# AGRI-ENVIRONMENTAL INDICATOR PROJECT

## Agriculture and Agri-Food Canada

REPORT NO. 25

# INDICATOR OF RISK OF SOIL DEGRADATION: EROSION COMPONENT
# THE RISK OF SOIL EROSION IN CANADA

Edited by: I.J. Shelton and G.J. Wall

Prepared by the Soil Degradation Working Group of Agriculture and Agri-Food Canada

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



FEBRUARY 1998

## PREFACE

The Agri-Environmental Indicator (AEI) Project of Agriculture and Agri-Food Canada (AAFC) was initiated in 1993 in response to recommendations made by several agencies, organizations and special studies. The overall objective of the project is to develop and provide information to help integrate environmental considerations into decision-making processes of the agri-food sector.

The project aims to develop a core set of regionally-sensitive national indicators that build on and enhance the information base currently available on environmental conditions and trends related to primary agriculture in Canada. The soil erosion component of the Indicator of Risk of Soil Degradation is an important part of the core set of indicators. Indicators are also being developed for other aspects of agricultural soil health and in relation to issues of agricultural water quality, agroecosystem biodiversity, agricultural greenhouse gases, farm resource management and agricultural production efficiency. Research results in the form of progress reports, discussion papers and scientific articles are released as they become available. A comprehensive AEI Project report will be published in 1999.

This report provides a regional perspective on soil erosion risk across Canada and complements material on soil erosion published by Agriculture and Agri-Food Canada in 1995 (Wall et al., 1995). The methods used to develop the erosion risk indicators are also described.

Comments or questions about this report should be addressed to:

**Dr. Greg Wall**
Ontario Land Resource Unit
Greenhouse and Processing Crops Research Centre
Research Branch, Agriculture and Agri-Food Canada
Guelph, Ontario
N1H 3N6

Telephone: (519) 826-2086
Facsimile: (519) 826-2090
E-mail: wallg@em.agr.ca

## TABLE OF CONTENTS

## Figures



## Tables

# SOIL EROSION RISK IN CANADA

## 1.0 INTRODUCTION

Soil erosion is the wearing away of the land surface by water, wind or ice. Erosion is a powerful, natural process that can occur on crop land, urban areas and forested land. Through human action, erosion can be accelerated to levels that cause environmental and economic problems, or managed so that specific uses of land are sustained.

The 1984 report entitled "Soil at Risk" documented the growing problem of soil erosion in Canada. This report increased public awareness of the real threat to the global ecosystem that soil erosion poses as well as the real cost of erosion to agricultural production. From this work it was estimated that the value of topsoil lost from water erosion alone is about $400 million dollars annually. Most farmland erosion is caused by wind and water. Tillage can also cause erosion but is limited to certain landscapes. The extent of erosion by each or a combination of these forces is highly variable: it can range from almost unnoticeable to catastrophic.

Consequently, several nation-wide and regional programs have been implemented to address the problems of soil erosion. Many soil conservation practices have been developed and adopted. There is an ongoing need in research to match the most suitable and cost effective ways to inhibit soil erosion on specific landscapes. The complex process of soil erosion is still intently studied by soil scientists around the world - mostly using empirical and process-based models. These models still cannot simulate erosion very well under all conditions. Irrespective of the state of soil erosion research there remains a need to evaluate what progress has been made to date to reduce the risk of erosion in Canada and to identify areas where further improvements are essential to sustain agricultural production.

Erosion can be controlled but it can't be eliminated. It is a natural process and will occur in nature regardless of anthropogenic influence. Moreover, some soils are inherently more susceptible to erosion than others. This report applies the principles of both **inherent** and **actual** erosion risk. **Inherent** erosion risk means that the land is assumed to be bare (ie. no protective vegetation or cover) and that no conservation practices have been employed. Using these assumptions allows us to examine the inherent characteristics of the landscape and climate and their direct effect, both combined or respective, on erosion potential. 'Inherent erosion risk' is useful for determining the likelihood of erosion occurring, identifying when and where soil conservation measures are needed to control erosion and targeting soil conservation programs. **Actual** erosion risk differs from inherent erosion risk in that land use practices are taken into account in terms of their effect on erosion potential. In this report, 'actual erosion risk' is used to reflect erosion trends under actual land management practices.

## 1.1 Objectives

This study reports indicators of soil erosion risk that focus on recent progress across the country in addressing issues of both wind and water erosion. The specific study objectives addressed in the following sections of this report are:

- to identify estimated rates of erosion risk at the national, provincial and soil landscape level across Canada; and
- to identify changes in soil erosion risk over a 10 year period (1981-1991).

# 2.0 BACKGROUND

## 2.1 Factors Affecting Soil Erosion

### *2.1.1 Water Erosion*

Several soil, landscape, and climatic factors can affect water erosion. Rainfall and runoff are the driving forces behind this process. The energy from a single raindrop causes **splash erosion** that has been found to move soil metres down slope. Runoff in the form of shallow sheet flow or concentrated rill flow transports soil from fields to streams. Soil texture also affects erosion rates. Medium textured soils high in silt and fine sand are often the most erodible while loamy and clayey soils that aggregate together are the least erodible. Organic matter content of the soil is also a contributing factor because it helps to bind soil particles into larger aggregates which are better able to resist erosion. Clearly, topography is a controlling factor because slope steepness and slope length will affect the rate that water and soil will move off the landscape. The principle being: the longer and steeper the slope - the higher the erosion risk. Some soil conservation structures like **contouring** and **terracing** help to reduce the impact of slope angle and length. Manipulation of these slope factors occurs primarily for high value crops where diversions or small earth dikes can be used to reduce slope length of terraces.

Research and in-field experiments confirm that vegetative soil cover and associated residues are the most critical factors controlling the erosion rate because they protect the soil from raindrop impact and help to reduce runoff. Farmers can control erosion losses by maximizing vegetative cover throughout the year. Direction and type of cultivation are other management factors which effect erosion and are within the farmer's control. Up and down slope cultivation accelerates soil erosion especially under row crop production. Whereas, **cross-slope tillage** is an inexpensive means of controlling runoff and soil loss. Landscape conditions affecting soil infiltration and drainage also influence soil erosion rates.

### *2.1.2 Wind Erosion*

Soil is most easily moved by the wind if it is dry, loose and unprotected by either growing vegetation or an adequate cover of crop residue. Native grassland seldom blows, unless badly overgrazed. It is said that wind erosion is nature's reply to man's misuse to the land. That misuse most commonly takes the form of excessive or improper tillage that breaks up surface clods and flattens or buries crop residues. And, if continued annually with little attention to soil management, the soil will lose its organic matter content in the topsoil. Such poor management properties enhance risk of wind erosion. Large fields that give the wind an unobstructed sweep for a long distance, the production of crops that generate little or no residue, and the frequent use of fallow, also contribute to the risk of wind erosion.

Within a particular region, the risk of wind erosion varies with the weather (precipitation and wind patterns), the soil conditions and the type and size of farms. Wind itself is a critical factor. A wind velocity as low as 25 kph. will cause drifting on a field where soil particles are small and there is no protection. High winds during periods of drought promote rapid drying of the soil surface, further increasing the risk.

Soils, depending on their texture (size of individual soil particles) and structure (arrangement of these particles into aggregates or clods), vary in their susceptibility to blowing. Sandy soils move readily in the wind where the surface is unprotected by vegetation. In the southern prairies clayey soils are also often subject to blowing, particularly in the early spring when the soil surface is loose and friable. Artificially drained peatlands can be seriously damaged by the wind if the surface becomes dry and pulverized.

### *2.1.3 Tillage Erosion*

Tillage operations can move soil down slope on certain landforms. Soil movement by tillage is affected by the speed and type of tillage implement used, slope gradient and shape, direction of tillage and tillage depth. Significant tillage erosion losses have been measured on convex-shaped slope positions. Soil factors such as moisture content and texture are also influential factors. Due to the relatively recent recognition of tillage erosion as a means of soil movement, details on its occurrence and severity within Canada are limited. Consequently, the remainder of this chapter will focus on wind and water erosion.

## 2.2 Recognition

Erosion can be obvious - especially when in the form of either a **gully** or a dust storm. More subtle forms, such as small **rills** or channels created by water erosion may involve significant soil loss. However, such erosion features are easily ploughed over and therefore less apparent, even if they reoccur repeatedly in the same positions. **Sheet erosion** (another type of water erosion) is often barely visible because it involves the gradual removal of a uniform thin layer or "sheet" of soil from the surface. Indicators of past sheet erosion activity are small "pedestals" of soil that form under stones or pieces of crop residue. The residue protects the underlying soil from the sheet erosion and deters soil movement. The effects of erosion only become noticeable when the loss of topsoil and its valuable nutrients result in poor crops and yield reductions. If enough of the topsoil erodes, the lighter coloured subsoil which is much lower in organic matter/nutrients will be exposed. Erosion is often most pronounced on slope crest positions that may be affected by a combination of wind, water, and tillage erosion processes.

## 2.3 Controlling Soil Erosion

Although agricultural practices accelerate the erosion process, attention to cropping, tillage and water management techniques can reduce erosion rates. Increasing the amount of crop residue left on the soil surface can be one of the most significant methods to reduce soil loss. Conventional farming methods, in most parts of the country, have involved ploughing the soil to bury old crop residue to prepare a "clean", fine seedbed for the next crop. Today, more and more farmers are adopting conservation tillage practices that leave much of the crop residue on the soil surface providing significant protection from erosion. Many producers across the country have realized the erosion-resistant benefits of no-till farming where the crops are planted directly into the residue of the previous crop.

Altering tillage practices is only part of a soil conservation system: erosion can also be reduced by changing the cropping systems. Inclusion of forage crops into rotations reduces soil erosion losses and contributes to rebuilding soil structure and organic matter levels. Planting row crops across the slope or following the contour of the land effectively creates many small dams that both slow the flow of water down the slope and promote greater infiltration into the soil, thus reducing the amount of soil carried off the landscape. Alternating tilled crops in narrow strips across a long slope (**strip cropping**) reduces the potential for water erosion. Water flow down the slope is impeded when it reaches a strip of a crop like hay or grain. Interseeding crops such as red clover into row crops or the use of cover crops can reduce erosion rates during the growing season and provide winter cover and erosion control.

Where water erosion is severe, conservation tillage and cropping systems might be inadequate to control erosion and runoff. Other soil conservation structures which can be more costly and labour-intensive might be required. The construction of **terraces** (or steps) effectively reduces the slope steepness and length, thereby reducing water velocity and the potential for soil movement. Permanent small earth berms or diversions run along the contour are another method used to 'reduce slope length'. Grassed waterways are effective in reducing the transport of soils from the fields into adjacent areas or watercourses. The areas in the field where water concentrates are graded and seeded to grass, which in turn traps sediment moving off of the field. The grass buffer is a permanent feature, with the farmer cropping only the land around the waterway.

Increases in surface residue, and consequently increased surface protection, reduces wind erosion. Rough soil surfaces, created through various tillage technologies, also can reduce wind velocities as does planting crops perpendicular to the prevailing wind direction.

Windbreaks, consisting of trees and/or shrubs planted along defined intervals in the fields, reduce windspeed.

## 2.4 Relationship to Soil Quality

Soil quality can be described as a "soil's fitness to support crop growth without resulting in soil degradation or otherwise harming the environment"(The Health of Our Soils 1995). Soil quality is defined as a composite of the soil's chemical, physical and biological properties as they perform three critical functions:

i) provide a medium for plant growth,
ii) regulate and partition water flow through the environment, and
iii) serve as an effective environmental buffer.

Gaseous partitioning could be considered a fourth critical function.

Soil erosion is related to soil quality in several ways. First, chemical, physical, and biological properties of soil (such as pH, cation exchange capacity and organic matter content; bulk density, structure and permeability; and soil organisms, respectively) are important as indicators of soil quality. Soil erosion can affect these factors through the removal and deposition of surface topsoil, changing the nature of the surface soil which in turn affects soil quality, often detrimentally. Erosion selectively removes the most easily dislodged and transported silt and very fine sand particles and organic material from the surface. The remaining soil is often coarser and lower in nutrients. Erosion causes a *decrease* in fertility levels and infiltration capacity on the eroded sites, and an *increase* in crusting problems, runoff and pH levels as the more alkaline subsurface soils are exposed. Changes in the soil influence landscape infiltration/runoff relationships. As erosion progresses, rills and gullies are created, through which the eroded material is transported and deposited offsite - at the base of the slope, in adjacent fields, or in nearby water courses. Soil erosion processes can negatively affect crop yields on site, yet enhanced fertility and organic matter levels can be experienced in depositional areas. Eroded sediments can cause costly physical problems, such as the clogging of drainage ditches. In downstream environments, water quality is affected through the presence of sediments or by sediment's role as a sink for contaminants.

Secondly, the degree of the soil erosion process itself affects the three critical functions shown above. Negative impacts caused by erosion on a soil's chemical, physical and biological properties reduce the ability of the soil to sustain the same level of production. Often, the erosion process accelerates as soil quality deteriorates. For example, a decrease in fertility levels on the eroded site can be reflected in lower yields and poorer vegetative covering of the soil, which then provides less coverage and erosion-protection.

## 3.0 METHODS

### 3.1 Water Erosion

#### *3.1.1 Inherent Erosion Risk*

**Soil Landscape of Canada (SLC)** maps have been published at a scale of 1:1 million for all of Canada and are available from the Research Branch of Agriculture and Agri-Food Canada in Ottawa. They are used as the basis for the water erosion risk calculations. Soil landscape polygons are depicted in these maps to portray the inherent characteristics of one or more soils in relation to the landscape. Soil and landscape attributes are recorded in the extended legend for both the dominant and subdominant soil landscapes found in each polygon.

The Universal Soil Loss Equation **(USLE)** was selected to estimate water erosion risk. It is an empirical model that combines the factors affecting water erosion and predicts soil losses (Wischmeier and Smith, 1978). The equation is:

$$\mathbf{A = R * K * LS * C * P}$$

where:
**A**= soil loss rate (t/ha/y)
**R** = rainfall and runoff erosivity factor (MJ mm/ha h y)
**K** = soil erodibility factor (t ha h/h MJ mm)
**LS** = slope length and steepness factor (unitless)
**C**= crop management factor (unitless)
**P** = conservation management factor (unitless)

Newer, more process-based models exist, but their data input requirements preclude their use on the landscape scale.

Utilizing Canada's soil and climatic databases, R, K and LS factors were determined for most of the individual soil landscape polygons (SLC polygons) in Canada.

R factors were calculated for Canada in the following way:

- British Columbia - Rs was calculated using the procedure by McCool et al. (1982).
- For areas east of the Rocky Mountains
  - Rt term represents total erosivity from rainfall (R),
  - Rs represents snowmelt and runoff

The Wischmeier and Smith (1978) method was used to determine R and Madramootoo's (1988) method was used to calculate Rs. Appropriate Rt values were obtained from interpolation of Madramootoo's isoline maps for individual soil landscape polygons

K factor values were calculated for both dominant and subdominant soils in each polygon using the Wischmeier and Smith (1978) methodology.

The topographic factor (LS) was determined for both the dominant and subdominant soil landscape in each polygon. The LS factor is a combination of slope length, based on the surface form, and steepness which is represented by the midpoint of the slope class.

For inherent soil erosion risk, the USLE is used with R, K and LS factors only, setting the C and P factors to 1. R, K, and LS are reasonable factors to predict **inherent erosion risk** because it assumes that the soil is bare and unprotected and that no structural conservation methods are in place to control erosion. The estimate is therefore termed inherent because it reflects the risk based only on physiographic and climatic features of a landscape and not on land management. More details on the R, K, and LS factor value calculations can be found in the Water Erosion Risk reports and maps published for most provinces.

### *3.1.2 Actual Erosion Risk*

Canadian Census of Agriculture data from 1981 and 1991 were linked to determine crop management factor values (C) for each soil landscape polygon across the country. The Territories and Newfoundland were excluded because of a limited agricultural land base.

#### *SLC Scale Calculation*

Generalized C factors were determined for summer fallow and crops grown in each province or each unique agricultural region within a province from available data and expert opinion. Area in *crop land* is the sum of land in summer fallow and land in annual and perennial crops. Land in *improved pasture, unimproved pasture and other improved land* were not included in crop land area. Unique regions were identified on the basis of unique cropping practice and/or climatic conditions. No rotational C factors were used because the census data did not provide any cropping practice history. These C factors were then weighted based on each crop's distribution within the polygon. The values were then summed to determine an overall C factor value for the polygon. The 1991 census differed from 1981 in that details on the areas under conventional, conservation and no till management were reported and linked to each polygon. Since tillage affects the C factor value, these data were useful in determining more accurate C factors for each polygon to reflect the management practice. And, since there was no management information by crop or type in the 1991 Census, it was generally assumed that the tillage areas were evenly distributed across all crops in the polygon. Consequently, the 1991 C factor for each crop was weighted according to the distribution of management practices reported for the whole polygon. In 1981, all tillage practices were assumed to be conventional so only a single C factor value was used for each reported crop in each region. An example of a polygon C factor calculation is given in Appendix 1.

*Calculation/Estimation of Erosion Trends*

Once weighted C factors were obtained for each polygon for the 1981 and 1991 Census data, comparisons were made to determine the erosion trend (i.e. percent improvement or degeneration) for each region (if applicable) and then for the entire province. The individual C factor value for each polygon was area-weighted for region and the province. It has been assumed that the other factors in the USLE (R, K, LS, and P) have remained the same for 1981 and 1991, so that percent changes in C factors can be directly interpreted as percent changes in soil erosion rates.

Using R, K, and LS rates for the dominant soil and the subdominant soil from the provincial erosion risk maps, soil loss rates were calculated using the 1981 and 1991 C factor values. It was assumed that 60% of the soil loss rate applies to the dominant soil and the remaining 40% applies to the subdominant soil.

Soil loss rates determined with the USLE were grouped into 5 erosion risk classes ranging from very low to severe. These are defined as follows:

| | | |
|---|---|---|
| <u>**Sustainable**</u> | **Tolerable** | - less than 6 tonnes/ha/yr. |
| <u>**Unsustainable**</u> | **Low** | - 6.0 to 10.9 tonnes/ha/yr |
| | **Moderate** | - 11.0 to 21.9 tonnes/ha/yr. |
| | **High** | - 22.0 to 32.9 tonnes/ha/yr. |
| | **Severe** | - greater than 32.9 tonnes/ha/yr |

The lowest class is generally considered to be a tolerable risk of soil erosion for sustainable crop production. The other low to severe classes of soil erosion represent conditions where the implementation of soil and water conservation practices are required for sustained production of agricultural crops. Reporting the actual erosion rates could be misleading, because the USLE as an empirical model does not measure erosion but gives a potential for loss, and also because it is a field-scale model being used on much larger areas (soil landscape polygons). Thus, computed values of soil erosion risk should not be used quantitatively; rather, they should be used qualitatively to compare polygons by erosion risk class.

Changes in erosion risk were also determined by comparing crop land areas within each risk class for 1981 and 1991. This analysis determined where erosion risk was improving due to improved cropping and tillage practices.

## 3.2 Wind Erosion

Wind erosion occurs in most parts of Canada. The problem is greatest in the Prairies, where the dry climate and large expanses of fairly flat land can produce widespread areas where wind erosion can take place. Conversely, the same conditions that contribute to wind erosion (low rainfall, wide open areas with gentle slopes) limit the damage caused by water erosion, making water erosion a much less serious problem in the Prairies. In areas other than the Prairies water tends to be the predominant erosion agent, and wind erosion occurs in relatively small, localized areas. Therefore, wind erosion estimates were only made for the Prairies.

The erosion analysis was based on 1:1 million scale Soil Landscapes of Canada maps for each of the Prairie Provinces. Pertinent soil and landscape attributes were recorded for each polygon (SLC) on the map. Climate and land use parameters were linked to the SLC polygons to provide an integrated land resource digital database to facilitate analysis.

The conceptual procedure for estimating the wind erosion risk involved first the calculation of inherent risk on bare unprotected soil, which was then modified by an erosion reduction factor which accounts for the effectiveness of the cover or management practices in reducing the inherent risk.

### *3.2.1 Inherent erosion risk*

Wind erosion rates for bare unprotected soil were calculated using an equation developed from the work of Chepil (1945, 1956) and Chepil and Woodruff (1963). The equation is as follows:

$$E = KC(V2 - 6\ W2)1.5$$

where
E = maximum instantaneous soil movement
K = surface roughness and aggregation factor
C = factor representing soil resistance to movement by wind
V = drag velocity of the wind at the soil surface
6 = soil moisture shear resistance
W = surface soil moisture content (volumetric)

The output was treated as a dimensionless index. For Alberta and Manitoba the data were taken from the wind erosion risk maps (Coote, Eilers and Langman, 1989), (Coote and Pettapiece, 1987). For Saskatchewan the bare soil erosion rates were calculated using a similar procedure to that in the neighbouring Provinces.

Table 1. Inherent Wind Erosion Risk* in the Prairies

| Wind Risk Class | Cultivated land (%) | | | |
|---|---|---|---|---|
| | Alberta | Saskatchewan | Manitoba | Prairies |
| Tolerable | 7 | 4 | 8 | 6 |
| Unsustainable | | | | |
| Low | 39 | 23 | 37 | 31 |
| Moderate | 24 | 34 | 19 | 29 |
| High | 27 | 33 | 30 | 30 |
| Severe | 4 | 7 | 5 | 6 |

* note: numbers represent % of cultivated land in each class

### *3.2.2 Actual Erosion Risk*

The actual erosion risk was estimated by reducing the erosion rate for bare soil by a factor based on the prevailing land use and management practices, such as crop type and tillage regime, for each SLC polygon. The trend in erosion risk was calculated for each polygon by comparing the erosion risk in 1991 with that in 1981.

*Census Information*

Land use and management information, such as crop type and the area of fallow, was obtained from the 1981 and 1991 Census of Agriculture and linked to the SLC polygons. (Table 1). The Census information was supplemented by a questionnaire sent to farmers, extension specialists, and soil conservationists to obtain a more reliable estimate of the use of conservation practices, for both the 1981 and 1991 periods (Table 2).

*Linkage of Census data and SLC polygons*

For 1981, the Census information was linked to SLC polygons via enumeration areas (EA), whereas for the 1991 census the linkage was based on farm headquarters. Since the two methods were different, the amount of cultivated land within each SLC polygon was considered a constant for both periods (1981 and 1991). Thus for the trend analysis the change in erosion risk was based solely on the change in cropping and tillage practices.

Table 2. Changes (%) in cropping practices on the Prairies, 1981 - 1991

| Region (soil zone) | Fallow '81-'91 | Cereals '81-'91 | Oilseed '81-'91 | Forage '81-'91 |
|---|---|---|---|---|
| Mixed grassland (Brown) | - 3.3 | + 0.5 | n/a | + 1.4 |
| Moist Mixed Grassland | - 6.7 | + 1.2 | + 2.1 | + 3.1 |
| Parkland (Black) | - 10.2 | + 2.1 | + 5.4 | + 3.1 |
| Boreal Transition (Gray) | - 9.3 | - 9.9 | + 6.4 | + 12.6 |

Table 3. Tillage practices on the Prairies, 1991

| Region (soil zone) | Fallow % of total area | | | Crop land % of total area | | |
|---|---|---|---|---|---|---|
| | Conv | Cons | No till | Conv | Cons | No till |
| Mixed grass (Brown) | 82 | 15 | 3 | 80 | 18 | 2 |
| Moist Mixed Grass (Dark Brown) | 82 | 15 | 3 | 77 | 20 | 3 |
| Parkland (Black) | 87 | 10 | 3 | 74 | 23 | 3 |
| Boreal transition (Gray) | 94 | 5 | 1 | 77 | 21 | 2 |
| Peace River | 86 | 13 | 1 | 86 | 13 | 1 |

* for the trend analysis the amount of conservation and notill in 1981 was assumed to be zero.
Source: farm questionnaire

*Wind erosion - residue reduction factor (RED)*

The erosion reduction factor for wind erosion is based on the amount of residue and its effectiveness in controlling erosion. Initial residues, or the residues at harvest, were calculated using ten-year average crop yields, adjusted for soil zone and soil texture, multiplied by a crop conversion factor (unit weight*straw:grain ratio)(Appendix 1). To calculate the residues for the following April-May period, which coincides with the highest wind erosion risk, initial residues were reduced according to cropping system and type and frequency of tillage. For the trend analysis, the use of reduced tillage systems was assumed negligible in 1981.

In order to estimate the amount of residue (RES) that remains the following April-May for each crop group, the following rotations and management scenarios were considered for each region.

Rotation: % Crop land to be fallowed the following year
% Crop land to be seeded the following year
% Fallow to be seeded the following year

Tillage: % Conventional
% Conservation
% No till (direct seeding)

For crop land to be fallowed the following year, it was assumed that the amount of residue present during the April-May period equals the initial residues less an over winter decomposition factor. Tillage regime is irrelevant. For crop land that is to be seeded the following year, tillage operations representing conventional, conservation, and no till systems were considered.

It was assumed that all crop land reported in the census was seeded the following year, with the exception of spring cereals which was apportioned between fallow and seeded. The area of spring cereals to be fallowed was assumed to equal to the current fallow area.

The proportion of the initial residues remaining the following April-May, along with assumptions of tillage practices associated with conventional, conservation and no till systems are given in Table 3. The calculation of the actual amount of residue for each crop group (RES) also requires an estimate of the relative area (%) in all 3 systems as well as the residue reduction associated with each tillage system.

e.g. Residue Cover for Cereals

$$RES(cereal) = \frac{\{IRc*Cf*Rcf\}+\{IRc*Csv*Rcsv\}+\{IRc*Css*Rcss\}+\{IRc*Csn*Rcsn\}}{Ct}$$

where IRc - initial residue for cereals (kg/ha)
Cf - area of cereals fallowed the following year (ha)
Csv - area of cereals seeded the following year under conventional tillage (ha)
Css - area of cereals seeded the following year under conservation tillage (ha)
Csn - area of cereals seeded the following year under no till (ha)
Ct - total area of cereals
Rcf - reduction for cereals fallowed the following year
Rcsv - reduction for cereals seeded the following year - conventional tillage(%)
Rcss - reduction for cereals seeded the following year - conservation tillage(%)
Rcsn - reduction for cereals seeded the following year - no till(%)

e.g. Residue Cover for Oilseeds

$$RES(oilseed) = \frac{\{IRo*Ov*Rosv\}+\{IRo*Os*Ross\}+\{IRo*On*Rosn\}}{Ot}$$

where IRo - initial residue (kg/ha)
Ov - area of oilseeds seeded the following year under conventional tillage (ha)
Os - area of oilseeds seeded the following year under conservation tillage (ha)
On - area of oilseeds to be seeded the following year under no till (ha)
Ot - total area of oilseeds (ha)
Rosv - reduction for oilseeds seeded the following year - conventional tillage(%)
Ross - reduction for oilseeds seeded the following year - conservation tillage(%)
Rosn - reduction for oilseeds seeded the following year - notill(%)

Table 4. Crop residue reduction in relation to tillage practices

| Ecoregion (soil zone) | Cropping sequence | Tillage system | Tillage operation | Remaining residue (%) (April-May) |
|---|---|---|---|---|
| Mixed grassland (Brown-Dark Brown) | Crop-->Crop | Conventional | s-cultivator | 50 |
| | | | s-disc | |
| | | | s-harrow (2x) | |
| | | Conservation | s-air seeder | 76 |
| | | | s-harrow | |
| | | Direct seeding | s-air seeder | 81 |
| | Crop-->Fallow | | none | 90 |
| | Crop-->Fallow-->Crop | Conventional | f-cultivator (4x) | 11 |
| | | | s-cultivator | |
| | | | s-disc | |
| | | | s-harrow | |
| | | Conservation Direct seeding | f-cultivator(2x) | 22 |
| | | | s-air seeder | |
| | | | s-harrow | |
| | | | s-air seeder | 36 |
| Parkland, Boreal | Crop-->Fallow | Conventional | f-cultivator | 45 |
| | | | s-cultivator | |
| | | | s-hoedrill | |
| | | | s-harrow (3x) | |
| | | Conservation | s-cultivator | 60 |
| | | | s-air seeder | |
| | | | s-harrow | |
| | | Direct seeding | s-air seeder | 81 |
| | Crop-->Fallow | | none | 90 |

| | | | | |
|---|---|---|---|---|
| | Crop-->Fallow-->Crop | Conventional | f-cultivator (6x) | 6 |
| | | | s-cultivator | |
| | | | s-hoedrill | |
| | | | s-harrow (2x) | |
| | | Conservation | f-cultivator (2x) | 20 |
| | | | s-air seeder | |
| | | | s-harrow | |
| | | Direct seeding | s-air seeder | 32 |

e.g. Residue Cover for Fallow

$$RES(fallow) = \frac{\{IRc*Fv*Rfv\}+\{IRc*Fs*Rfs\}+\{IRc*OFn*Rfn\}}{Ft}$$

where IRc - initial residue (cereals) (kg/ha)
Fv - area of fallow under conventional tillage (ha)
Fs - area of fallow under conservation tillage (ha)
Fn - area of no till fallow (ha)
Ft - total area of fallow (ha)
Rfv - reduction for fallow - conventional tillage(%)
Rfs - reduction for fallow - conservation tillage(%)
Rfn - reduction for no till fallow (%)

The wind erosion reduction value (RED) was calculated for each crop group (e.g. cereals, oilseeds etc.) according to the following equation.

e.g. RED = A + B(RES)-C(EROS)

where RED = wind erosion reduction factor
A,B,C = coefficients based on crop type (cereal, oilseed, fallow etc.)
RES = amount of residues (kg/ha)
EROS = bare soil erosion rate

The RED value for each soil landscape type within the polygon was calculated as a weighted average of the crop groups.

$$RED = \frac{\{RED(cereals)*Area\text{-}C\}+\{RED(oilseeds)*Area\text{-}O\}+\{RED(fallow)*Area\text{-}F\}\ldots}{\text{Cultivated Area}}$$

The above procedure was repeated for the cultivated land in the subdominant soil landscape. It was assumed that the proportion of cultivated land within the polygon was the same for both the dominant and subdominant components. If this was obviously not the case (e.g. subdominant slope = d), then adjustments are made. It is also assumed that the extent of cultivated land and relative extent of the various crops was the same for subdominant landscape as for the dominant landscape. The actual erosion rate was then estimated for each of the dominant and subdominant soil landscapes as follows:

$$NEROS = EROS\ (1\text{-}RED)$$

where
NEROS - actual erosion rate (kg/ha)
EROS - bare soil erosion rate (kg/ha)
RED - reduction factor

For the trend analysis, the total amount of erosion (tonnes) was calculated for each polygon by multiplying the actual soil erosion rate by the area of cultivated land in each soil landscape. The dominant and subdominant soil-landscapes were then summed for the polygon as a whole. The trend was based on the difference between the 1981 and 1991 periods.

# 4.0 RESULTS

## 4.1 Water Erosion

### *4.1.1 Inherent Erosion Risk*

Table 5. gives a national summary of inherent water erosion risk information. Approximately 63 % of the Canadian cultivated agricultural land base has a negligible to low water erosion risk while 20 % has a high to severe risk. The provinces with the highest water erosion potential include British Columbia, Ontario, Quebec and the Maritimes where greater than 40% of the agricultural land base has a high to severe water erosion potential. The prairie provinces have a high (greater than 50%) percentage of land with negligible to low water erosion potential due to their relatively dry climate and gently sloping landscapes.

Table 5. Inherent Water Erosion Risk* in Canada

| Water | BC | Alta | Sask | Man | Ont | Que | NB | NS | PEI | Canada |
|---|---|---|---|---|---|---|---|---|---|---|
| **Tolerable** | 5 | 39 | 51 | 35 | 12 | 18 | 0 | 3 | 1 | 40 |
| **Unsustainable** | | | | | | | | | | |
| Low | 8 | 16 | 26 | 41 | 11 | 12 | 4 | 6 | 7 | 23 |
| Moderate | 13 | 17 | 19 | 6 | 24 | 14 | 16 | 4 | 11 | 17 |
| High | 3 | 10 | 3 | 4 | 25 | 4 | 13 | 3 | 37 | 7 |
| Severe | 72 | 18 | 1 | 14 | 27 | 43 | 67 | 84 | 44 | 13 |

* note: numbers represent % of cultivated land in each class

### *4.1.2 Actual Erosion Risk*

#### *SLC Scale Analysis*

*British Columbia*

British Columbia was subdivided into 4 agricultural regions (Fig.1) on the basis of unique climate, soil landscape and agricultural practices.
The **South Coastal Region** which includes the Lower Fraser Valley and Vancouver Island contains 10% of the crop land area in B.C. This area is unique from the other 3 regions because of a wet coastal climate. Seventy percent of the normal annual precipitation (mainly rain) occurs through the October through March period when crop cover is often absent and exposed soils are very prone to erosion. Intensive row cropping of vegetables and berries contribute to the erosion risk for this region.

The **Southern Interior Region** includes the Cariboo, Thompson, Okanagan and Kootenay Regions, and contains just under 30% of the crop land area in B.C. Agriculture varies from beef production in the Cariboo Region to tree fruits and grapes in the Okanagan Valley. The **Central Interior Region** has approximately 11% of the provincial area in crop land, where cereal grains and forages are sometimes grown in steep soil landscapes of the foothills. The **Peace River Region** contains just over half the crop land area in B.C. Cereal grains, oil seeds, grass for seed and forage are the major crops grown on long slopes and in a rolling topography with medium to highly erodible soils.


Figure 1. Agricultural regions of British Columbia

The **Peace River** and **South Coastal Regions** have been recognized before as high and medium high erosion risk areas in B.C. respectively, based on the intensity of agricultural use and erosion prediction calculations (Novak and van Vliet 1983). In the early 80's, soil conservation practices were very rare in all regions of the province. By the late 80's, greater awareness on the benefits of conservation farming saw more and more producers utilizing some form of conservation measure. Consequently, a drop in overall actual erosion risk is seen. Results of the weighted C-value analysis showed improvements in actual erosion risk between '81 and '91 for all regions in B.C., ranging from a marginal improvement of less than 1% for the South Coastal region to a 12% improvement for the Peace River Region (Table 6). These improvements are due to changes in cropping with regards to the types of crops and distribution of the different crops grown, and to reductions in cropland areas. Since improvements from tillage management practices such as conservation tillage and no-till applied only to the Peace River Region, these were included in the analysis, hence the combined improvement of 12% due to cropping and tillage practices for this region.

When the regional C-values were weighted for the proportion of total cropland area in B.C., improvement in actual erosion risk of 9% for British Columbia was realized as a result of reduction in cropland areas, shifts in the types of crops grown and implementation of conservation tillage and no-till practices. These figures do not account for improvements from erosion control practices like grassed waterways, terracing, contour cropping, strip cropping and winter cover crops.

Soil loss rates determined with the USLE were grouped into 5 erosion risk classes and the distribution of these classes for 1981 and 1991, expressed as a percent of cropland, are shown in Table 7. Improvements in erosion risk are the result of the combined effects of reductions in cropland areas, shifts in the types of crops grown and in addition, for the Peace River Region, the implementation of conservation tillage and no-till practices.

For the province, nearly 60% of B.C.'s cropland in 1991 has a very low risk of erosion compared to 56% in 1981. This improvement is caused by a shift of approximately 6000 ha of cropland into the very low erosion risk class from the other classes. Just under 7% of the cropland area in B.C. has a high to severe risk of erosion, with an improving trend in the high erosion risk class (less cropland in 1991 than in 1981.) The low and moderate erosion risk classes occupy about 35% of the cropland area in B.C., with an improving trend in the low erosion risk class. The soil loss level in the very low erosion risk class is also considered to be a tolerable soil loss, since this level of soil loss would not affect the long term production capability of the soil for sustainable agriculture. It is interesting to note that between 1981 and 1991 no new areas changed from a "tolerable" to "intolerable" rating. To the contrary, cropland has generally shifted in the preferred direction, from intolerable classes to the tolerable erosion risk class. However, the fact that there are still significant portions of the province remaining in the intolerable water erosion risk classes in 1991, despite the improving trend, is a reflection of the slow implementation of conservation practices in B.C. in the 1990's in terms of cropping and tillage. Observations by district agriculturalists and crop specialists point towards a much faster progress since 1991 in the rate of implementation of conservation tillage and particularly of no-till in all regions of B.C., and also for other erosion control practices such as winter cover crops and grassed waterways.

Examination of the data by region helps to uncover trends in more detail and in a somewhat spatial context. For 3 of the 4 regions, the trends in actual erosion risk are similar to the ones observed for the province. The exception is the **Central Interior Region**, which showed less cropland in the very low class, and more cropland in the low and high erosion risk classes in '91 than in '81. This region experienced an increase in the cropland area in alfalfa, probably onto the more erodible soil landscapes, which may explain less cropland in the very low risk class than in any other region. This was surprising considering the intensive cropping taking place in this region and the rapid increase in areas planted to row crops during approximately the same time period. (Runka 1990). Examination of the agricultural census data confirms this increase in the area in row crops such as vegetables and berries, but at the same time showed a decrease in the area in spring cereals, silage corn and hay, although the total cropland area for the **South Coastal region** remained the same. Therefore, significant shifts in cropping resulted in more cropland in the very low, moderate, high and very high risk classes and less cropland in the low risk class.

In summary, when targeting conservation measures to regions in B.C., the C-value analysis has shown that in light of the very marginal improvement of less than 1% in actual erosion risk for the **South Coastal Region** compared to the other regions, this region would benefit most from conservation and erosion control practices to reduce the erosion risk. Also, results on the distribution of erosion risk classes by regions and for the province has demonstrated the need to focus soil conservation and erosion control efforts in each region on getting more cropland into the tolerable risk range (very low class) by reducing the area in cropland in the other erosion risk classes. It is important to first reverse the negative trend into an improving erosion risk trend for the very low (tolerable) class for the **Central Interior Region**. Lastly, compared to bare, unprotected soil conditions, the effect of cropping and tillage (actual erosion risk, Table 7) has caused a dramatic shift in land from the severe erosion risk classes (72%) in Table 5 to the low and very low (tolerable) erosion risk classes (80% of B.C.'s cropland in Table 7). This clearly shows the extreme importance of the type of crops and the crop and residue cover in reducing the actual erosion risk. (Example: Changes from continuous row crops to better rotations, inclusion of hay in the rotation, or pasture will improve cover and be reflected in lower C values) The better the crop and residue cover for soil protection, the lower the risk.

Table 6. Trends in Actual Erosion Risk from C factor analysis for British Columbia

| Region | C Factor Value (Cropland area weighted for region) | | |
|---|---|---|---|
| | '81 | '91 | Change (%) |
| South Coastal | 0.1878 | 0.1876 | -0.1 |
| Southern Interior | 0.1542 | 0.1495 | -3.0 |
| Central Interior | 0.1805 | 0.1681 | -6.9 |
| Peace River | 0.3143 | 0.2754 | -12.4 |
| Province | 0.2414* | 0.2197* | -9.0 |

Table 7. Predicted actual water erosion risk* in British Columbia, 1981 and 1991.

| Region | Cropland ha. | | Tolerable | | Low | | Moderate | | High | | Severe | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | '81 | '91 | '81 | '91 | '81 | '91 | '81 | '91 | '81 | '91 | '81 | '91 |
| South Coastal | 3428 | 275 | 70.2 | 76.6 | 21.8 | 13.9 | 3.0 | 3.6 | 4.7 | 5.4 | 0.3 | 0.5 |
| Southern Interior | 57532 | 57043 | 50.8 | 53.5 | 19.0 | 19.1 | 20.3 | 24.3 | 7.9 | 2.6 | 2.0 | 0.5 |
| Central Interior | 301304 | 291415 | 62.4 | 56.7 | 25.6 | 28.8 | 7.6 | 8.4 | 1.5 | 2.2 | 2.9 | 3.9 |
| Peace River | 65538 | 70871 | 54.6 | 58.7 | 29.0 | 23.0 | 10.4 | 11.8 | 4.7 | 3.9 | 1.3 | 2.6 |
| Province | 427802 | 419604 | 55.9 | 58.8 | 25.1 | 21.8 | 12.2 | 13.9 | 5.2 | 3.5 | 1.6 | 2.0 |

* numbers represent % of cropland in each erosion risk class

*Alberta*

Alberta was subdivided into eight ecoregions on the basis of climate and soil development (Figure 2). Individual ecoregions also differ in farming practices.

Three ecoregions - the **Mixed Grassland, Moist Mixed Grassland** and the **Parkland** - are in the Prairie Ecozone. Soils have relatively high natural fertility levels and good moisture-holding capacity. Topographical relief is relatively low and well suited to highly mechanized farming; however, the soils exposed by intensive land use and summer fallowing are susceptible to wind erosion, particularly in areas where water deficit and/or high wind conditions exist.
Agriculture in the semiarid **Mixed Grassland** ecoregion of southeastern Alberta consists of spring wheat and other cereal grains in rotation with summer fallow. Flaxseed and durum wheat are also produced on the dissected, undulating and kettle landscape of the brown chernozemic soils. The remaining half of the cultivated land is used for pasture or rangeland.
Slightly more annual precipitation falls in the semiarid **Moist Mixed Grassland** area than in the mixed grassland region (350-400 mm compared to 250-350 mm). The dark brown soils of the area are characterized by the glacial tills, on the hummocky to kettle terrain, and the sandy to clayey lacustrine deposits on level to gently undulating topography. Crops grown include spring wheat and other cereal grains, in rotation with fallow, and oilseeds.
The **Parkland** area is some of the most productive agricultural land, producing a wide variety of crops such as spring wheat, other cereals, oilseeds, forages and specialty crops. The region's black soils occur on undulating to kettle, level to hummocky or ridged topography.

The **Boreal Transition, Mid Boreal Upland, Western Alberta Upland** and **Peace River** are located in the Boreal Plains Ecozone. This ecozone is slightly cooler on average than the Prairie Ecozone, with less of its land base used for agricultural purposes, with the exception of the Peace River area. The **Peace Lowland** ecoregion has a warmer climate than the surrounding areas, supporting small grain and grass production on 45% of the area. Soils are clayey lacustrine and sandy fluvial deposits or fine-textured tills on gently undulating or sloping land. Included in the Peace River Lowland are the Hay River Lowland and Northern Alberta Uplands, which are part of the Taiga Ecoregion. Agriculture in this colder area is limited to forage crops. In the **Boreal Transition** and **Mid Boreal Upland** ecoregions, agriculture is limited more by the cool short summers and cold winters than by the subhumid precipitation conditions. Spring wheat, other cereals, oilseeds and forage crops are produced in the regions.

The eighth region is the **Cordillera Ecozone**, where grazing and forages are the extent of agricultural land uses in the lower elevations.

The degree to which water erosion risk was influenced by changes in tillage practices and in cropping systems for the analysis period 1981 to 1991 is illustrated by the trends outlined in Tables 8 and 9. Soil conservation practices were very rare in the early 80's in

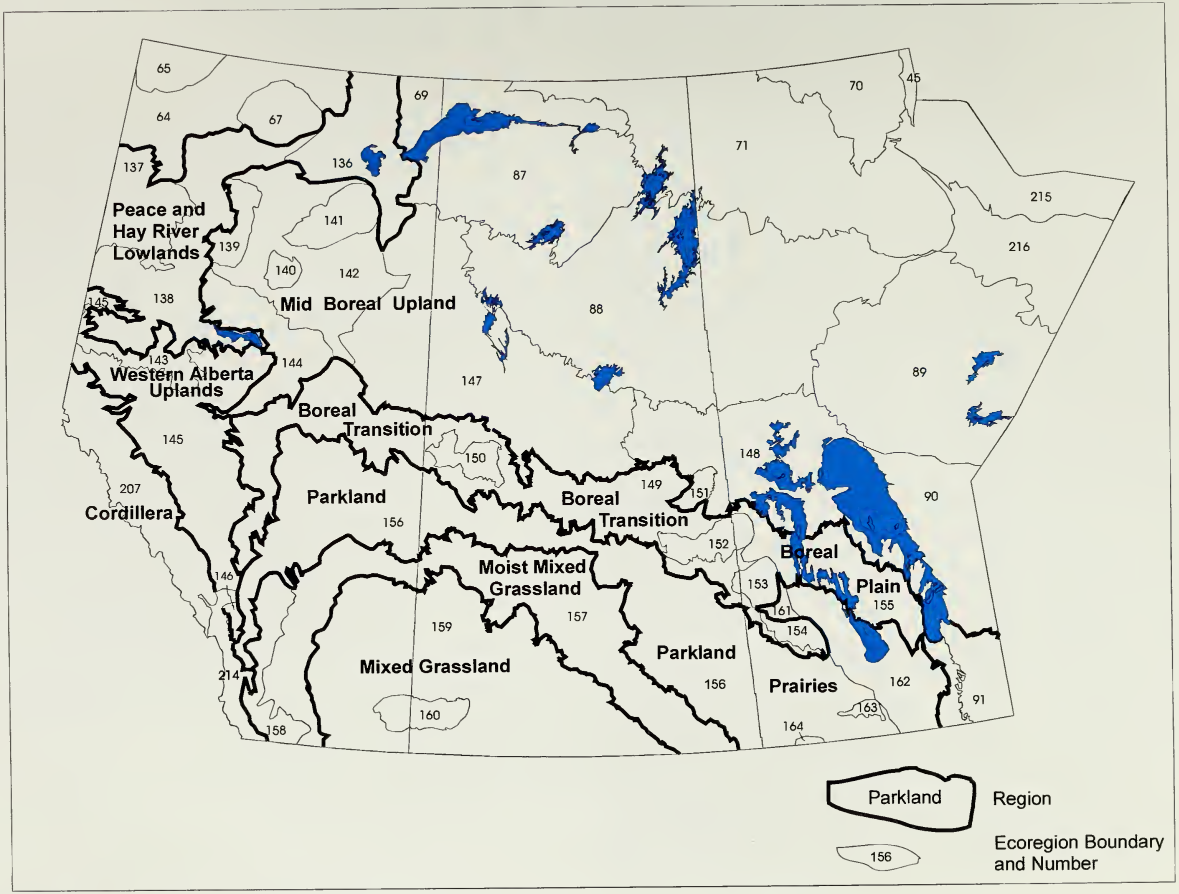


Figure 2. Agricultural Regions of the Prairie provinces

Alberta. Consequently, erosion risk was high especially in areas where summer fallow practice was used extensively. By 1991, increased use of conservation farming practices combined with increase in proportion of alfalfa and tame hay resulted in a drop in overall erosion risk. When the regional C-values (Table 8) were weighted for the proportion of total cropland area in Alberta improvement in actual erosion risk of 16.5% for province was realized as a result of implementation of conservation tillage, decrease in summer fallow practices and shifts in the types of crops grown. The largest improvement in C-factor was in **Mid Boreal Uplands** and **Boreal Transition** ecoregions. The relatively lower C-values for these areas reflect the less intensively-farmed nature of agriculture in these regions, when compared to regions with higher C values.

Table 9 reflects change in soil erosion risk in Alberta for the 1981-1991 period. Overall, the trend in water erosion risk is downward. The proportion of cultivated land in the tolerable risk class increased from 77.0% in 1981 to 83.6% and decreased in all other erosion risk classes. The greatest improvement was found in the **Moist Mixed Grass** ecoregion, where the proportion of soils with tolerable risk rose by 11.6%, followed by that in the **Peace River** and **Parkland** ecoregions. There was only small improvement in the semiarid **Mixed Grassland** ecoregion where summer fallow is still extensively used as a moisture conserving practice. A significant proportion of cultivated land with high erosion risk remains in **Mid Boreal Uplands** ecoregion, despite the largest improvement weighted C-factor appearing in this region. The high erosion risk is a function of the region's large proportion of soils having a high inherent erosivity rating. More aggressive conservation measures will be required on such land.

Table 8. Trends in predicted actual erosion risk from C factor analysis for Alberta.

| Ecoregion | C factor value (Cropland area weighted for region) | | |
|---|---|---|---|
| | >81 | >91 | Change (%) |
| Mixed Grassland (Brown) | 0.382 | 0.326 | -14.67 |
| Moist Mixed Grassland (Dark Brown) | 0.335 | 0.284 | -15.26 |
| Parkland (Black) | 0.275 | 0.236 | -13.85 |
| Boreal Transition (Dark Gray) | 0.225 | 0.185 | -18.31 |
| Mid Boreal Upland (Luvisols) | 0.209 | 0.160 | -22.04 |
| Western Alberta Uplands | 0.26 | 0.11 | -57.7 |
| Peace River | 0.323 | 0.269 | -16.91 |
| Cordillera | 0.204 | 0.233 | +14.2 |
| Province | 0.290 | 0.2243 | -16.50 |

Numbers represent % of cropland in each erosion class

Table 9. Predicted actual water erosion risk* in Alberta, 1981 and 1991.

| Ecoregion (soil zone) | Cropland Hectares | | Tolerable | | Low | | Moderate | | High | | Severe | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | '81 | '91 | '81 | '91 | '81 | '91 | '81 | '91 | '81 | '91 | '81 | '91 |
| Mixed Grassland (Brown) | 1687178 | 1513154 | 81 | 79.6 | 10.1 | 12 | 9 | 8.4 | 0 | 0 | 0 | 0 |
| Moist Mixed Grassland (Dark Brown) | 2606700 | 2549438 | 67.3 | 77.2 | 23 | 18 | 9.7 | 4.8 | 0 | 0 | 0 | 0 |
| Aspen Parkland (Black) | 3309614 | 3273484 | 83.5 | 89.1 | 11.6 | 6.2 | 3.2 | 4.7 | 1.7 | 0 | 0.1 | 0 |
| Boreal Transition (Dark. Gray) | 1437297 | 1333725 | 73.2 | 81.1 | 15.8 | 9.0 | 9.3 | 8.2 | 1.7 | 1.7 | 0 | 0 |
| Mid Boreal Upland (Luvisols) | 141508 | 133061 | 55.9 | 77.9 | 34.8 | 13.5 | 9.3 | 8.6 | 0 | 0 | 9.7 | 7.3 |
| Western Alberta Uplands | 353711 | 299965 | 29.1 | 20.1 | 13.5 | 18.8 | 33.7 | 23.6 | 11.6 | 8.4 | 12.1 | 6.6 |
| Peace River | 1568931 | 1514877 | 74.5 | 76.9 | 13.7 | 12.7 | 9.2 | 8.0 | 2.6 | 2.3 | 0 | 0 |
| Cordillera | 25093 | 18865 | 1.1 | 1.8 | 8.1 | 12.3 | 65.6 | 70.1 | 0 | 0 | 25.7 | 15.7 |
| Province | 11130032 | 10617704 | 74.5 | 80.3 | 15.2 | 11.4 | 8.4 | 7.1 | 1.5 | 0.9 | 0.4 | 0.3 |

* numbers represent % of cropland in each erosion risk class

*Saskatchewan*

The trend in water erosion risk from 1981 to 1991, in essence, illustrates the degree to which the risk of water erosion has been influenced by the changes in cropping systems and tillage practices (Table 10 ). Overall, the trend is downward by nearly 15% in Saskatchewan. The bulk of the decrease is attributable to a change in the cropping systems, and in particular to a reduction in fallow and an increased area of forage. The remainder is due to the increased use of conservation or reduced tillage systems.

In the more arid regions of Saskatchewan, the risk of water erosion has diminished due to the combined influences of changing cropping systems and the adoption farming systems involving reduced tillage. In the **Moist Mixed Grassland** and **Parkland** soil zones (Figure 2) the reduced water erosion risk is considerably greater than in the **Mixed Grassland** soil zone due mainly to a change in cropping systems. In the **Boreal Transition** zones, the reduction in the water erosion risk has been significantly greater than in the more southern regions. This has to do mainly with a marked reduction in the amount of fallow, and in increase in forages at the expense of annual crops.

The reduction in water erosion risk due to cropping practices includes changes in the types of crops grown as well as in the amount of fallow. The change in water erosion risk due to tillage practices has to do with the adoption of conservation and no-till systems.

Table 10. Trends in predicted actual erosion risk from C factor analysis for Saskatchewan

| Ecoregion | C factor value (Cropland area weighted for region) | | |
|---|---|---|---|
| | >81 | >91 | Change (%) |
| Mixed Grassland (Brown) | 0.651 | 0.594 | -9.2 |
| Moist Mixed Grassland (Dark Brown) | 0.574 | 0.498 | -12.3 |
| Parkland (Black) | 0.560 | 0.455 | -17.9 |
| Boreal Transition (Dark Gray) | 0.429 | 0.328 | -23.3 |
| Province | 0.57 | 0.49 | -13.6 |

Numbers represent % of cropland in each erosion class

Table 11. Reduction in predicted water erosion risk in Saskatchewan from 1981 to 1991

| Region (soil zone) | Reduction due to Cropping (%) | Tillage (%) | Total Reduction (%) |
|---|---|---|---|
| Mixed Grassland (Brown) | 5.8 | 2.9 | 8.7 |
| Moist Mixed Grassland (Dark Brown) | 12.8 | 2.9 | 15.7 |
| Parkland (Black) | 15.6 | 3.0 | 18.6 |
| Boreal Transition (Gray / Dark Gray) | 23.0 | 2.3 | 25.3 |
| Province | 11.4 | 2.9 | 14.2 |

Table 12. Predicted actual water erosion risk* in Saskatchewan, 1981 and 1991.

| Region (soil zone) | Cropland hectares | Tolerable | | Low | | Moderate | | High | | Severe | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | '91 | '81 | '91 | '81 | '91 | '81 | '91 | '81 | '91 | '81 | '91 |
| Mixed grassland (Brown) | 5484374 | 68.9 | 73.5 | 24.8 | 22.3 | 3.9 | 2.4 | 1.1 | 0.8 | 1.3 | 1.0 |
| Moist mixed grassland (Dark Brown) | 5195784 | 44.9 | 51.2 | 29 | 27.8 | 12.9 | 9 | 9.1 | 10.7 | 4.1 | 1.3 |
| Parkland (Black) | 5611216 | 71.3 | 81.1 | 21.7 | 12.5 | 3.9 | 4.8 | 2.8 | 1.2 | 0.3 | 0.4 |
| Boreal Transition (Gray / Dark Gray) | 2867335 | 79.9 | 91.2 | 15 | 6 | 3.9 | 1.7 | 0.1 | 0.3 | 1.1 | 0.9 |
| Province | 19158709 | 64.3 | 71.8 | 23.7 | 18.8 | 6.5 | 4.8 | 3.7 | 3.7 | 1.8 | 0.9 |

* numbers represent % of cropland in each erosion risk class

*Manitoba*

The risk of water erosion in Manitoba declined between 1981 and 1991 by about 11%. Six per cent of this decline resulted from changing cropping practices and 9% was attributed to reduced tillage practices (Health of Our Soils). The change in cropping practices relates to more continuous cropping and the recent trends of more crop diversification. This has resulted in more land in annual crops and probably longer rotations due to inclusion of new crops. The change in cropping practice is also reflected by the decline in the per cent age of annual cultivated land in summer fallow from about 12% in 1981 to about 6% in 1991 (Manitoba Agricultural Year Book 1995).

The change due to tillage practices on the other hand, is likely related to the decreased numbers of operations, as reflected in the decline in summer fallow and a growing interest in adopting minimum and zero till practices. Much of the research and verification for reduced tillage systems was being developed in the latter half of the decade. The trend in this period was to more residues left on the surface or partially incorporated at the surface and, consequently, more protection against erosion. The decline in risk is evident in nearly all categories of erosion risk in Manitoba, with a slight exception in the moderate class (Table 14). Other considerations which could account for a decline in erosion risk could be an increased awareness of soil conservation programs showing that conservation pays, adoption of soil saving practices such as windbreaks and inclusion of more forages in rotations.

Table 13. Trends in predicted actual erosion risk from C factor analysis for Manitoba.

| Ecoregion | C factor value (Cropland area weighted for region) | | |
|---|---|---|---|
| | >81 | >91 | Change (%) |
| Prairies (Black, Brown, Dark Brown) | 0.300 | 0.200 | -33.00 |
| Boreal Plain (Gray, Dark Gray) | 0.316 | 0.321 | +1.58 |
| Province | 0.324 | 0.287 | -11.42 |

Numbers represent % of cropland in each erosion class

Table 14. Predicted actual water erosion risk* in Manitoba, 1981 and 1991.

| Region (soil zone) | Cropland Hectares | | Tolerable | | Low | | Moderate | | High | | Severe | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ‘81 | ‘91 | ‘81 | ‘91 | ‘81 | ‘91 | ‘81 | ‘91 | ‘81 | ‘91 | ‘81 | ‘91 |
| Prairies - Parkland, Grassland and Moist Mixed Grassland (Black, Dark Brown, Brown) | 3743846.6 | 3780806.8 | 91.0 | 91.8 | 3.9 | 3.8 | 2.3 | 3.1 | 1.8 | 0.8 | 1.0 | 0.5 |
| Boreal Plains (Gray) | 1057161.8 | 1073255.2 | 74.7 | 77.2 | 7.9 | 6.6 | 6.6 | 7.4 | 1.6 | 2.0 | 9.2 | 6.8 |
| Province | 4801008.4 | 4854062.0 | 87.7 | 88.6 | 4.8 | 4.4 | 3.2 | 4.1 | 1.4 | 1.1 | 2.8 | 1.9 |

* numbers represent % of cropland in each erosion risk class

*Ontario*

Ontario was divided into 4 agricultural regions on the basis of climate, soil landscape and agricultural practices (Figure 3). Three of the ecoregions (135,134, and 132) are part of the Mixedwood Plains Ecozone, characterized by its location in the lower Great lakes-St. Lawrence valley, gentle topography, fertile soils, warm growing season and abundant rainfall (Ecological Stratification Working Group, 1995). Region 98, the Algonquin-Lake Nipissing ecoregion, is part of the Boreal Shield Ecozone. The combination of strongly bedrock-controlled topography, a short warm growing season and slightly higher precipitation tends to limit the nature and extent of agricultural activities in this region in comparison to those in the other 3 regions.

The **Lake Erie Lowland region** (Region 135), in the extreme southern part of the province, extends from Windsor to Toronto and includes the Niagara Peninsula. Approximately 40% of the Ontario cropland is contained in this region and much of this land is used for corn, soybean, tobacco, vegetable and tender fruit production. Region 135, with one of the warmest climates in Canada, has humid, warm to hot summers, mild snowy winters and an even distribution of precipitation throughout the year.
The southern part of the **Manitoulin-Lake Simcoe region** (Region 134) is more intensively farmed than the north, and erosion potential is generally high due to agricultural practices, rolling topography and moderately erodible soils. Forty percent of Ontario cropland is contained in this region.

The **St. Lawrence lowland region** (Region 132; containing 10% of Ontario cropland) in eastern Ontario centres around Ottawa. Climate is similar to the Manitoulin-Lake Simcoe region, but the winters are colder and agricultural practices tend to focus more on livestock and forage production. The combination of finer soils on low-relief topography with forage-based or less-intense land use results in lower potential erosion risk.
The combined effects of the humid cool temperate ecoclimate, relatively high precipitation rate, shallow-to-bedrock soils and undulating to hummocky topography of the **Algonquin-Lake Nipissing region's** cropland (Region 98) would result in a severe risk of water erosion if it were not for the predominance of forage and pasture-based agriculture.

Ontario soils are generally prone to erosion due to several factors. Significant amounts (700-1000mm) of precipitation fall in the southern half of the province each year. During the winter or early spring months, rainfall on semi-frozen ground has limited infiltration capability and enhanced runoff potential. These conditions, combined with little to no vegetative cover, can cause severe erosion. Intensive row crop agriculture often occurs on steeply sloping land with moderate to highly erodible soils. Many traditional farming methods do not leave adequate crop and/or residue protection for relatively shallow or highly

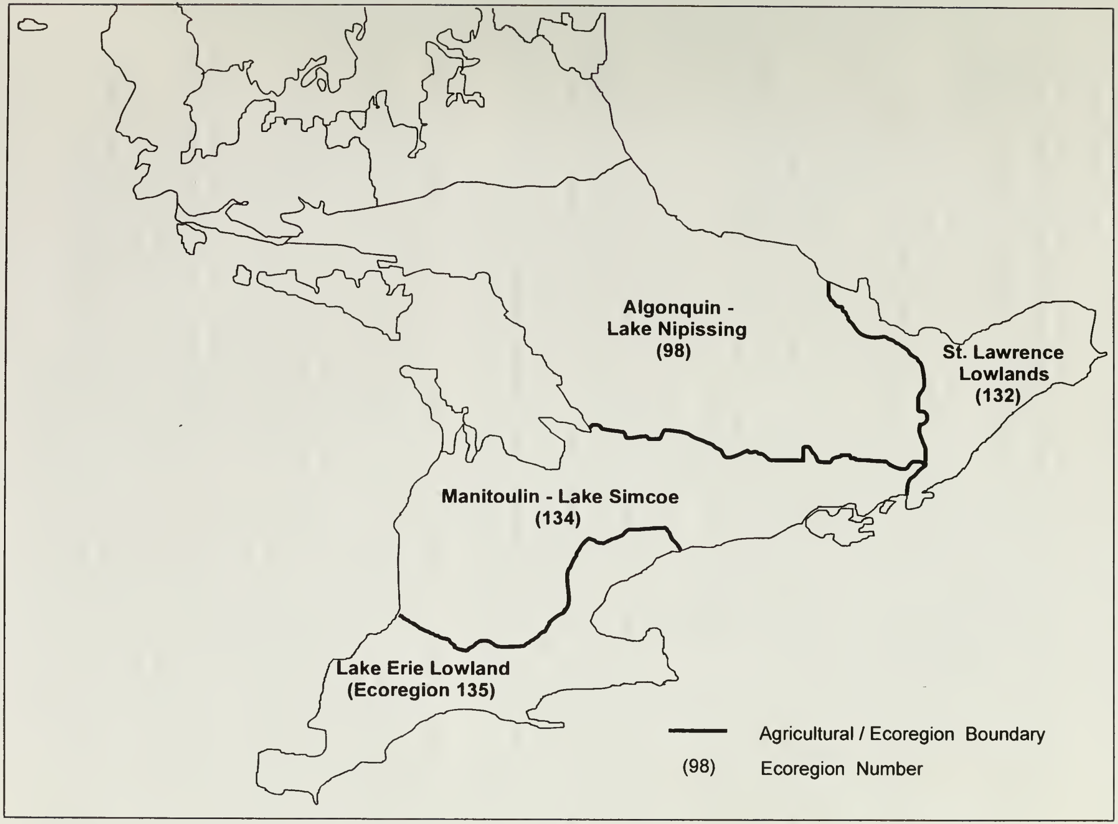


Figure 3. Agricultural regions of Ontario

erodible soils. In intensely farmed or overused areas it is not uncommon to see fields where all of the A horizon has been eroded away leaving more erodible B horizon soil exposed.

In the early 80's, soil conservation practices were uncommon in Ontario. Consequently, erosion risk was severe in many areas of the province (Soil at Risk, 1984). By 1991, more producers utilized some form of soil conservation measure. Consequently, a drop in overall erosion risk was seen. Slightly more than half (56%) of the province's cultivated land has a tolerable risk of erosion as opposed to 51% in 1981. However, 10% of the land still has a high to severe risk of erosion in 1991. Obviously, there are still major areas within the province where the combination of intense farming practices and inherently erodible land result in erosion risk that exceeds a tolerable rate. In regards to the change from 1981 to 1991 no new areas which exceed tolerable risk have occurred since 1981. This means that the shift is in the right direction for all polygons. However, significant portions of the province exhibited intolerable water erosion risk in 1981 and still do in 1991 because of insufficient implementation of conservation practices and/or inappropriate intensive land use. Some activities may have shifted land out of the severe class to high, moderate or low but the overall goal of moving to tolerable risk has not yet been met.

Examination of the data on a regional scale reveals the underlying reasons for the changes in risk. Data in Table 16 illustrates the change in the percent of the SLC polygon in each risk class from 1981 to 1991. The **Lake Erie Lowland** and **Manitoulin-Lake Simcoe Regions** have experienced the greatest movement of land from higher erosion risk classes into the tolerable class. However, these are also the regions where significant areas still remain at intolerable risk. The **Algonquin-Lake Nipissing Regions** which are less intensely farmed started out with 98% of their cultivated land in the tolerable risk class.

The southern portion of the **Lake Erie Lowlands** is where the greatest portion of land is in the tolerable risk category. This is primarily due to the level landscape of the area. Farming practices there are intense and contain significant amounts of row crops but the soil has inherently tolerable risks of erosion. The northern portion of the region, however, along with the majority of the **Manitoulin-Lake Simcoe region** exhibit more rolling and hummocky terrain which results in inherently higher erosion risk. This, coupled with the fairly intense farming in this area, leads to the occurrence of intolerable erosion risks for 63% of the land. It is this area where future soil conservation practices need to be implemented to be most effective. Agriculture in the **Algonquin** and **St. Lawrence regions** is much less intense with more forages and grains being grown. The limited amounts of row crops in these areas means erosion risk is kept fairly low. However, there has been an increase in row crops (primarily soybeans) in the St. Lawrence Lowland Region in recent years which may reverse the trend for overall reductions in water erosion risk there. This analysis will help to keep track of these changes to help guide the implementation of conservation activities occurs where they are most needed.

Future conservation initiatives would have a significant impact on erosion reduction in all regions of Ontario, but particularly so in the Manitoulin-Lake Simcoe region. Less than 37% of the cultivated land in this region is within a tolerable erosion risk level.

Table 15. Trends in predicted actual erosion risk from C Factor analysis for Ontario

| Ecoregion | C factor value (Cropland area weighted for region) | | |
|---|---|---|---|
| | >81 | >91 | Change (%) |
| Lake Erie Lowland | 0.399 | 0.371 | -7.02 |
| Manitoulin-Lake Simcoe | 0.283 | 0.248 | -12.37 |
| St. Lawrence Lowlands | 0.154 | 0.137 | -11.04 |
| Algonquin-Lake Nipissing | 0.215 | 0.191 | -11.16 |
| Province | 0.318 | 0.288 | -9.3 |

Table 16. Predicted actual water erosion risk* in Ontario, 1981 and 1991

| Region | Cropland Hectares | | Tolerable | | Low | | Moderate | | High | | Severe | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | '81 | '91 | '81 | '91 | '81 | '91 | '81 | '91 | '81 | '91 | '81 | '91 |
| 1 (Lake Erie Lowland) | 1513355 | 1312028 | 54.1 | 59.9 | 24.9 | 21.0 | 12.5 | 11.1 | 7.6 | 7.1 | 0.9 | 0.8 |
| 2 (Manitoulin-Lake Simcoe) | 1402930 | 1380222 | 30.5 | 36.8 | 35.0 | 32.7 | 18.6 | 15.3 | 15.4 | 14.8 | 0.5 | 0.4 |
| 3 (Algonquin-Lake Nipissing) | 137390 | 123410 | 97.8 | 99.4 | 1.6 | 0.6 | 0.6 | 0 | 0 | 0 | 0 | 0 |
| 4 (St. Lawrence Lowland) | 441731 | 366465 | 98.3 | 98.3 | 1.7 | 1.7 | 0 | 0 | 0 | 0 | 0 | 0 |
| Province | 3494406 | 3182125 | 50.5 | 55.5 | 25.7 | 23.2 | 13.3 | 11.3 | 9.9 | 9.5 | 0.7 | 0.5 |

* numbers represent % of cropland in each erosion risk class

*Quebec*

Erosion trend analyses were calculated for 8 ecoregions in Quebec (Figure 4). The region that contains by far the greatest proportion of the province's agricultural land (62.2%, Table 19) is the **St. Lawrence Lowland Region**, described in the Ontario erosion section. The next-largest proportion of the provincial agricultural base (20.8%) is contained in the Appalachian region. This region, along with the **Northern New Brunswick Upland region**, is part of the Atlantic Maritime Ecozone, characterized by a cool, moist maritime climate, upland podzolic soils and fertile lowland Luvisols. The remainder of the province's agriculture is located in the Boreal Shield Ecozone (the **Southern Laurentian, Central Laurentian, Abitibi Plains, Lac Temiscamingue Lowlands** and **Riviere Rupert Plateau regions**). Similar to Ontario's Algonquin - Lake Nipissing region, water erosion could be a problem if not for the predominantly forage- and pasture- based agricultural systems on the region's humid high cool temperate ecoclimate, relatively high precipitation rate, shallow-to-bedrock soils and undulating to hummocky topography.

The application of the Universal Soil Loss Equation (USLE) weighted by Soil landscape polygon for Quebec reveals that 4 million tonnes of surface soil were eroded in 1991 as compared to 4,6 million tonnes in 1981 (see Table 18). This represents a 12.5% improvement for the whole province. There are some important regional variations. The St-Laurent Lowlands ecoregion shows a negative trend that is the result of increased areas grown in grain corn and in soybeans in 1991. The grain corn hectares have almost doubled from '81 to '91 and those in soybeans have quadrupled.

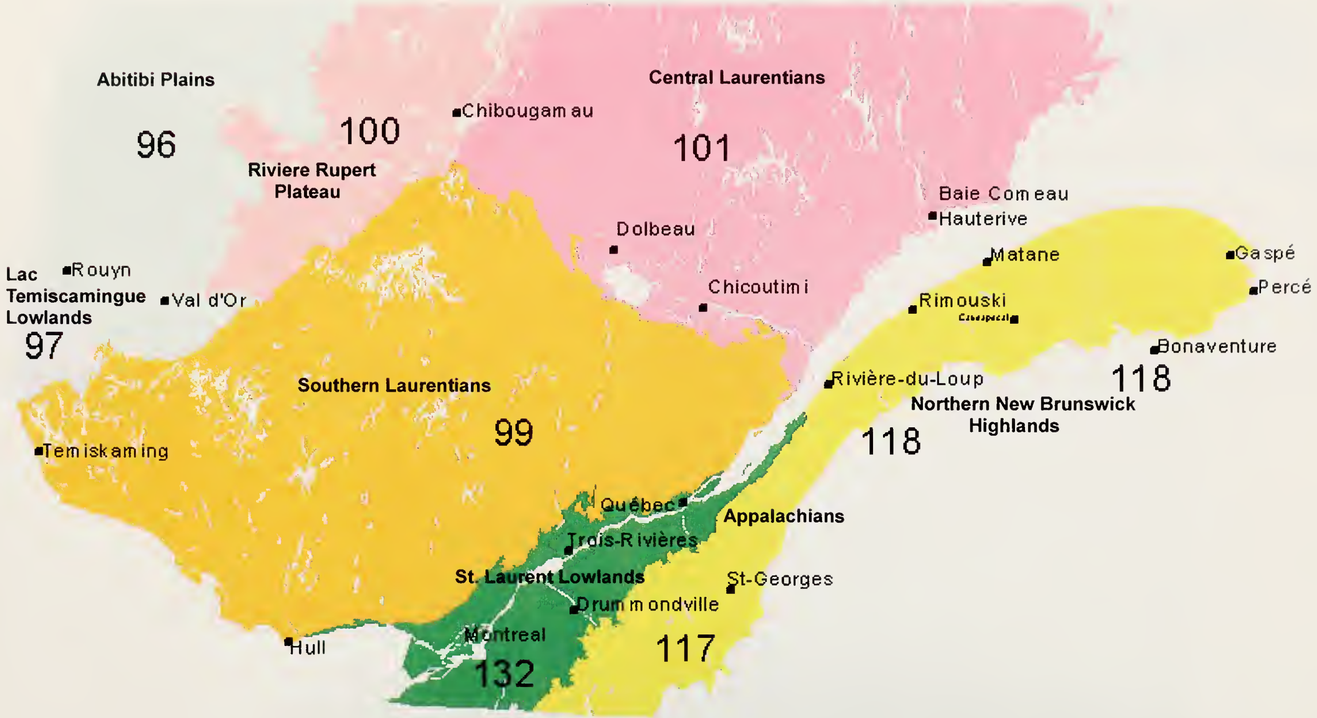


Figure 4. Agricultural regions of Quebec

Table 17. Trends in predicted actual erosion risk from C Factor analysis for Quebec

| Ecoregion | C factor value (Cropland area weighted for region) | | |
|---|---|---|---|
| | >81 | >91 | Change (%) |
| St.-Laurent Lowlands (132) | 0.109 | 0.112 | +2.8 |
| Applachians (117) | 0.040 | 0.030 | -25.0 |
| Central Laurentians (101) | 0.100 | 0.109 | +9.0 |
| Southern Laurentians (99) | 0.350 | 0.238 | -32.0 |
| Lac Temiscamingue Lowlands (97) | 0.109 | 0.094 | -13.8 |
| Abitibi Plains (96) | 0.167 | 0.110 | -34.1 |
| Northern New Brunswick Uplands (118) | 0.353 | 0.275 | -22.1 |
| Riviere Rupert Plateau (100) | 0.021 | 0.139 | +561.9 |
| Province | 0.101 | 0.089 | -10.9 |

Table 18. Predicted actual soil erosion for Quebec, 1981 and 1991

| Ecoregion | Soil loss (t) | | | % change |
|---|---|---|---|---|
| | '81 | '91 | '91-'81 | |
| St-Laurent Lowlands | 2 272 809 | 2 328 301 | 55 492 | -2.4 |
| Appalachians | 1 608 459 | 1 116 204 | -492 255 | 30.6 |
| Central Laurentians | 182 843 | 201 696 | 18 853 | -10.3 |
| Southern Laurentians | 289 310 | 196 479 | -92 831 | 32.1 |
| Lac Témiscamingue Lowlands | 124 599 | 107 829 | -16 770 | 13.5 |
| Abitibi Plains | 89 642 | 59 067 | -30 575 | 34.1 |
| Northern New Brunswick Uplands | 70 299 | 54 741 | -15 558 | 22.1 |
| Rivière Rupert Plateau | 955 | 6 329 | 5 375 | -563.1 |
| Province | 4 638 915 | 4 070 646 | 568 269 | 12.5 |

Table 19. Predicted actual water erosion risk* in Quebec, 1981 and 1991

| Ecoregion (Ecoregion #) | Cultivated land in 1991 (ha) | % of province | Tolerable | | Low | | Moderate | |
|---|---|---|---|---|---|---|---|---|
| | | | '81 | '91 | '81 | '91 | '81 | '91 |
| St Laurent Lowlands (132) | 964,910 | 62.2 | 96.4 | 96.2 | 2.5 | 2.2 | 1.1 | 1.7 |
| Appalachians (117) | 323,059 | 20.8 | 79.1 | 80.8 | 15.6 | 18.4 | 5.3 | 0.8 |
| Central Laurentians (101) | 82,731 | 5.3 | 99.3 | 96.5 | 0.7 | 3.5 | 0 | 0 |
| Southern Laurentians (99) | 104,555 | 6.7 | 953 | 95.6 | 4.7 | 4.4 | 0 | 0 |
| Lac Temiscamingue Lowlands (97) | 25,558 | 1.6 | 92.8 | 90.8 | 7.2 | 9.2 | 0 | 0 |
| Abitibi Plains (96) | 36,151 | 2.3 | 83.5 | 99.7 | 16.5 | 0.2 | 0 | 0.1 |
| Northern New Brunswick Highlands (118) | 11,859 | 0.8 | 51.5 | 54.2 | 48. | 45 | 0 | 0 |
| Rivière Rupert Plateau (100) | 1,734 | 0.1 | 100 | 100 | 0 | 0 | 0 | 0 |
| Iles-de-la-Madeleine | 102 | 0 | | | | | | |
| Province | 1,743,557 | 100 | 91.6 | 92.6 | 6.5 | 6.2 | 1.9 | 1.2 |

* numbers represent % of cropland in each erosion risk class

All of the Quebec cropland falls into the “tolerable” to “moderate” erosion risk classes (Table 19). No cropland was identified as having an actual erosion risk in either the “high” or “severe” categories. At the general provincial level, conditions are improving. The actual risk level rose 1% in the “tolerable” category to 92.6%. The greatest improvement was seen in the Appalachian region, where the proportion of land in the “moderate” risk class dropped from 5.3% in 1981 to 0.8% in 1991. The percentage of cropland in the “tolerable” erosion risk category increased in the St- Laurent Lowlands, Appalachians, Southern Laurentians, Abitibi Plains and Northern New Brunswick Highlands. The “tolerable” level of 100% cropland remained unchanged in the Riviere Rupert Plateau.

Despite the relatively low erosion risk in most areas of Quebec, especially in relation to other parts of the country, some agricultural regions are under increasing pressure and hence show increasing trends towards degradation. In the St-Laurent Lowlands the area of cropland in the moderate risk class increased by 0.6% for 1991. Although the land in this ecoregion is relatively flat and less susceptible to erosion, it is also the region where a four fold increase of grain corn and soybean area occurred. These crops offer little protection to the soils against erosion. The Central Laurentians (Saguenay Lac St-Jean area) and the Lac Temiscamingue lowlands are following the same trend to a lesser degree (2% or more increase in the low risk class )

T*he Maritime Provinces*

For the purpose of this analysis, the Maritime Provinces were subdivided along provincial boundaries - **New Brunswick, Prince Edward Island** and **Nova Scotia**, representing land areas of 7.3M, 0.6M and 5.9M ha, respectively (Figure 5). Although political in origin, these subdivisions result in areas with unique climatic regimes, soil and landscape conditions, and agricultural practices.

Inherent soil and climatic conditions (RKLS) impact on distribution of actual water erosion risk experienced in the region (Table 5). The growing season in the Maritime Provinces is characterized by a cool wet spring, a warm summer with ample rainfall, and a cool wet fall (Dzikowski et al. 1984). Despite its maritime location, **New Brunswick** has more of a modified continental type climate with a wide range in temperature, whereas coastal areas of **Prince Edward Island** and **Nova Scotia** tend to be more maritime moderated, with milder winters and cooler summers, due to the ocean's impact. Higher rates of precipitation coupled with maritime thermal conditions have resulted in **Nova Scotia's** cropped lands being subjected to significantly higher (33%) average values for erosivity of rainfall and snowmelt and winter runoff (R=1950) than found in **New Brunswick** (R=1450) and **Prince Edward Island** (R=1500). Rolling topographic conditions with moderately long slope lengths found in **New Brunswick**

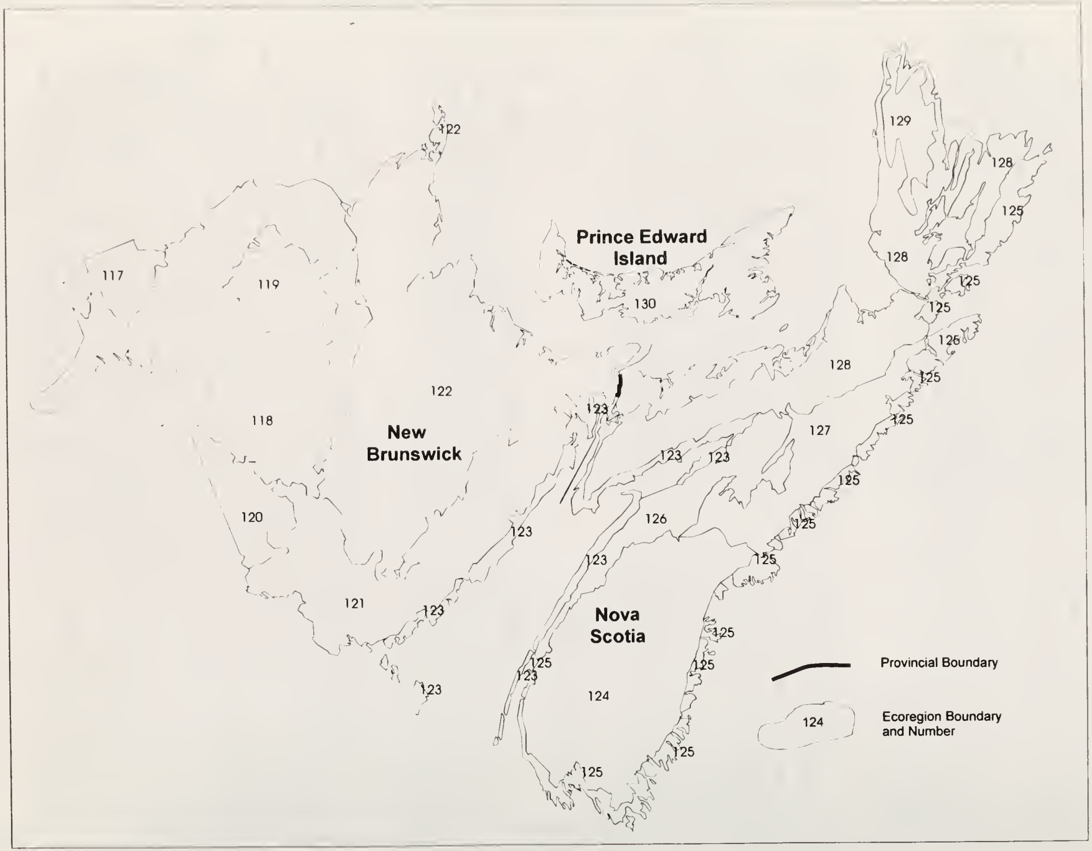


Figure 5. The Maritime provinces

manifest themselves in an average provincial cropped land LS-factor (slope length and steepness) two and a half times greater than that of the typically undulating landscapes of **Prince Edward Island**. Although all of the Maritimes region was subjected to glaciation, with the subsequent deposition of till and morainic materials of varying thickness, there is still considerable variation in soil erodibility (K-value) among the three provinces. Higher K-values in **Prince Edward Island** are a reflection of the predominance of fine sandy loam surface soil materials that are more easily eroded. Coarser textured sandy loam surface soils in **Nova Scotia** have resulted in that province's average K-value being lowest of the three provinces.

*Cropland / Land use*

The greatest concentration of cropped land in the Maritime Provinces occurs in **Prince Edward Island**. Of the provincial land base, 27% is cropped. In contrast to this, only 1.7 and 1.9% of New Brunswick and Nova Scotia, respectively, are cropped. However, where found, agricultural land usage tends to be concentrated, resulting in localized areas of very intensive production, i.e., the potato belt in Northwestern New Brunswick and the Annapolis Valley in Nova Scotia. Agricultural production hectarage in the Maritime Provinces is dominated by a mixture of tame hay, alfalfa and spring cereal production. These crops tend to be "erosion-friendly" in that they provide relatively satisfactory levels of soil protection. Production of row crops, such as potatoes, vegetables and to some degree berries, results in a higher potential for soil erosion. Both New Brunswick and Prince Edward Island have large areas of intensively cropped potato lands, accounting for 17 and 21% of their respective crop land areas in 1991. Soil erodibility associated with spring cereals planted following potato production in New Brunswick and Prince Edward Island is also greater than that associated with spring cereals that follow a forage crop. Nova Scotia has a smaller hectarage of potato production, but has larger areas under vegetables and berries.

Between 1981 and 1991, census data indicated that crop land in the Maritimes was reduced by 6.2, 2.6 and 5.8%, in New Brunswick, Prince Edward Island and Nova Scotia, respectively. The New Brunswick crop production profile remained relatively constant over this period, with increases in berries and alfalfa areas more than off-set by a large reduction in tame hay (abandoned land) and more minor deficits in potatoes, silage corn, beans, buckwheat and spring cereals. Prince Edward Island's cropland experienced a large reduction in spring cereal area but potato lands expanded by over 20%, increasing from just under 26 thousand ha to slightly over 31 thousand ha. The beans/peas/lentils/buckwheat category also increased dramatically. In Nova Scotia, increased berry and alfalfa production were countered by reduced areas of tame hay, spring cereals, winter wheat and silage corn.

*Soil erosion and conservation in Atlantic Canada*

Soil erosion by water has long been recognized as a serious threat to agricultural sustainability in the Maritimes, particularly in relation to potato production in the Potato Belt of northwestern New Brunswick and on Prince Edward Island. Scarcity of available farmland, absence of livestock to consume forages, and low value of small grains as a cash crop, have hindered the implementation of adequate potato crop rotations in New Brunswick. Potato-grain rotations are common. Structural measures and variable grade diversions with grassed waterways have been supported through provincial extension services since the 1960's. Agronomical practices of strip-cropping, underseeding cereals, winter cover crops and conservation tillage (chisel plowing) have also been encouraged. Soil erosion problems in Prince Edward Island are concentrated in parts of the province where potato production and rough topography are found. Engineering and agronomic practices such as crop rotations (changing from continuous potatoes to grain/potatoes or from grain/potatoes to grain/forage/potatoes), cover crops, terracing and strip cropping, have been adopted. Crop residue management, or conservation tillage, has been promoted heavily in recent years. In addition, mulching following potato harvest has been targeted to areas of high soil erosion risk. Erosion-problem crops in Nova Scotia include potatoes, vegetables, corn (both silage and grain) and berries. Presently in Nova Scotia, less than 50 ha is protected annually with soil conservation practices of strip cropping, hay mulching or terracing. Cover cropping, conservation tillage and crop rotations are used throughout the province, but not as extensively as in the major row cropping areas of Prince Edward Island and New Brunswick.

*Trends*

Results of the weighted C-value analysis (Table 20) showed variable degrees of success in reducing crop/management associated erosion risk between '81 and '91 in the Maritime Provinces. Summer fallow values listed in the census data were considered to be unreliable and were not used. Idle land may have been inappropriately listed as Summer fallow. Problems with no-till estimates for the Maritime Provinces also precluded its use in this analysis. Census data estimates of conservation tillage hectarages (6872, 7999 and 1884 ha in **New Brunswick, Prince Edward Island** and **Nova Scotia**, respectively) were applied to potato production in **New Brunswick** and **Prince Edward Island**, and proportionately to berries, vegetables, potatoes, grain corn and silage corn in **Nova Scotia**. **New Brunswick** was the only province that recorded a reduction in the C-factor value over the 1981-1991 period (-8.7%). This improvement was due in large part to the implementation of conservation tillage management practices and to a lesser extent to a reduction in area of erosion-prone crops (potatoes, silage corn, etc.). Thirty four percent of the land under potato production was managed by conservation tillage. In **Prince Edward Island**, conservation tillage was practised on an estimated 26% of the hectareage used for potato production. However, this improvement in cultural practices was not sufficient to off-set increases in the C-factor due to expanded area of potato production. Thus there was a minimal worsening (+1.5%) in the overall situation. Intensification of cropping resulted in **Nova Scotia** having an 8.6% increase in weighted C-factor before considering conservation tillage improvements, and a net increase of 6.7%.

When the provincial C-factor values were weighted for the proportion of total cropland in the Maritimes, there was minimal change in the average impacts of cover and management practises on potential to erode (0.9% decrease). This was realized as a result of the combined effects of: a reduction in total cropland area, an increase in the percentage of erosion-sensitive crops that were grown; and implementation of conservation tillage practices. Essentially the benefits of conservation tillage (7.3%, 3.4% and 1.9% in **New Brunswick, Prince Edward Island** and **Nova Scotia**, respectively) were negated by intensification of cropland use. These values do not account for improvements from erosion control practices such as better crop rotations, cover crops, diversions and grassed waterways, strip cropping, contour cultivation and other soil conservation initiatives. Between 1981 and 1991, about 1500 ha under potato production in **Prince Edward Island** and about 3000 ha in **New Brunswick** were protected by variable-grade diversion terraces, grassed waterways, or strip-cropping. These methods reduce soil loss under potato crops by as much as 90% compared with traditional up- and down-slope cultivation.

Estimated soil erosion rates determined using the R, K, LS and C-factors in the Universal Soil Loss Equation were calculated and grouped into five erosion risk classes. The distribution of these classes for 1981 and 1991 are shown as a percent of cropland in Table 21.

In **New Brunswick**, predicted soil loss changes indicate a general improvement with a reduced percentage in the severe class and an increase in the low class. It appears that there was a general cascading effect with some areas in the moderate, high and severe classes being improved. While this reduction in predicted soil loss is positive, it is important to note that very little area was improved to the extent of being classified as "tolerable". Nine percent of the cropped land base in **New Brunswick** was in the high to severe category in 1991. These were predominantly lands under potato production in northwestern New Brunswick.

Very little severely eroding cropland occurs in **Prince Edward Island** (0.1%), and only 3.8% highly eroding land (1991). In excess of 80% of the cropland is in the tolerable to low classes. The increased hectarage used for potato production in 1991 appears to have only slightly elevated the area subjected to moderate erosion risk, while conservation tillage has reduced the percentage of land in the high risk of erosion class and as well has slightly increased the area rated tolerable.

Albeit relatively small, **Nova Scotia** shows the most serious increase in predicted water erosion risk. While 74% of the cropland is still (as of 1991) in the tolerable risk category, there has been a significant reduction (3.6%) in the area rated tolerable. This is coupled with increases in areas of cropland rated as high and severe.

*Soil Loss Changes*

Table 22 summarizes predicted average and total soil losses for **New Brunswick**, **Prince Edward Island** and **Nova Scotia**. Both average and total predicted soil loss estimates for **New Brunswick** were reduced over the period 1981-1991, however, both values are the highest recorded in the Maritimes. **Prince Edward Island** had a marginal increase in average soil loss per hectare, but a net reduction in total provincial soil loss. **Nova Scotia** showed an increase in both average and total predicted soil loss. Average soil loss per hectare increased by in excess of 10% while total provincial soil loss increased by almost 5%.

In the Maritime Provinces, **New Brunswick** has by far the most severe soil erosion problems on a per hectare basis, but reduced cropland area and conservation tillage practices have helped to reduce the problem. **Prince Edward Island** has off-set increased row crop production with conservation tillage, thus reducing net provincial soil loss. Although **Nova Scotia** has both the lowest average and provincial total soil loss rates, both have factors increased over the 1981-1991 period.

Table 20. Trends in erosion risk from C-factor analysis for the Maritime Provinces.

| Province | C-Factor Value | | | | |
|---|---|---|---|---|---|
| | '81 | | '91 | | % change |
| | w/ocon. till | with con.till | w/o con. till | with con.till | |
| New Brunswick | 0.1209 | 0.1192 | 0.1104 | -1.4 | -8.7 |
| Prince Edward Island | 0.1341 | 0.1407 | 0.1361 | + 4.9 | + 1.5 |
| Nova Scotia | 0.0673 | 0.0731 | 0.0718 | + 8.6 | + 6.7 |
| Maritimes | 0.1108 | 0.1148 | 0.1098 | + 3.6 | -0.9 |

Table 21. Predicted actual water erosion risk* in 1981 and 1991.

| Province | Cropland Hectares | | Tolerable (<6T/ha) | | Low (>=6, 11T/ha) | | Moderate (>=11, <22T/ha) | | High | | Severe | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | '81 | '91 | '81 | '91 | '81 | '91 | '81 | '91 | '81 | '91 | '81 | '91 |
| New Brunswick | 130178 | 122094 | 42.9 | 44.4 | 23.0 | 33.2 | 22.1 | 13.5 | 6.1 | 6.3 | 5.9 | 2.7 |
| Nova Scotia | 112662 | 106134 | 74.0 | 70.4 | 14.2 | 14.6 | 9.8 | 12.0 | 0.1 | 0.6 | 1.9 | 2.5 |
| Prince Edward Island | 158277 | 154106 | 58.8 | 59.7 | 23.4 | 21.8 | 13.6 | 14.6 | 4.2 | 3.8 | 0.1 | 0.1 |
| Maritimes | 401117 | 382334 | 58.0 | 57.9 | 20.7 | 23.4 | 15.2 | 13.2 | 3.7 | 4.0. | 2.4 | 1.6 |

* numbers represent % of cropland in each erosion risk class

Table 22. Predicted average and total soil loss changes in the Maritimes between 1981 and 1991.

| Soil Loss Changes | New Brunswick | | | Prince Edward Island | | | Nova Scotia | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1981 | 1991 | % Change | 1981 | 1991 | % Change | 1981 | 1991 | % Change |
| tonnes/ha | 9.95 | 9.14 | -8.1 | 6.36 | 6.40 | +0.6 | 5.37 | 5.97 | + 11.2 |
| Total tonnes | 1,289,363 | 1,109,833 | -13.9 | 1,006,213 | 986,136 | -2.0 | 602639 | 631693 | 11.2 |

### 4.2 Wind Erosion

The proportion of the cultivated land across the prairies in each inherent erosion risk class is given in Table 4. Most areas in the highest risk classes have a high inherent erosion risk, and are usually sandy soils, or to a lesser extent clayey soils in the southern regions. Otherwise, the risk generally diminishes from the south to north, a refection of lower wind speeds, cooler temperatures and higher precipitation. Less summer fallow combined with higher yields and more residues also contribute to a lower erosion risk in the more northern areas.

The trend in wind erosion risk from 1981 to 1991, in essence, illustrates the degree to which the risk of wind erosion has been influenced by the changes in cropping systems and tillage practices. (Table 23). Overall, the trend is downward by nearly 7% across the prairies. About one third of the decrease is attributable to a change in the cropping systems, and in particular to a reduction in fallow. The remainder is due to the increased use of conservation or reduced tillage systems. Actual wind erosion risk is indicated in Table 24.

In the more arid regions of Saskatchewan and Alberta, the risk of wind erosion has diminished significantly due mainly to the adoption farming systems involving reduced tillage. The change in cropping systems, on the other hand, has had only a minimal effect on wind erosion risk, and in fact the increase in oilseeds and specialty crops at the expense of cereals has itself marginally increased the risk in some areas. The exception is the extremely sandy areas where the change from annual crops to perennial forage has dramatically reduced the wind erosion risk. Overall, however, the trend is downward by about 5% to 7%.

In the Black, Dark Gray and Gray soil zones, the reduction in the wind erosion risk has been slightly greater than in the more southern regions. This has to do mainly with a marked reduction in the amount of fallow, and a slight increase in forages at the expense of annual crops. And although the adoption of conservation practices has been significant, their effectiveness in reducing the wind erosion risk has been slightly less than in the more arid regions.

It should be noted also that according to most observers, the trend toward less fallow and increased use of reduced tillage systems has not only continued, but has indeed accelerated since 1991. In fact, most estimates put the increased use of reduced tillage systems since 1991 at least equal to that between 1981 to 1991. Assuming that is the case, then the wind erosion risk has perhaps diminished an additional 4 to 5% since 1991.

Table 23. Reduction in wind erosion risk in Prairie Provinces from 1981 to 1991.

| Region (soil zone) | Soil Texture | Reduction due to Cropping (%) | Reduction due to Tillage (%) | Total Reduction (%) |
|---|---|---|---|---|
| | Sand | 5.9 | 1.4 | 7.4 |
| Mixed Grassland | Sandy loam | 5.4 | 2.6 | 8.0 |
| (Brown) | Loam | 0.6 | 4.6 | 5.1 |
| | Clay loam | -1.6 | 5.4 | 3.9 |
| | Clay | 1.3 | 5.6 | 6.9 |
| | **Average** | **0.5** | **4.8** | **5.3** |
| | Sand | 21.3 | 2.0 | 23.3 |
| Moist Mixed Grassland | Sandy loam | 5.9 | 3.5 | 9.4 |
| (Dark Brown) | Loam | -1.3 | 5.9 | 4.6 |
| | Clay loam | -2.6 | 6.6 | 4.0 |
| | Clay | 2.4 | 7.1 | 9.6 |
| | **Average** | **1.2** | **5.8** | **7.0** |
| | Sand | 10.4 | 2.0 | 12.4 |
| | Sandy loam | 4.1 | 3.3 | 7.4 |
| Parkland | Loam | 1.2 | 4.6 | 5.8 |
| (Black) | Clay loam | 2.1 | 4.8 | 6.9 |
| | Clay | 1.1 | 5.0 | 6.1 |
| | **Average** | **2.6** | **4.3** | **6.8** |
| | Sand | 6.8 | 1.4 | 8.2 |
| | Sandy loam | 9.1 | 2.0 | 11.1 |
| Boreal Transition | Loam | 8.8 | 2.4 | 11.2 |
| (Gray) | Clay loam | 9.8 | 2.5 | 12.3 |
| | Clay | 9.0 | 3.1 | 12.1 |
| | **Average** | **8.9** | **2.4** | **11.3** |

1. The reduction in wind erosion risk due to cropping practices includes changes in the types of crops grown as well as in the amount of fallow

2. The change in wind erosion risk due to tillage practices has to do with the adoption of conservation and no till systems

## 5.0 REFERENCES


Chepil, W.S., 1945. Dynamics of wind erosion: II Initiation of soil movement. Soil Sci 60: 397-411

Chepil, W.S., 1956.Influence of moisture on erodibility of soil by wind. Soil Sci. Am Proc.20: 288-292.

Chepil, W.S. and N.P. Woodruff, 1963.The physics of wind erosion and its control. Adv. Agron. 15: 210-302.

Coote D.R., R. Eilers and M. Langman, 1989.Wind erosion risk - Manitoba. Canada-Manitoba Soil Inventory. Land Resource Research Centre, Research Branch, Agriculture Canada.

Coote, D.R., Gordon, R., Langille, D.R., Rees, H.W. and Veer, C. 1992. Water erosion risk - Maritime Provinces. Contr. No. 91-10, Centre for Land and Biological Resources Research, Research Branch, Agriculture Canada, Ottawa, Ontario. pp. 9 + map.

Coote D.R. and W. Pettapiece W, 1987. Wind erosion risk - Alberta. Canada-Alberta Soil Inventory. Land Resource Research Centre, Research Branch, Agriculture Canada.

Dzikowski, P.A., Kirby, G., Read, G and Richards, W.G. 1984. The climate for agriculture in Atlantic Canada. Pub. No. ACA 84-2-500, Agdex No. 070, Atlantic advisory Committee on Agrometeorology. pp 19 + maps.

Ecological Stratification Working Group. 1995. A National Ecological Framework for Canada. Agriculture and Agri-Food Canada, Research Branch, Centre for Land and Biological Resources Research and Environment Canada, State of the Environment Directorate, Ecozone Analysis Branch, Ottawa / Hull. Report and national map at 1:7,500,000 scale.

McCool, D.K., W.H. Wischmeier and L.C. Johnson, 1982. Adopting the Universal Soil Loss Equation to the Pacific Northwest. Trans. ASAE 25: 928-934.

Novak, M.D. and L.J.P. van Vliet, 1983. Degradation effects of soil erosion by water and wind. Pages 46-70 in Proceedings 8th B.C. Soil Science Workshop: Soil Degradation in British Columbia. B.C. Ministry of Agriculture and Food, Victoria, B.C.

Shelton, I.J., G.J. Wall and D.R. Coote. 1991. Water erosion risk - Ontario (south). Contr. No. 90-71, Centre for Land and Biological Resources Research, Research Branch, Agriculture Canada, Ottawa, Ontario. pp. 9 + map.

Wall, G.J., E.A. Pringle, G.A. Padbury, H.W. Rees, J. Tajek, L.J.P. van Vliet, C.T. Stushnoff, R.G. Eilers, and J.M. Cossette. 1995. Erosion. Pages 61-76 *in* D.F. Acton and L.J. Gregorich (eds). The health of our soils - toward sustainable agriculture in Canada. Centre for Land and Biological Resources Research, Research Branch, Agriculture and Agri-Food Canada, Ottawa, Ontario.

**Appendix 1: Sample calculation of polygon C factor for Actual Water Erosion Risk**

**STEP 1.** **"C" factors were obtained for each crop, for each region and for conventional, conservation and notill systems where applicable using all available sources (eg. RUSLEFAC, local expertise)**

For Alfalfa, Sod, Other Tame Hay and Summer fallow, it was assumed that only conventional practices were applied and that these crops were not grown in conservation or notill systems.

**STEP 2.** **A "C" factor table was created.**

Tables were created to summarize the information used in the C factor calculations. An example of the table layout is shown in Table 1a. Values were checked to determine whether or not they seemed reasonable, through verification with local agriculturalists and by comparison of the values with trends of similar crops in other regions of the country.

Table 1a: Example of Portion of C factor table for n regions.

| Crop | C factors for Region 1 | | | C factors for Region 2 | | | C factors for Region n | | |
|---|---|---|---|---|---|---|---|---|---|
| | Conv. | Cons. | Notill | Conv. | Cons. | Notill | Conv. | Cons. | Notill |
| Soybeans | 0.56 | 0.32 | 0.31 | 0.47 | 0.33 | 0.32 | 0.49 | 0.33 | 0.32 |
| Silage Corn | 0.55 | 0.32 | 0.25 | 0.53 | 0.32 | 0.24 | 0.47 | 0.32 | 0.24 |
| Alfalfa | 0.02 | - | - | 0.02 | - | - | 0.02 | - | - |
| etc. | | | | | | | | | |

**STEP 3. Census of Agriculture Data**

Use of the Census of Agriculture data required the Soil Landscape polygon number, (column #1 of Table 2a) and the hectares of each crop grown ( identified in STEP 1) within each polygon and the hectares in conventional, conservation and notill. Only cropland (excluding unimproved pasture) data was required. Columns (or fields) of census information which were not required for the C factor determination were deleted to simplify the spreadsheet, including items such as the number of farmers reporting, owned, rented land, sales and # of windbreaks.

**STEP 4. An "adjusted cropland" area was calculated.**

An "adjusted cropland" area (column #2) was created by summing up the total hectares of all the crops being used. This was the area used for all polygon calculations.

**STEP 5. The percentage of conventional, conservation and notill management in each SLC polygon was calculated.**

The hectares in each management system was given for each polygon but in many cases, did not sum to the new "adjusted cropland" determined above. The distribution was determined by calculating the breakdown in percent using the sum of the hectares in the three systems (column #3, #4 and #5). These percentages were applied to the adjusted cropland value.

**STEP 6. The proportion of polygon C factor was calculated for each crop.**

A weighted C factor for each crop was calculated by taking into account the distribution of management system (Note: for data prior to 1991, management system data were not reported). It was assumed that the polygon distribution of management system applied equally to all crops except for alfalfa, sod, other tame hay and Summer fallow which were assumed to be 100% conventional.

Four additional columns were created beside each "crop hectares" column (Column #6) for the calculations (column # 7,# 8, # 9 and #10).

Column # 7 contains the weighted C Factor for the crop under conventional tillage. It was obtained as follows:

i) The hectares of the crop grown in a polygon were divided into the adjusted cropland value for the polygon.
ii) That number was multiplied by the percentage distribution of conventional management in that polygon.

iii) The resultant number was multiplied by the C factor chosen for that crop (see Part 1)
iv) The process was repeated for conservation and notill management (Columns #8 and # 9)
v) Columns # 7, #8 and #9 were summed for a weighted C factor for that crop in that polygon (Column #10)

Steps i) through v) were repeated for all crops. Crops which were only managed conventionally have only 1 column beside the crop ha column since there was only one C Factor multiplication was required.

**STEP 7. A weighted C factor was calculated for the entire polygon.**

A weighted C factor for the entire polygon was obtained by summing columns #10, #15 etc (the columns which sum for each crop) (Column #n). This number should range from about 0.02 to 1.0. Under no circumstances should this number exceed 1.