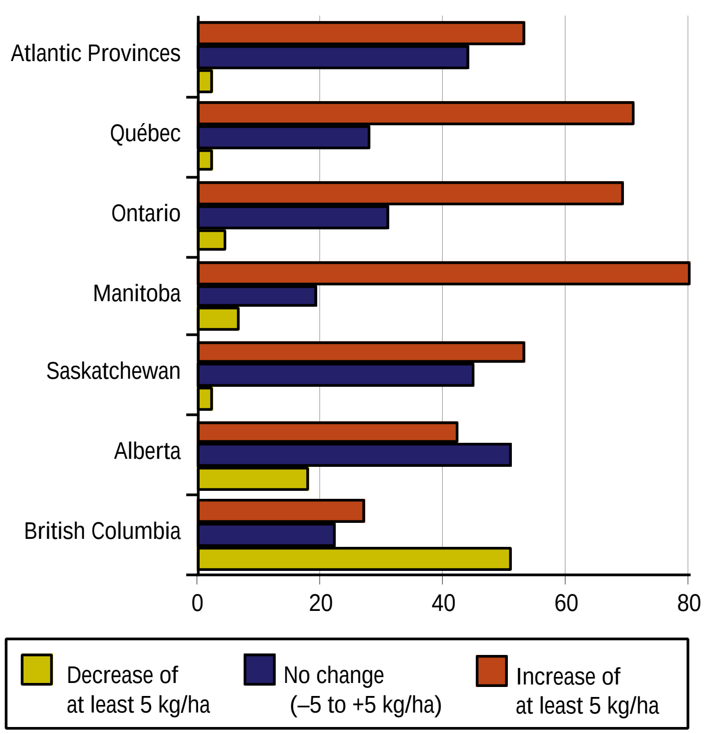
Issue

Applying nitrogen in excess of crop needs reflects inefficient nutrient management, incurs unnecessary costs, and poses a threat to water quality. Movement of nitrogen into the atmosphere as ammonia and nitrous oxide contributes to poor air quality and potentially to global warming.

Indicator description

The indicator estimates the difference between the amount of nitrogen available to the growing crop and the amount removed in the harvested crop. This difference was called residual nitrogen. Canadian farmland was assigned to one of four classes of residual nitrogen: Class 1: less than or equal to 20 kilograms of nitrogen per hectare (kg N/ha) (minimal), Class 2: 21 to 40 kg N/ha (expected in areas of intensive agriculture with low-demand crops, such as cereals), Class 3: 41 to 60 kg N/ha (expected in areas of intensive agriculture with high-demand crops), and Class 4: more than 60 kg N/ha. Classes 3 and 4 may represent areas where nitrogen is accumulating and poses an environmental risk. The performance objective for the indicator is to have all Canadian farmland in classes associated with no net accumulation of nitrogen over time.

Share (%) of farmland for which there was a change in the level of residual nitrogen between 1981 and 1996



Key results

In 1996, the Atlantic Provinces (52%) and British Columbia (70%) had the largest share of farmland in Class 1. Ontario (37%) and Quebec (28%) had the highest shares of farmland in Class 4. High levels of residual nitrogen (Class 4 in areas with high demand crops and Class 3 in areas with low demand crops) were associated with areas where the trend toward cropping intensification is confirmed by other indicators.

There was a strong trend between 1981 and 1996 toward increasing levels of residual nitrogen in all provinces except British Columbia. The share of farmland showing an increase in residual nitrogen levels of at least 5 kg/ha between these 2 years ranged from 27% in British Columbia to 80% in Manitoba.

Conclusion

The indicator shows a trend toward increasing amounts of residual nitrogen on farmland, but limitations of the data used to calculate the indicator allow only general interpretations of results. The indicator appears to be useful for regional comparisons and to highlight areas where field testing should be carried out to confirm actual levels of soil nitrogen. Further development of the indicator depends on refining many data components.

17 Indicator: Energy Use

R.J. MacGregor, R. Lindenbach, S. Weseen, and A. Lefebvre

Geographic Scope: National, regional
Time Series: 1981 to 1996

Issue

Agriculture requires energy as an input and produces products that contain energy. To meet growing world demand we must continually strive to increase output on a relatively fixed land base. This increase usually means having to use new technologies that need additional inputs, including energy. The issue is whether these new systems are sustainable.

Indicator description

Two indicators were developed to estimate the amount of energy contained in agricultural inputs and the amount contained in outputs used or consumed by humans. The preliminary performance objectives for these indicators are reduced energy input and increased energy output.

Key results

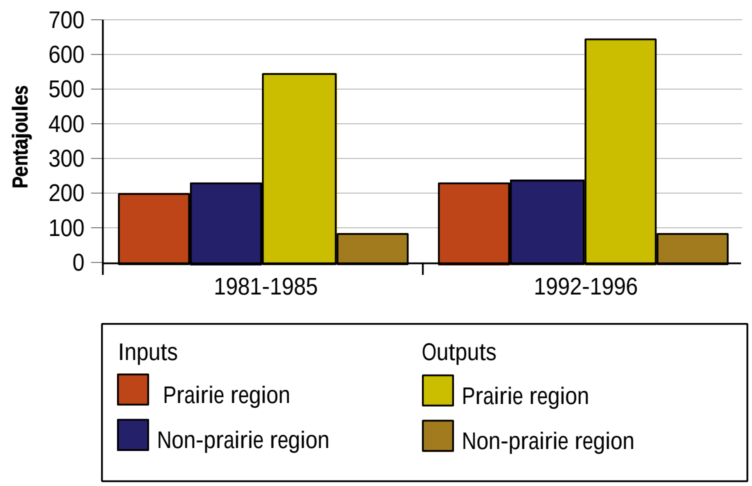
The indicator compares energy inputs and outputs between the early 1980s (1981–1985) and mid 1990s (1992–1996). Between these periods, the amount of energy input into Canada's primary agricultural production grew by 8%, from 341 petajoules (PJ) to 368 PJ. Greater use of mineral fertilizers accounts for this increase. The use of diesel fuel also grew (3% annually), but this change was largely offset by a drop in the use of gasoline (–5% annually) as farmers replaced gas powered equipment with diesel powered equipment. Canada's total energy output in agricultural primary products grew by 13%, with large contributions from major grains, animals, and other commodities. Total energy output can vary by more than 100 PJ from one year to the next, depending on grain yields.

The Prairies, with their greater emphasis on grain output (and bulk grain exports), are characterized by energy output greatly exceeding energy input: energy input grew by 14% and energy output grew by 19% (104 PJ). The non-Prairie regions that specialize to a greater degree in livestock production and energy-intensive cropping (e.g., horticulture) show a greater energy input than output: energy input grew by 3% while energy output dropped by 3% (2 PJ) in the same period. Agricultural energy output appears to be most affected by fluctuations in climate, but also by improvements in crop varieties and farming practices and by commodity prices.

Conclusion

Nationally, the growth rate of energy output exceeded that of energy input during the study period. The situation in the prairie provinces mirrored and influenced the national trend, whereas in the non-prairie region, energy inputs increased whereas energy outputs dropped. The energy contained in various inputs is a significant cost, and producers are expected to try to minimize these costs. This indicator provides some support for this proposition.

Total regional annual energy inputs and outputs, 1981–1985 and 1992–1996



18 Regional Analysis of Environmentally Sustainable Agriculture

T. McRae and C.A.S. Smith

Geographic scope: British Columbia, Prairie Provinces, Ontario, Quebec, Atlantic Provinces
Time series: 1981, 1991, 1996

British Columbia

Primary agricultural GDP grew by about 30% between 1981 and 1996 and environmental risks varied. Improvements were achieved for soils, but substantial portions of cropland remain at risk of unsustainable levels of water and tillage erosion. Wildlife habitat for a majority of habitat use units remained stable in the central portion of the province, increased in the Peace River region, but declined in the areas of more intensive agriculture in the Pacific Maritime ecozone. Greenhouse gas emissions were stable. The risk of water contamination by nitrogen increased, as did agricultural energy use intensity. Some soils in the Montane Cordillera ecozone and Peace River region are underfertilized, whereas other areas of the province under intensive horticulture and livestock production show increases in residual nitrogen.

Prairie Provinces

In the Prairie Provinces, strong growth (about 59%) in primary agricultural GDP was accompanied by notable progress in protecting soil health, increasing the area of agricultural habitats for most habitat use units, and reducing energy use intensity. Environmental costs from agriculture were mainly the result of greater greenhouse gas emissions. Increases in residual nitrogen had the mixed effect of conserving soil fertility, contributing to increased greenhouse gas (nitrous oxide) emissions, and possibly increasing the risk of water contamination by nitrogen. Indicators are currently lacking for important prairie issues such as water management and the effects of irrigation and intensive livestock operations on water quality.

Central Canada

Ontario achieved only moderate growth in agricultural GDP (about 8%) and mixed success in reducing environmental risks. The risk of soil degradation declined, except for that associated with soil compaction, but substantial portions of cropland remain at risk of unsustainable levels of water and tillage erosion. Greenhouse gas emissions remained stable. Agricultural habitat for most habitat use units held steady in the northern agricultural area of the province but declined in the south, south-central, and southeastern regions. Levels of residual nitrogen and risk of water contamination from nitrogen both increased considerably over much of the province. Agricultural energy use intensity remained largely unchanged.

Quebec showed moderate growth in agricultural GDP (about 13%) and environmental risks varied. Progress is evident for soils, for which most degradation risks remained steady or declined. Most cropland is at risk of tolerable levels of soil erosion. Greenhouse gas emissions also declined. Agricultural habitat area for most habitat use units remained stable in the northern portions of the province but shrank in areas of the Mixedwood Plains ecozone where production is more intensive. Levels of residual nitrogen and risk of water contamination by nitrogen rose considerably over much of the province. The risk of water contamination by phosphorus rose between 1981 and 1991 but dropped back to 1981 levels by 1996. Agricultural energy use intensity remained largely unchanged.

Atlantic Provinces

Agricultural GDP grew only slightly (about 1%) in the Atlantic region and environmental risks varied. Improvements were made in conserving agricultural wildlife habitat for most habitat use units, in increasing soil cover, and in reducing degradation risks to some soils. However, substantial portions of cropland remain at risk of unsustainable levels of erosion. Estimated levels of residual nitrogen and the risk of water contamination from nitrogen increased considerably over much of the region. Agricultural energy use intensity decreased slightly.

19 Conclusions

T. McRae and C.A.S. Smith

Canadian agriculture has made considerable progress in conserving the natural resource base which supports production, although some soils remain above tolerable levels of degradation risk. With regard to agriculture's compatibility with natural systems, performance is mixed. Several environmental risks have increased and environmental conditions have sometimes worsened. The main factor responsible has been an intensification of agriculture across much of the country resulting from structural changes in farming and increased market demand for some products.

The agri-environmental indicator study has made extensive use of available data, research and expertise, and revealed key strengths and limitations in the national capacity to assess the environmental sustainability of agriculture. To enhance analytical capacity, additional research is required to further understand agriculture–environment interactions and processes, and more work is needed to address data limitations and gaps.

The findings of this study suggest a need for ongoing efforts by policy makers, producers, researchers, analysts, educators, and consumers to achieve a more environmentally sustainable agriculture industry. Examples of how agri-environmental indicators can be used to support actions are provided and discussed in the full study report, *Environmental Sustainability of Canadian Agriculture: Report of the Agri-Environmental Indicator Project*.

Key findings for agriculture's environmental performance

Chapter or Section	**Findings** (1981–1996, except where noted otherwise)
Driving forces	Globalization and changes in technology, population growth, and market demand have often intensified agricultural production, sometimes with environmental consequences. At the same time, social preferences have evolved to demand a more environmentally sound agriculture. Potential environmental risks will continue to increase as intensification continues, requiring management responses from industry, governments, and consumers.
Farm management	Management of agricultural soils has improved overall. Overall, sound fertilizer and pest management practices are in use, although there is room for improvement. Manure is the nutrient source most needing improved management (above based on 1995 data only).
Soil quality	Soil degradation risks have been reduced overall. Additional effort is required to conserve soils remaining at risk of unsustainable levels of degradation.
Water quality	The risk of water contamination from nitrogen has increased overall in most humid areas (the risks were not assessed on the Prairies, but these have likely increased due to intensive livestock operations).
Greenhouse gas emissions	There was a small overall increase in emissions, with most increases occurring from 1991 to 1996. Carbon dioxide emissions decreased, nitrous oxide emissions increased, and methane emissions remained stable.
Agricultural wildlife habitat	Agricultural lands are used extensively by wildlife for their habitat needs. Most habitat uses were supported by an increasing agricultural habitat area, except in southwestern B.C. and southern Quebec and Ontario, where most habitat uses were supported by a shrinking agricultural habitat area.
Production intensity	Levels of residual nitrogen per hectare increased in all agricultural regions except B.C. (where some regional increases were evident). Increases on the Prairies are beneficial to soils in production systems with a net nitrogen deficit. Relative gains were realized nationally and on the prairies, as growth in agricultural energy output exceeded growth in agricultural energy input. In the non-prairie region, overall energy inputs increased, whereas overall energy outputs dropped.