THE FEDERAL-PROVINCIAL CROP INSURANCE PROGRAM

An Integrated Environmental-Economic Assessment

Economic and Policy Analysis Directorate
Policy Branch

October 1998

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Project Team:
Agriculture and Agri-Food Canada
Policy Branch
Economic and Policy Analysis Directorate (EPAD)
Environment Bureau (EB)
Insurance Division (ID)
Research Branch
Ontario Land Resources Unit (OLRU)
Saskatchewan Land Resources Unit (SLRU)
CanSIS

Project Leader:
Robert J. MacGregor (613) 759-7441 e-mail: Macgrbo@em.agr.ca

Analysis:
John Giraldez (EPAD), Robert J. MacGregor (EPAD), Ian Campbell (EB)
Greg Wall (OLRU), Bruce Junkins (EPAD), Ravinderpal Gill (EPAD)
Irene Shelton (OLRU), Bruce Stephen (ID), Glenn Padbury (SLRU)

Report Production: Nasreen Islam (EPAD)

Maps: Mavis Wade (EPAD), Diane Matley (EPAD), André Villeneuve (CanSIS)

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To obtain additional copies, contact:

Information Production and Promotion Unit
Economic and Policy Analysis Directorate
Policy Branch
Agriculture and Agri-Food Canada
Ottawa, Ontario
K1A 0C5
Tel: (613) 759-7443
Fax: (613) 759-7034
E-mail: ipp@em.agr.ca

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Table of Contents

List of Tables

List of Figures

Acronyms

A

AAFC	Agriculture and Agri-Food Canada

C

CFIA	Canadian Food Inspection Agency
CRAM	Canadian Regional Agricultural Model
CI	Crop Insurance

D

DU	Ducks Unlimited

E

EA	Environmental Assessment
EPIC	Erosion Productivity Impact Calculator

F

FIPA	Farm Income Protection Act

G

GHG	Greenhouse Gases
GRIP	Gross Revenue Insurance Program

M

MC	Marginal cost
MEC	Marginal environmental cost
MPC	Marginal private costs

P

PMP	Positive Mathematical Programming
PW	Price Waterhouse

R

RED	Residue Reduction Value (Wind erosion reduction value)
RES	Amount of residue

S

SLC	Soil Landscape of Canada

U

USLE	Universal Soil Loss Equation

W

WEE	Wind Erosion Estimator

Executive Summary

This report evaluates the environmental and economic impacts of the Federal-Provincial Crop Insurance Program which provides protection to participating agricultural producers against crop yield risk. It estimates the regional and national impact that Crop Insurance has on resource use, and provides estimates of the associated environmental consequences.

This report was undertaken for three reasons. First, Agriculture and Agri-Food Canada (AAFC) made a commitment to undertake an environmental assessment of Crop Insurance for the Eighth Report of the House of Commons Standing Committee on Environment and Sustainable Development. The Standing Committee recommended that the federal government assess its taxes, grants and subsidies for their environmental impact. Second, AAFC's first sustainable development strategy as outlined in *Agriculture in Harmony with Nature: Strategy for Sustainable Agriculture and Agri-Food Development in Canada* (AAFC 1997a) committed the Department to improve its analytical capabilities to account for environmental factors in its decision making. Finally, the Farm Income Protection Act requires a periodic environmental assessment of safety net programs.

A comprehensive analytical framework is used to quantify the economic/environmental impacts of Crop Insurance. The framework's four elements are an economic agricultural sector model, wind and water erosion models, Geographical Information Systems (GIS), and a methodology which integrates the first three elements. The Canadian Regional Agricultural Model (CRAM) is used to simulate the impact of Crop Insurance on the resources used by agricultural producers. Expected utility theory is used to integrate risk into CRAM's objective function. The Universal Soil Loss Equation (USLE) and Wind Erosion Estimator (WEE) are used to estimate the impact of changes in agricultural management practices on the risk of water and wind erosion, respectively. Impact on soil salinity and wildlife habitat are examined using GIS techniques.

This report employs a number of simplifying assumptions that need to be understood to interpret the results properly. It assumes that the response of agricultural producers to risk and to Crop Insurance can be simulated by treating all producers in a region as having the same response to risk. Consequently, producers within a region are assumed to have the same risk preferences, expected income and associated income variance. An upper limit on arable cropland is also specified in each region which limits the quantity of grains and oilseeds that can be produced. The linkage of land use estimates for larger CRAM regions to

environmental information at the more detailed soil polygon level also creates limitations. The assumption made is that changes at the CRAM region level would be reflected in all soil polygons contained within a CRAM region.

Yield data are a major concern with this report. Data that provide information on the distribution of yields by crop and by region over time, using different production systems, are not available. Data generated by models such as EPIC (Erosion Productivity Impact Calculator) and average annual data for a whole region had to be used to generate data on income variability related to yield risk. In relaxing some of these assumptions the structural robustness of the model in estimating the impact of Crop Insurance is evaluated. However, with the assumptions and limitations noted, the model remains a highly simplified representation of the complexities of the real world.

The following conclusions compare a situation without Crop Insurance to one with Crop Insurance. This report estimates that Crop Insurance would have the following impacts on resource use, production, trade, income and the environment:

- Some marginal land would shift to grain and oilseed production from less intensive uses such as hay production. For relatively weak market conditions reflective of 1994, roughly 685,000 hectares would be affected (2% of the arable land base). The impact would be felt mainly in Western Canada where most of the insured crops are grown. The response is sensitive to market conditions. Stronger market returns significantly reduce the estimated effect Crop Insurance would have on resource decisions.

- Cropping patterns would be altered slightly, increasing the relative production of hard red spring wheat, barley, flax, soybeans, and oats.

- Summerfallow area in Western Canada would not be significantly affected in total, decreasing in some regions, increasing slightly in others.

- Exports of grains and oilseeds would increase 4.2% (1.2 million tonnes) under weak market conditions.

- The income of grain and oilseed producers would increase 8% ($220 million), largely due to the subsidization of Crop Insurance premiums by government.

- The impact of Crop Insurance on the risk of soil erosion and soil salinity would be minimal. In no instance did the rate of water erosion increase sufficiently to change a region’s risk rating. When measured at the provincial level, the change in the annual rate of water erosion varies from a reduction of 2% in Alberta to an increase of 5% in Ontario. At the provincial level, the rate of wind erosion would increase only in Manitoba, reflecting an estimated increase of only 0.1 tonne per hectare per year. Although of minimal impact at the provincial level, Crop Insurance may contribute to soil salinity risk in sensitive areas of Saskatchewan and water erosion risk in sensitive areas of Ontario. Also, Crop Insurance may lead to improvements in areas of south-western Alberta that have a high risk of water erosion and salinity due to a reduction in the use of summerfallow.

- It is estimated that other environmental impacts would be limited. Crop Insurance could contribute to problems of siltation and eutrophication in Ontario due to the small increases in water erosion attributable to the program. Crop Insurance would not affect water quality in other regions based on this analysis.

- Some habitat loss would result from bringing additional land into annual grain and oilseed production. Crop Insurance would affect land use in the waterfowl rich region on the Manitoba and Saskatchewan border and may decrease wildlife habitat in south-western Ontario.

- Also demonstrated by this analysis is an evolving capability to evaluate the environmental implication arising from government programs in conjunction with the economic implications. Developing this type of capacity is a commitment made in *Agriculture in Harmony with Nature* (AAFC 1997a).

In summary, this report estimates that the effects of the Federal-Provincial Crop Insurance Program on resource utilization by the agricultural sector are small, even when market conditions are weak as was the situation in the early 1990s. The impact declines to insignificant when market conditions return to more normal levels experienced in the last several years. The environmental implications also range from very small to none. Based on this analysis, Crop Insurance would not appear to have any significant environmental implications which would warrant making modifications to the program. Many other factors such as market conditions, technology, and other domestic and foreign government programs have the potential of much greater impacts on resource decisions, and hence, on the environment.

Introduction

Background

Governments have adopted a policy of sustainable development which generally is interpreted to mean using resources today while securing the future for the generations to come. This concept, as an ideal, appeals to a very broad spectrum of the public and recognizes that societal welfare depends on more than production and Gross Domestic Product. A broader and more comprehensive concept of societal welfare takes into account not only what we consume, but also how the products we consume are produced, and what is left behind. In response to this goal, the federal government in the *Guide to Green Government* (Government of Canada 1995a) established a policy framework that requires all activities of government to be evaluated on the much broader basis. Inherent in this broader basis of sustainable development is the merger of economic, social and environmental goals. The newly created Commissioner of the Environment and of Sustainable Development within the Auditor General's Office, is responsible for ensuring Departments and other federal agencies live up to this policy framework.

Under this framework, and in consultation with the agri-food sector, Agriculture and Agri-Food Canada (AAFC) prepared *Agriculture in Harmony with Nature: Strategy for Sustainable Agriculture and Agri-Food Development in Canada* (AAFC 1997a). The first strategic direction is to focus and enhance "the Department's analytical capabilities and provide timely and appropriate information to encourage greater integration of environmental factors into sectoral and departmental decision making"(p. 11). It commits the Department to specific actions, including development of an integrated economic-environmental modelling system to assess and predict the impact of policies and production decisions on soil, water, and climate change, as well as to review federal policies, programs and initiatives aimed at rural Canada to ensure that agri-environmental interests are taken into account. This report makes a significant contribution to this commitment.

Furthermore, this report is part of AAFC's commitments in the Government Response to the Eighth Report of the House of Commons Standing Committee on Environment and Sustainable Development, *Keeping a Promise: Towards a Sustainable Budget* (Government of Canada 1995b). The Standing Committee's report, released in December 1995, recommended that the federal government assess its taxes, grants and subsidies for their environmental impacts. As part of the government response to this report, AAFC committed to conducting an assessment of Crop Insurance (CI). CI was chosen because it is a central element of the government's safety net program and because the program is currently under review.

As required by the Farm Income Protection Act of 1991, an environmental assessment (EA) of the CI program was completed in 1994 (Price Waterhouse 1994). However, the analytical capability to carry out a quantitative EA was limited, and many inferences about the environmental implications were derived from a limited set of farm level opportunity costs related to various cropping choices. AAFC is now in a position to improve the methodology employed in the Price Waterhouse study using data, concepts and models developed over the last number of years. This report integrates economic models that predict changes in agricultural land use in response to economic policies with biophysical models that relate how changes in land use impact on environmental indicators such as the rate of erosion and water quality.

Purpose

The objective of this report is to carry out an integrated economic-environmental assessment of the CI program, making use of new quantitative tools developed by AAFC. This will, in part, respond to AAFC's commitment to undertake an assessment of CI for the Standing Committee and represents a first step in the Department's commitment to evaluate all its initiatives as set out in *Agriculture in Harmony with Nature* (AAFC 1997a). The primary focus of this particular report is to quantify and assess the economic and environmental impact of CI over fairly broad regions of Canada. CI is modelled in a generic manner for the country in total. Various program options that exist, or are being discussed for different provinces, are not assessed in this report. One of the critical outputs from this effort will be the experience and knowledge gained to improve the methodology for future policy analysis related to risk management instruments and the environment.

Outline of Report

A brief background on CI and previous environmental assessments is provided in Section 1. In Section 2 various management practices are discussed as they relate to the environment: tillage, rotations, input use, and land use. This is followed in Section 3 with a conceptual discussion of how a risk reduction program such as CI would be expected to affect management decisions and of the rationale for government offering a CI program. A brief discussion of the empirical framework and the results of the quantitative economic analysis is presented in Section 4. The impact of CI on soil and other natural resources is presented in Section 5. After discussing some of the limitations with the analysis, the overall conclusions are drawn in Section 6.

Section 1: Background to Crop Insurance and Review of Environmental Assessments

Program History

In Canada, the history of CI begins in 1939 with the introduction of the Prairie Farm Assistance Act by the Canadian Government. This act provided permanent crop loss disaster assistance for grain producers in the Prairies and the Peace River area. In 1959, the CI Act was passed to replace the Prairie Farm Assistance Act and provide more adequate protection to farmers in all provinces. CI has been a key federal support program since 1959 aimed at helping to stabilize farm incomes against production related risks. The reason governments got involved in CI was because the market failed to provide risk management tools for farmers to deal appropriately with production risk. CI has varied little over the years in that it was designed on the basis of participation by both levels of government (federal and provincial) and producers, shared program costs, voluntary participation, provincial administration, and actuarial soundness in the long run.

The CI Act of 1959 enabled the federal government to assist provinces in making CI available to producers at a 60% coverage level. Originally the federal government's share of total premiums was 20%, with a 50% share of administrative expenses. In 1964, the Act was amended to incorporate general provisions for a reinsurance agreement between the provinces and the federal government. Further amendments were made in 1966 and 1970 concerning coverage levels and the federal government contribution to total premiums. The next amendment to the Act, in 1973, provided two options for the federal-provincial-producer cost-sharing arrangements. In one option, the federal and provincial governments each contributed 25% of total premiums and 50% of administrative costs. In the other option, the federal government contributed a total of 50% of premiums and the provinces paid all administrative costs. In the 1990 amendment, the maximum coverage was increased to 90% for low risk crops. Furthermore, the single cost-sharing formula was adopted, where the federal government and provinces each pay 25% of total premiums and 50% of administration costs. Other changes included waterfowl crop damage compensation, and regulations concerning self-sustainability and actuarial soundness requirements.

Although federal legislation establishes the national framework, a lot of flexibility exists for provinces to modify the program to meet the needs of their producers. Provincial plans are developed through consultations with all three parties on a commodity basis. CI is available in all provinces for a wide variety of crops but coverage is not universal, nor are participation rates necessarily high in spite of the fact that the cost of the program is subsidized by government. Currently, AAFC allocates approximately $200 million per year to CI from its total safety net envelope of $600 million. In 1996–97 it is estimated that the federal government's expenditures reached $207 million compared to an average of $166 million over the three previous years (AAFC 1997b). Provincial governments spent $251 million in 1996–97 which compares to an average of $175 million over the previous three crop years. By far the largest component of the program covers grain and oilseed production on the Prairies, but even here participation has fallen below 60% of seeded area.

Crop Insurance Program Design

CI can be divided into three major program components: premiums, indemnities and administrative costs. Premiums are calculated as follows:

$$\text{Premium} = \text{premium percentage}*\{\text{coverage level}*\text{long term average yield}\} *\text{insurance price} \tag{1.1}$$

Farmers are free to choose different coverage levels, however, most chose a coverage level of 70%. The premium percentage is set by CI administrators to ensure the program is actuarially sound. The insurance price is adjusted each year to reflect expected market returns for a representative grade of each crop. Long term average yields are based on either the individual farmer's historical yields or a regional average. The federal government and the provinces each pay 25% of the premium, the rest being paid by the farmer. Indemnities are paid out when the actual yield falls below the long term average yield adjusted for the selected coverage level. Indemnities are calculated as follows:

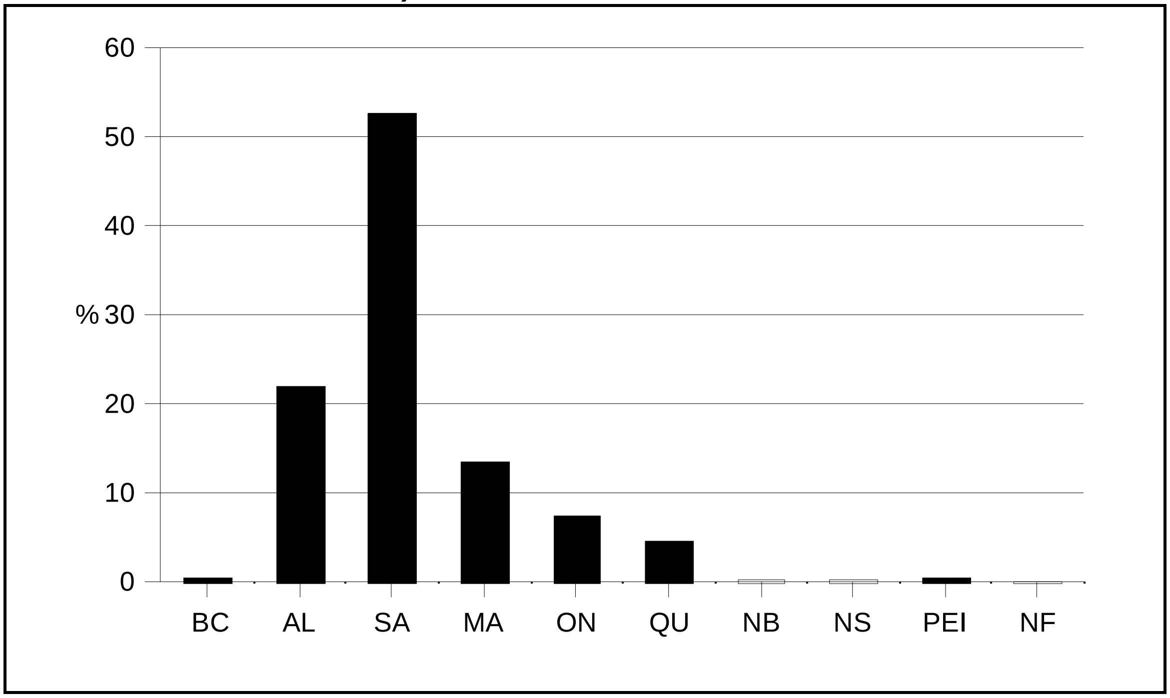
$$\text{Indemnity} = \max\{ [(\text{coverage level}*\text{long term average yield}) - \text{actual yield}] * \text{insurance price}, 0\} \tag{1.2}$$

with actual yield determined at the whole farm level.

The administrative costs are shared evenly between the provinces and the federal government. Administrative cost as a percentage of total premiums in the 1995–96 crop year ranged from a low of 11% in Alberta to a high of 342% in Newfoundland (AAFC 1995a).

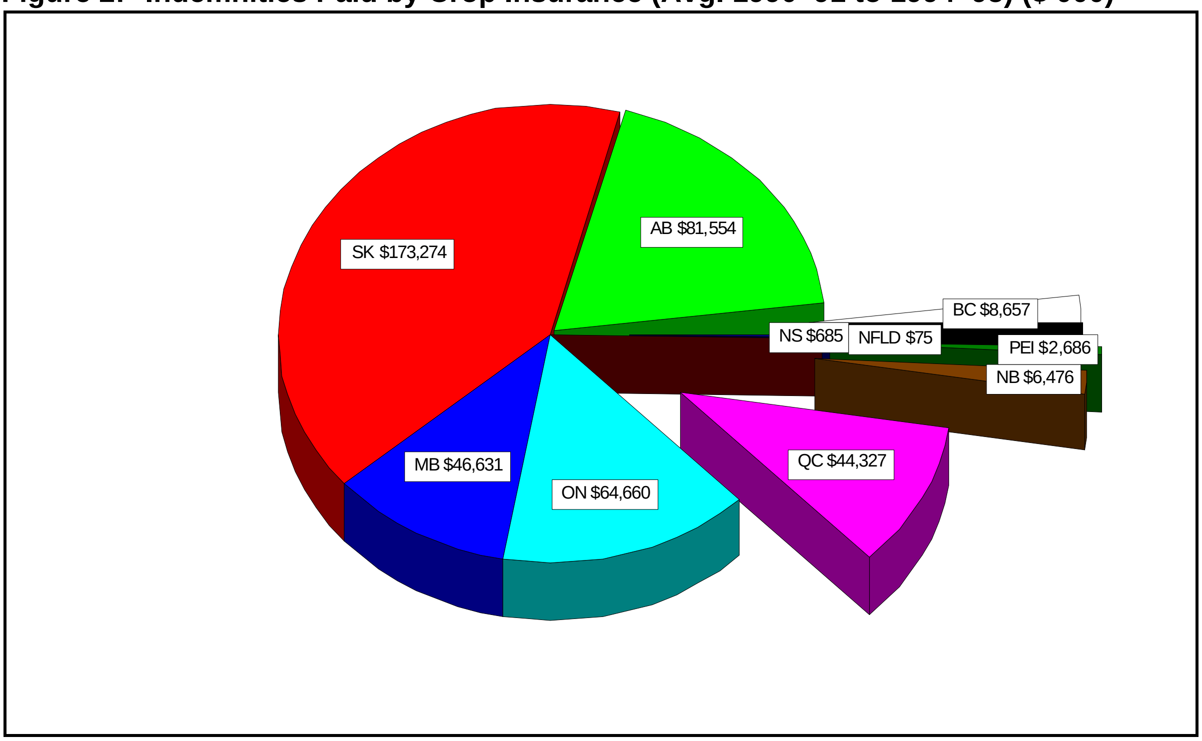
Producer enrolment in the CI program has been very low in some regions. In the Maritimes in 1995–96, the percentage of producers insured ranged from a low of 17% (3% of acres) in Newfoundland to a high of 29% (29% of acres) in Prince Edward Island. In Quebec and Ontario the percentage of producers insured were 60% (47% of acres) and 34% (38% of acres), respectively. The western provinces had enrolment ranging from 32% (9% of acres) in British Columbia to a national high of 71% (55% of acres) in Saskatchewan. The percentage distributions of the total Canadian insured acres by province are shown in Figure 1. The financial importance of CI, seen in Figure 2, shows the average provincial indemnities for the 1990–91 to 1994–95 period across Canada.

Figure 1: Percentage Distribution of Total Area Insured Under Crop Insurance (Avg. 1990–91 to 1994–95)



Source: Agriculture and Agri-Food Canada 1995a.

Figure 2: Indemnities Paid by Crop Insurance (Avg. 1990–91 to 1994–95) ($'000)



Source: Agriculture and Agri-Food Canada 1995a.

Future changes

CI enrolment peaked in 1991 with 23 million hectares, approximately 70% of all Canadian cropland, being covered. Since then the number of insured crop acres has declined to 16 million hectares or about 50% of the total. Reductions in enrolment run across all commodities and provinces except for New Brunswick and Prince Edward Island. AAFC (1995a) attributed these declines to a number of causes, including:

- difficulties with program design;
- high premiums due to deficits accumulated in the late 1980s;
- good recent crop loss experience, which may reduce the perceived value of CI protection;
- producer concern about program manipulation; and
- competition from other safety nets.

This decline in enrolment has been the driving force behind reforming CI and moving toward a two-tier system. The two-tier system would provide producers of insurable crops a basic protection of 50–60% of long-term yields at little or no premium cost. This would be viewed strictly as disaster relief for all producers. Producers could then purchase additional coverage, but would have to pay the majority of the premium costs of this added coverage. Provinces now are starting to adopt the two-tier CI system. British Columbia, Alberta and Saskatchewan started moving toward a two-tier design in 1997. Manitoba already has a two-tier CI plan in place. Two-tier systems are under consideration or are the subject of consultations with farmers in a number of other provinces. The two-tier insurance option is not modelled in this report explicitly because it represents a slight increase in the level of subsidy provided by the current CI program in most provinces. Two-tier insurance options would make similar indemnity payments as the traditional CI program, consequently, it is felt that the environmental impacts would be similar.

The questions the federal government must answer are: first, how does CI as a subsidized program affect the resources used by producers in that it modifies their behaviour, and second, how would this effect be modified in any new formulation of CI now being considered, or recently implemented. Although this second issue is not addressed in this report, a capability to look at design issues is demonstrated.

Previous Environmental Assessments of Government Income Support/ Stabilization Programs

Undertaking environmental assessments (EA) of income support programs is a relatively new venture. In part, this is a consequence of the difficulty inherent in determining how farm production activities affect the resource base over a very diverse landscape in which many different technologies are used. Economic analysis is greatly simplified in that it is based almost entirely on the concept of marginality. This states that as far as market impacts are concerned, we are only really interested in how output or input change at the margin (the last unit). At an aggregate level it does not really matter where or who produces that last unit, the impact on the market is the same. This simplification does not hold when we turn our attention to the environment and resource utilization because it really does matter which resources are impacted. The spatial dimension of the problem cannot be assumed away. It is only through recent advancements in data management and methodological innovations, underpinned by years of research and increased computer capabilities, that we can feasibly start to address this issue in a comprehensive manner using quantitative tools. Development of behaviour models such as the Canadian Regional Agricultural Model (CRAM) (Horner et al. 1992), as well as critical modelling advances in the biophysical disciplines such as contained in the *Health of Our Soils* (Wall et al. 1995) and in the work advancing in the Agro-Environmental Indicator project within AAFC (AAFC 1997a), now enable us to undertake a quantitative assessment of CI.

The last environmental assessment (EA) of CI (Price Waterhouse (PW) 1994a) noted that the unambiguous determination of the impacts of a policy is extremely difficult without the aid of empirical models which link farm production and the environment. Generally, most EAs have been qualitative in nature, with environmental impacts based on changes in farm production models that indicate changes in land use, outputs and inputs. PW resorted to the use of a series of farm-level optimization models incorporating a risk averse criterion function to determine the financial incentive arising from CI for cropping patterns to change. The farm level models used by PW provided more of a sense of the direction in which CI impacts Canadian agriculture than the actual magnitude of the impact. This incentive to change cropping patterns was then employed in a qualitative assessment of the environmental implications of CI. The actual changes in production patterns were not quantified, nor were the environmental implications, which meant the PW study maintained the weaknesses noted in most other EAs done to date on agricultural programs. [1]

In the PW review of previous analysis of CI, they concluded that the "availability of subsidized yield insurance increases crop production slightly, at least in some circumstances" (PW 1994b) and the impact on the technology used is very limited. This leads to the hypothesis that the environmental implications of CI would also be small. This basic finding was supported in PW’s own analysis where they concluded that for the environmental issues considered (crop selection, stewardship, input use, crop rotations, marginal land, "good farming practices," summerfallow, wildlife habitats, and organic production) that the impact of CI on the environment is negligible and often indeterminant in direction. This program is relatively small and swamped by market conditions and other government programs that producers must account for in making production decisions.

Since that report, the CRAM-EPIC modelling system has been developed and an assessment of the market risk component of the Gross Revenue Insurance Program (GRIP) was carried out (Bouzaher et al. 1995). GRIP was designed to respond to both market and production risks and included CI as a subset. In that analysis, it was determined that GRIP would have only a minor impact on production decisions made by Prairie producers and therefore its environmental implications as measured solely by the aggregate rate of wind and water soil erosion was determined to be very small. The key innovations of this analysis were that cropping activities within CRAM were differentiated by tillage system employed, and the changes in erosion rates were estimated at a very disaggregated level to ensure the spatial dimension of the problem would be adequately addressed. Also the CRAM model was enhanced by adopting a methodology referred to as Positive Mathematical Programming (Howitt 1995) that greatly increased the model’s ability to reflect adjustments going on at the farm level as compared to analysis conducted using a previous Linear Programming version of this model (Kirk 1990; TAEM 1992).

1. PW (1994b) included an extensive review of the literature related to EA of government programs, as well as economic frameworks that can be employed. This will not be repeated here. Suffice to say that this report adopts the economic framework suggested in the PW analysis and overcomes some of the noted limitations by employing some of the bio-physical models discussed in the PW study.

Bouzaher et al. (1993, 1994 and 1995) found that GRIP did affect the mix of crops grown, along with tillage regimes used. However, the most significant finding relative to the environment was the reduction in the use of summerfallow by some 180,000 hectares. This accounted for most of the 0.5–2.0% reduction in the annual rate of wind and water soil erosion which they concluded was not very significant. They did not investigate the implications of the CI component of GRIP, and they dealt with erosion only in the three Prairie provinces.

Section 2: Impact of Agricultural Management Practices on the Environment

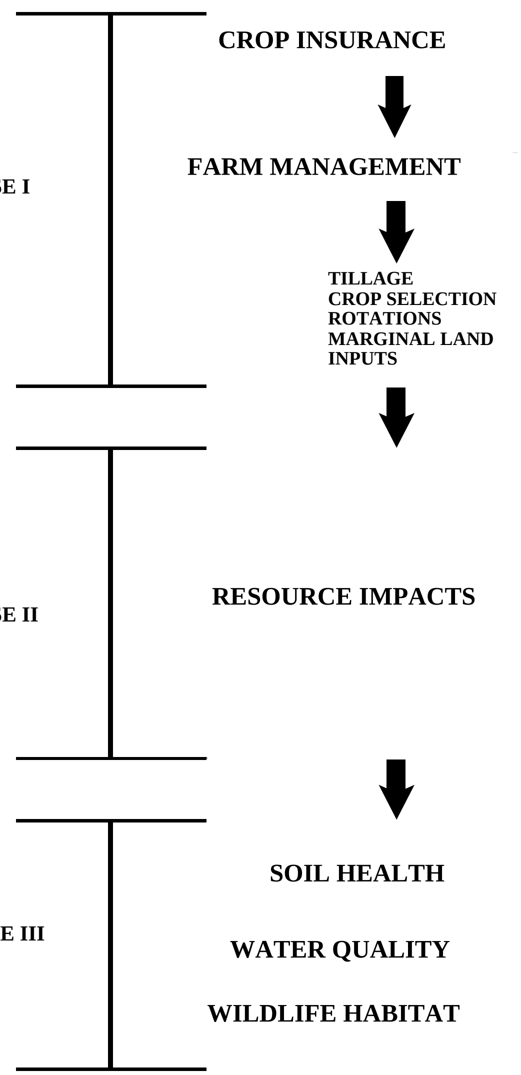
Introduction

Producers' management decisions on the combination of resources, technology, fixed and variable inputs to use are based on the information provided on relative prices, returns and risk. Government programs, such as CI, impact agricultural management practices by increasing farm revenues and decreasing production risks. Throughout this analysis we maintain that producers exhibit behaviour consistent with profit maximization. First, the decisions that can be affected by changes in relative prices or returns will be discussed along with the role that the attitude toward risk can play. Next, how agricultural management practices may affect the environment will be discussed. In terms of the flow of the discussion, Figure 3 attempts to show the relationship drawn among CI, farm management decisions and the environment. If resources are being used in an unsustainable manner, in time, productivity and profitability would be expected to decline which would eventually affect decisions. At this time, no such feedback linkage is incorporated in the analysis.

Technology and Output Decisions

Farmers' decisions can be discussed in terms of three substitution possibilities. The most basic is the input-output decision. The basic economic principle guiding the use of inputs is that a farmer will continue to add inputs to a production process up to the point where the value obtained from the last unit of input used is just equal to the incremental cost of the input, where the marginal value product of output equals marginal factor cost. This holds wherever the production relationship can be characterized by diminishing marginal productivity. For example, farmers will use more fertilizer if output prices increase, or the cost of fertilizer decreases. If a program such as CI improves returns, increased input use would be expected and could include chemical fertilizers, pesticides, and fuel related to tillage operations. Present literature does not support a positive link between CI and input use. In fact both Babcock and Hennessy (1996) and Smith and Goodwin (1996) found a negative response as producers exhibited behaviour consistent with moral hazard[2]. Inputs, such as pesticides, are applied to reduce the probability of a crop failure. With the added protection offered by CI, farmers may reduce the application of certain inputs thus increasing the probability of a payout from the program.

Figure 3: Environmental Assessment of Crop Insurance



Besides changing the intensity of input use on a per hectare basis, the firm can also change the amount of land under cultivation. As returns increase or risk decreases, farmers would be encouraged to expand production onto previously marginal land in terms of its economic viability. High returns and lower risk per unit of output can encourage land to be brought

2. Moral hazard occurs when the probability of loss can be altered by the actions of the insured, and the insurer has imperfect information concerning these actions (Gravelle and Rees 1992).

into production that is lower yielding or higher cost. If CI improves returns and reduces risk, it could have a similar effect. PW (1994a) cite a number of studies that reach a similar qualitative conclusion, but provide little quantitative support that CI is bringing environmentally sensitive or economically marginal land into production. A U.S. study by Gardner and Kramer (1986) did find historical support for this impact.

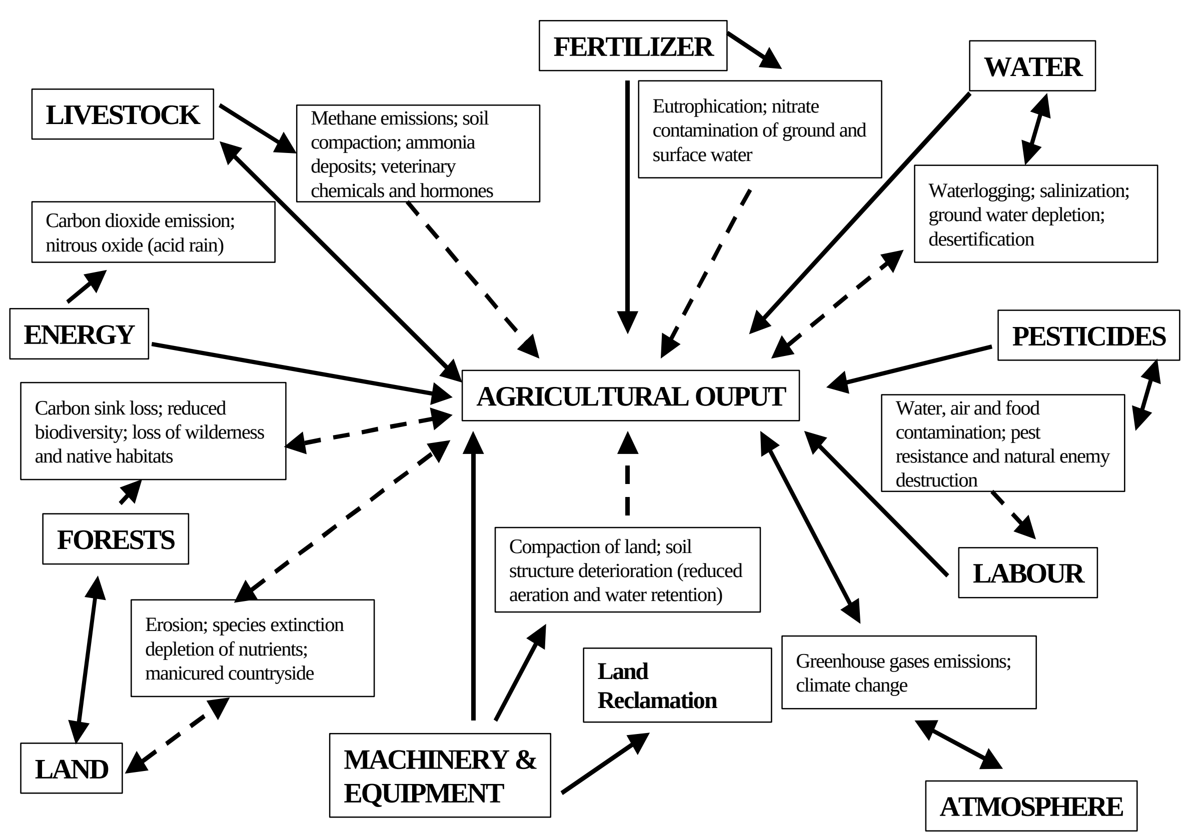
The second substitution possibility relates to the output-output choices. Most crop producers do not produce a single commodity but a mix of crops. In many instances there are agronomic considerations that force farmers to plant a mix of crops, but economics and other resource constraints also play a role in the choices made. The basic decision rule that a multi-output firm follows (with at least one binding resource constraint such as land) is that producers allocate the limiting resource in a way that at the margin each cropping activity provides the same return to the limiting resource. The implication here is that if the market or a government program such as CI improves the return of one crop relative to another, then the producer is going to be encouraged to allocate more of his land to that crop. In some cases the implications for the environment may be very small as the basic agronomic characteristics and production technology employed may be very similar as in the case of most small grains. However, crops such as corn, canola, potatoes, soybeans and flax may have significantly different implications for the environment due to how they are produced and their agronomic characteristics. Turvey (1992) and von Massow and Weersink (1993) found very minor responses in crop selection to CI.

The final choice that producers make relates to the input-input possibilities. Few, if any, aspects of the production technology used in agriculture can be characterized by fixed input relationships. Fertilizer and chemicals, to a certain extent, can substitute for land or labour, and machinery can to a certain extent substitute for chemicals in controlling weeds. Producers will tend to use more of the relatively cheaper input, at least as far as the technology will allow. *A priori*, it cannot be determined which inputs would be increased in response to an increase in output returns in a multi-input technology. This means it is an empirical question as to what inputs would increase or decrease and, therefore, what would be the environmental consequence of a program such as CI. One critical substitution possibility worth noting is the summerfallow to purchased input relationship (MacGregor and Graham 1988). Basically the argument is that farmers can replace purchased inputs through a rotation that incorporates summerfallowing which helps improve fertility and aids in weed control, and conserves moisture. As crop returns increase, the value of land increases while the prices of other inputs generally remain constant. Producers are encouraged to use more purchased inputs and less summerfallowing.

Linkage of Management Practices to the Environment

Some of the direct linkages from production decisions to the environment were alluded to above. Agricultural production occurs within a managed environment over broad landscapes. In most agricultural regions the natural landscape of woods, grasslands or marshes was modified by modern agriculture. The natural biological system has been altered as farmers now generally monocrop non-native plants using a variety of manufactured inputs which require the soil to be disturbed continually. Figure 4 shows the basic system of relationships that exists which link agricultural production activities to soil, water, the atmosphere and the surrounding landscape.

Figure 4: Main Effects of Agricultural Production on the Natural Environment



Source: Anderson and Strutt 1996, p. 156.

Tillage affects the soil and the surrounding environment. Tillage is used to prepare a seedbed and remove and control unwanted plants. Tillage can commence right after harvest, followed by a number of spring operations up to seeding and include cultivation during the growing season for some row crops. Although smooth bare fields are an indication of a new cycle of production and harvest, soil left unprotected by plant cover is susceptible to erosion by rain and wind. Brown streams, gullies in the fields and blowing dirt are the obvious signs that erosion is occurring. Agricultural productivity is based solely on the thin layer of topsoil in which crops are produced. Erosion is the movement of this topsoil and its loss threatens the long term sustainability and productivity of the sector. Generally, the potential for erosion is a function of the likelihood of a weather event, the time soil is left unprotected, the slope of the land, and the type of soil with fine textured sandy soils being very erosive. What farmers grow and how often they till the soil will have a direct bearing on the rate of erosion. Besides erosion, cultivation can have other impacts including salinization, acidification, loss of organic matter, and compaction to name a few. In the Prairies, the practice of summerfallowing is a real concern because it leaves the soil devoid of plant cover and, therefore, highly susceptible to erosion.

Besides soil, plants need nutrients and water. Nutrients are obtained from the soil, and if there are not enough then the producer must add them either in the form of animal manure or chemical fertilizers (nitrogen, phosphorous and potassium plus other trace elements). They also use chemical pesticides to control weeds, insects, fungi and other pests and diseases. Unfortunately, many of these elements are either soluble in water and therefore move quickly from the field into surface or groundwater, or simply move with eroded soil to other locations including streams, rivers and lakes. These chemicals which are so valuable to modern agriculture are referred to as contaminants when they are found in water, and at even very low levels can render the water unfit for other uses. Production systems that require extensive use of chemicals have the potential to lead to more serious water quality problems. This is usually referred to as non-point source pollution and what we see in bodies of water represents the accumulated effects of all production activities that occur in a watershed.

The atmosphere is also affected. Plants while growing transpire, changing the concentration of gases in the atmosphere, but the impact of agriculture goes far beyond this. International concern about global warming as the concentration of greenhouse gases (GHGs) in the atmosphere increases is leading to new policies and programs being discussed to control GHG emissions. Agricultural activity will have to be accounted for as the burning of fossil fuels, disturbing the soil, manure production and using fertilizer can all contribute to net GHG emissions.

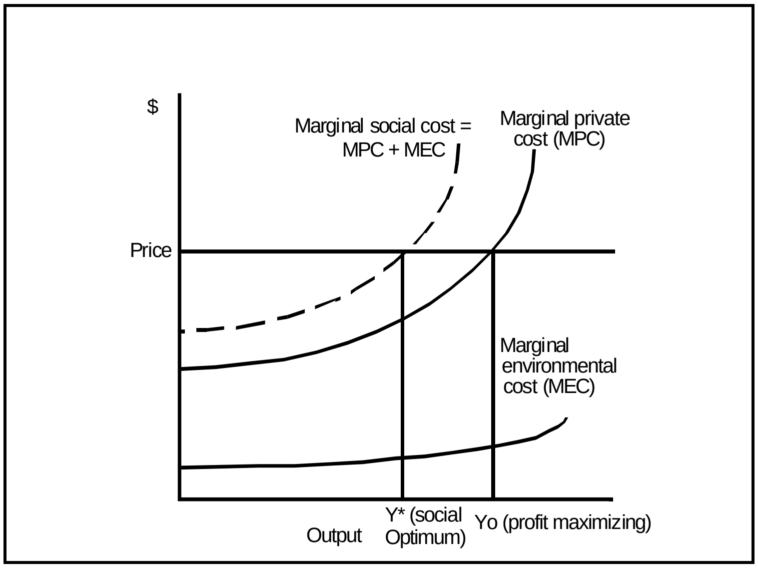
Finally, monoculture and the control of species found in a field all impact on bio-diversity. Obviously, monoculture changes the landscape and limits its availability for native species. It replaces a wide variety of native species of grasses, herbs, shrubs and trees with non-native plants. Less visible is its impact on microorganisms in the soil and small invertebrates both above and below ground. The "food chain" for many species is broken and natural predators that keep populations in check are removed.

Accounting for Environmental Impacts

Economic theory points out that environmental problems are often the result of market failures. Market failure results when markets depart from perfectly competitive equilibrium. Consequently, market equilibrium cannot be relied on to yield socially optimal outcomes. Environmental problems are mainly the result of two types of market failure, public goods and externalities. A public good is a commodity whereby its consumption by one individual does not preclude its consumption by another individual. The problem with no-exclusive public goods is that if a producer provides a unit of the public good all individuals benefit. This results in the free-rider problem where each consumer has an incentive to enjoy the benefits of the public good, but does not contribute to it.

Externalities result when a firm or consumer is directly affected by the actions of other agents without their consent. Externalities are often the result of poorly defined property rights. Environmental effects are not always incorporated into the production costs of producers, and as a result can lead to inefficient decisions from the point of view of society as a whole. For example, decreases in water quality from silt or nutrients do not generally enter into the profit-maximizing decisions of agricultural producers. Similarly, farmers are not generally compensated for protecting wildlife habitat on their land. This lack of market signals can lead to excessive use of natural resources and under-provision of public benefits. In addition, producers in highly fluctuating or risky sectors may use short-term time horizons in their production decisions and under-invest in long-term assets such as maintenance of soil health. For a firm this is demonstrated in Figure 5 (Tietenburg 1992). The firm wanting to maximize profit will produce Y_o, the point where marginal private costs (MPC) equals price. Marginal environmental cost (MEC) is shown as an increasing function of output and if the firm had to take these additional costs into account would produce Y*, the socially optimum level of output.

Figure 5: Production Decisions with Environmental Costs Included and Excluded



Source: Tietenburg, 1992.

The key policy question is whether environmental damages, or the under-provision of environmental goods and services, are large enough to merit corrective intervention. In the case of CI, policy makers must decide whether to modify the program in order to achieve environmental gains. If the program causes significant damage, or could be used to provide valuable public goods, modifications should be considered. However, if the potential for improvement is small, or the costs of corrective measures are large relative to their benefits, it may not be efficient to make changes to account for environmental costs.

The integration of risk and how it affects production decisions has yet to be incorporated in this framework. As indicated above, CI is a risk management tool made available to producers by government because this kind of instrument is not offered by the private sector. The next section will deal with the implications of risk and how a program such as CI would be expected to affect behaviour. Once this is complete, the empirical model will be discussed.

Section 3: Economic Basis for Dealing with Risk

Economic Basis for Government Intervention

Extensive economic literature addresses the question of how consumers and producers respond to uncertainty and risk[3] (Silberberg 1990; Varian 1984; Sandmo 1971). These concepts underpin the rationale for the existence of contingency claim markets that allow risk to be traded, similar to a commodity or service. The insurance industry and futures markets are the most obvious examples of the market responding to the demand for greater certainty relative to entities willing to sell these instruments to assume or take over the risk at a price. In this section implications of risk for producers will be discussed, why government plays a role, and how this behaviour has been incorporated in firm theory. Once the theoretical foundations for the empirical model have been established, some previous studies will be discussed.

Firm Response to Risk

The neoclassical theory of the firm starts from a situation of perfectly competitive markets and assumes that all entities have perfect information. What this means is that when the commitment of resources is made the firm knows exactly the prices it will face in input and output markets, and with the technology employed, what output will be obtained from inputs committed to the production process. In the short run, a firm, where at least some resources (or costs) are considered fixed, will maximize profits at the point where the marginal cost of a unit of output is just equal to the market price for that output. For this to hold, the critical requirement is that the firm is subject to diminishing marginal productivity as input use increases. This gives rise to an upward-sloping marginal cost function for the firm, and industry supply function once aggregated.

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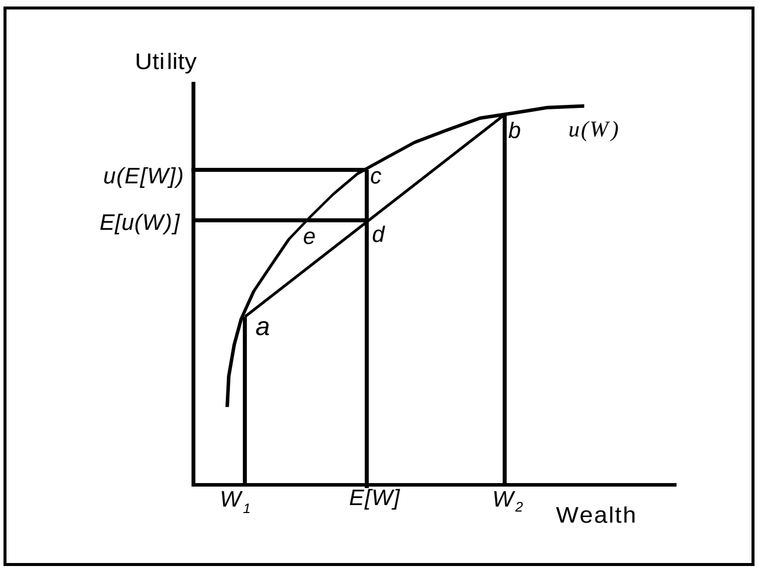
3. Knight (1921) distinguished between risk and uncertainty based on whether probabilities are objective or not. The theory of subjective probabilities would reduce all uncertainty to risk through the use of beliefs expressed as probabilities (Mas-Colell et al. 1995).

In reality firms, especially farms, rarely know with certainty how much they will produce or what the prices will be for their products when they are ready for market. The former is referred to as technological risk (i.e. yield variability due to weather) and the latter as market risk. For CI, it is the yield variability risk with which the program is designed to deal. In understanding a firm's response to risk, a framework employing a von Neumann-Morgenstern expected utility function is used. Based on utility and expectations, this framework postulates that agents take risk into account when making decisions and that a risk averse individual would prefer the expected outcome with certainty as compared to facing a fair lottery. This is based on the premise that the marginal utility of wealth (including profits) diminishes as wealth increases, and therefore the utility lost if the random outcome is below the expected outcome is greater than the utility gained if the random outcome is above the expected outcome.

Figure 6: Impact of Risk on Utility



This situation is depicted in Figure 6. Utility *u* is measured on the y-axis and wealth on the x-axis. The utility function is concave to the origin reflecting risk averse behaviour.[4] The chord drawn between *a* and *b* represents the possible outcomes of a fair lottery with E(W) representing the expected outcome. If a risk averse individual can obtain point *c* on *u*(W) with certainty they will prefer this to *d* on the chord even though both have equivalent expected outcomes, E(W). Stated more formally, the $u[E(W)] \geq E[u(W)]$. In terms of contingent liability markets this simple framework also establishes the basis for trading in risk. A risk averse individual who is subject to a risky outcome would be willing to give up some of his expected wealth in order to shift the risk to someone else. In Figure 6, the distance *ed* represents how much they would be willing to pay, the risk premium. Point *e* is referred to as the *certainty equivalent* outcome and a risk averse individual is indifferent in terms of utility as to whether they are at *d* by playing the game or can obtain *e* with certainty. The wealth

4. A utility function convex to the origin would represent risk loving behaviour while a straight line would represent risk neutral behaviour. In reality, the behaviour of a firm that is risk neutral is equivalent to a firm having perfect knowledge of outcomes.

measured by *ed* represents the potential profit available to an entity which has a lower aversion to risk and is willing to accept the random outcome. One additional piece of information can be obtained from this framework and that is a measure of the degree of risk aversion. The more concave the function *u*(W) is with respect to the origin, the greater the degree of risk aversion. This can be measured by the Arrow–Pratt coefficient of absolute risk aversion A_a which is:

$$A_a = \frac{-u''(W)}{u'(W)} \tag{3.1}$$

where $u''(W) < 0$ and $u'(W) > 0$ for a risk averse individual. These relationships simply restate the fact that utility increases with wealth, but at a decreasing rate.

In terms of the behaviour of a firm maximizing the expected utility of profits, it can be shown that when risk is introduced the decision criteria for determining the optimal input level changes from $p = c'(y)$ to $p \geq c'(y)$ (Sandmo 1971; Silberberg 1990, p. 457), where $c'(y)$ is marginal cost and p is unit price. This implies that the firm will reduce its level of output in the face of risk, if the decision maker is risk averse. This can be shown with the following model generally used in optimization models (Hazell and Scandizzo 1977; Turvey et al. 1995; PW 1994a):

$$EU(\pi) = P\bar{Y} - C(Y) - .5\phi P^2 \sigma_y^2$$

$$where \tag{3.2}$$

$$Y = \bar{Y} + \epsilon_y$$

The criterion function indicates that the expected utility of profits $EU(p)$ is equal to market price P, which is known with certainty in this formulation, times the expected yield $\bar{Y}$ where ε_y is a random deviate from the mean Y from which total cost $C(Y)$ must be deducted along with a risk premium where σ^2_y is the variance of yields and f is an estimate for the coefficient of absolute risk aversion, A_a. By including the risk premium in the optimization problem it is the certainty equivalent profit that is being maximized.

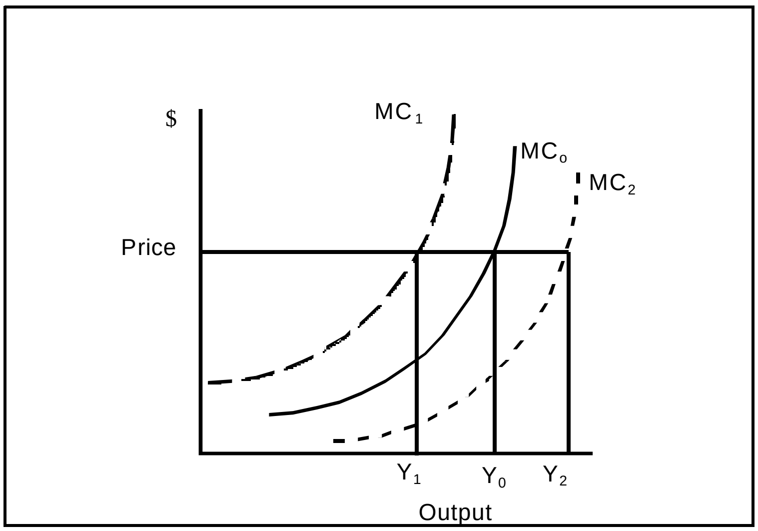
The solution to this problem is:

$$\frac{\partial EU(\pi)}{\partial Y} = P - C'(Y) - \phi P^2 \sigma_y^2 = 0 \tag{3.3}$$

Obviously, this establishes the above relationship for a competitive firm where with risk the firm's output level would be less than the optimal level with certainty by the risk premium as determined by the last term in Eq. (3.3). For a firm, this is shown in Figure 7 where the impact of risk is to shift the firm's marginal cost *MC* curve to the left, reducing output from Y_0 to Y_1. At the industry level if the majority of firms could be characterized as risk averse, then the impact of risk would result in the industry supply curve shifting to the left as compared to the situation where no market or production risk existed. The question is what happens when contingent claim markets such as CI are available that allow risk to be transferred outside the industry. In part this can be answered by assessing the impact on the firm's output decision if risk is reduced.

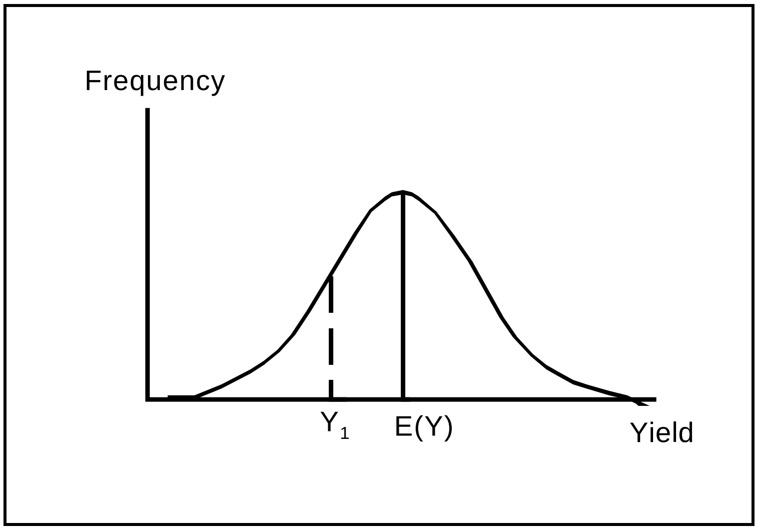
Although Figure 7 indicates that in the presence of risk, a risk averse firm will produce at a level below the optimal level and therefore indicates resources are not being used efficiently, this interpretation very much depends on what costs the firm takes into account in making its decisions. The normal economic interpretation of the above is that with the introduction of efficient risk markets, firms would increase output moving toward Y_0, the optimal level of output where resources are being utilized efficiently and societal welfare would increase. If a subsidized insurance program is made available, the industry could actually end up at an output level of Y_2, beyond the optimal level of output, resulting once again in an inefficient use of resources.

Figure 7: Risk Averse Firm's Response to Risk



Increases in expected returns would result in the firm expanding output (Sandmo 1971; Silberberg 1990). For example a subsidy would result in higher output. This holds regardless of whether price or yield is the random variable. Yet, the same unambiguous result does not hold for a change in riskiness, holding expected return constant (Sandmo 1971; Gravelle and Rees 1992). Referred to as a mean-preserving shift for the random variate, the impact of a change in riskiness on output cannot be determined, *a priori*, unless additional restrictive assumptions are made related to the technology and behaviour. Gravelle and Rees (1992) point out that for a very small mean-preserving shift the impact is negatively related to output. In the model formulated in Eq. (3.2), a mean-preserving spread would be reflected in a change in variance of yields σ^2_y and is negatively correlated with output. For a program such as CI that truncates the distribution of yields below the mean without affecting the expected returns above the mean, it seems plausible to formulate a negative correlation between riskiness and output for risk averse producers. In Figure 8, an actuarially sound CI program that simply truncated risk below *E(Y)* (expected yield) would not change *E(Y)*, but would reduce the risk premium in the final term in Eq. (3.3). The reduction in output from Y_0 in Figure 7 would not be as great as Y_1. If the CI program were perfect, it might move the producer back to Y_0 but this is not likely to be realized. If the cost of the program is subsidized by the government, it is also possible that the firm expands output beyond Y_0 to Y_2, resulting in efficiency losses again (Turvey et al. 1995).

Figure 8: Crop Insurance Program



This simple analysis of optimal resource allocation may not hold if the firm's marginal cost function does not include all costs, such as non-market costs associated with non-point source pollution, other externalities, or if firms discount future returns below an optimum level and therefore do not invest enough in conserving the productivity of the resources they use. This was discussed in Figure 5. The implication is that the societal impact of introducing contingent claim markets is no longer as simple to determine, *a priori,* as the conceptual model in Figure 7 would suggest. First, because not all costs are accounted for by private firms, we are not sure where Y_0 is compared to the true socially optimal level of output, call it Y_0^* in Figure 5, with no risk. What this means is that once a firm takes account of risk and responds to insurance markets, it is making adjustments to the left of Y_0, but we have no information as to these adjustments in relation to Y_0^*, the true socially optimal level of output that takes into account environmental costs. Restating this argument, we lack sufficient information to conclude, *a priori,* that an increase in output as a result of introducing insurance markets is welfare increasing or decreasing when environmental factors have not been accounted.

In the above discussion, the optimal resource allocation was defined by economic criteria ignoring externalities. It is a complex question as to what societal output would be if externalities were incorporated into the firm's decision making. What this means for this analysis is that on strictly economic terms, introduction of CI should move the firm in the direction of an optimum allocation of resources and output would generally increase. More intensive use of resources sometimes has a negative impact on the environment. No attempt will be made in this report to reconcile these opposing forces, only to try to quantify the economic consequences of having a CI program and the environmental consequences related to changes in resource utilization.

Incorporation of Risk in CRAM

This section discusses the method by which risk is incorporated into CRAM. The version of CRAM used for this analysis includes the differentiation of cropping activities by tillage practices (Bouzaher et al. 1993, 1994 and 1995). Risk behaviour is represented in a sector model by the following term:

$$-.5\varphi(x'\Omega\ x) \tag{3.4}$$

where φ is the risk aversion parameter for all regions, *W* is a variance-covariance matrix of unit net returns for the activities, and *x* is a *nx1* vector of input activity levels. The risk term used in a sector model is equal to the sum of individual risk premiums over all farms (Hazell and Norton 1986). Basically, the sector model's risk term is the aggregate of a group of farm risk terms. Risk is modelled in CRAM by adding Eq. (3.4) to the objective function so that it maximizes consumer and producer surplus (CPS); that is,

$$\underset{x,t}{MAX}\ CPS(x,t) = P(Q)'Q - TC(x) \pm G'x - T't - .5\varphi(x'\Omega x), \tag{3.5}$$

where

x = a vector of input activity levels,

Q = a vector of outputs where Q = $f(x)$,

P() = a vector of price dependant demand function,

TC(x) = the total cost function,

G = a vector of government payment (or net indemnities), and

Tt = transportation costs for cost T and quantity shipped t.

This model maximizes the area under the demand curve and above the supply function, plus government payments, minus the transport costs and a risk premium for risk averse producers.

In terms of static analysis, CI affects the objective function in two ways. First, it affects government payments and due to the subsidization of premiums it will have a positive impact on farm incomes over time. If the program is actuarially sound, in the long run producers can expect to get back not only their own premiums, but also the government's portion since administrative costs are covered separately by the federal and provincial governments. Second, CI reduces risk by stabilizing farm incomes. CI will reduce the risk premium since it reduces the variability of farm returns and, therefore, the covariance matrix Ω . Furthermore, relative differences between the impact of CI on different crops could result in production shifting between crops. In summary, CI is expected to increase land use and shift production among crops by reducing the relative farm risk and increasing farm returns.

Estimation of the Variance-Covariance Matrix

To model CI, the variance-covariance matrix Ω is calculated for net returns using a 12-year series of farm net returns per hectare for each farm activity as follows:

$$\text{Net Returns} = \text{market revenue} - \text{crop production costs}, \tag{3.6}$$

and when CI is added it becomes

$$\text{Net Returns} = \text{market revenue} - \text{crop production costs} + \text{indemnity} - \text{premiums} \tag{3.7}$$

where the premium and indemnity have been defined above in Eqs. (1.1) and (1.2). Premiums are paid based on the coverage level chosen by farmers, and in this report the most popular coverage level of 70% was selected for all crops and all regions. Annual indemnity payments are triggered when the yield in a given year falls below a 10-year moving average yield times the coverage level of 70%. If the 10-year moving average yield times the coverage level does not fall below the current yield, the farmer receives no payout. For this analysis, the government payments in Eq. (3.5) are represented by the net indemnities (indemnity-premium) from the CI program. Market revenues are net of transportation costs.

To calculate the variance-covariance matrix Ω, the first step is to estimate expected net returns taking into account technological change over time in terms of yields. To do this, expected net returns are estimated as a linear function of time from which actual net returns are subtracted to obtain the error term ε for each period. The variance-covariance matrix Ω is calculated as follows:

$$\Omega = \varepsilon\varepsilon' / (n-1) \tag{3.8}$$

where ε is the *nx1* vector of the difference between detrended expected net returns and actual net returns over *n* years. The result is a large covariance matrix of net returns to crop activities within a given region, with or without CI.

Determination of Risk Aversion Coefficient

Paris (1979) developed a method for determining the value of the risk aversion coefficient φ based on observed behaviour. The underling variability of production activities is used to infer farmers' attitudes toward risk. This report calculates φ based on Paris' equation:

$$\varphi = -\delta / (x' \Omega x)^{.5} \tag{3.9}$$

where

δ = the standard normal percentile for a parameter *b* which defines an acceptable loss ratio and corresponds to the area to the left of Y_1 in Figure 8,

x = a vector of input activity levels, and

Ω = the variance-covariance matrix of unit net returns for the activities with crop insurance premiums and indemnities included.

The acceptable loss ratio assumed for this report is 1 to 7. This means a risk averse producer is willing to accept a loss (negative net returns) only one year in every seven. This gives a b value of 0.1429, an acceptable probability of losing roughly 14% of the time. Assuming normal distribution, the corresponding value for δ is 1.07. The calculated value for φ is 2.05273E-6 using a value of 1.07 for δ, the observed activity levels, and the covariance matrix Ω of detrended net returns including CI. Risk aversion coefficient φ is a measure of absolute risk aversion since it depends on the income of producers in the particular data set. Although in the model (Eq. (3.5)) Ω will change depending on whether CI is included or not, φ is held constant as it is an estimate of the attitude toward risk derived from observed behaviour. Sensitivity analysis will test for different attitudes toward risk, including risk neutral behaviour.

Yield Data

CI is supposed to assist in stabilizing farm income against production risks beyond producers' control as it relates to production shortfalls resulting from natural hazards. Yield fluctuations, mainly caused by weather or disease, are a critical natural hazard affecting the variability in farm revenues. Consequently, indemnity payments are driven by fluctuations in annual yields.

CRAM uses historical average annual yield data obtained from Statistics Canada (1996) and generated with the Erosion Productivity Impact Calculator (EPIC)(Bouzaher et al. 1993, 1994, and 1995). EPIC generated yield distributions for each crop, crop sequence (fallow or stubble), and tillage combination in a given CRAM region for the Prairies over a 30-year period based on historic climate data. Statistics Canada's yield data are not available according to rotations and tillage practices. The EPIC yields were adjusted downward to the levels of the observed 10-year average yields obtained from Statistics Canada. The Prairies accounted for 87% of the total area insured in the 1995–96 crop year. Statistics Canada's (1996) provincial yield data are used for the other provinces.

By using EPIC generated yield data, CRAM can simulate insurance premiums and indemnities for each crop, rotation and tillage practice, for the 1980–92 period. A 10-year moving average is used to calculate indemnities. The variance-covariance matrix Ω used in the objective function to represent risk is computed using a detrended time series of net farm returns. Net farm returns are estimated based on indemnities, premiums, market revenues and farm costs. Yields drive the CI component of CRAM since indemnity payments are triggered when crop yields fall below their 10-year moving average times the coverage level. The higher the yield variability the more often indemnity payments will be triggered. Therefore, CI reduces risk by improving the stability of net farm returns by eliminating the left hand tail of the distribution of returns (Figure 8).

Concerns were raised that regional average yields across time do not represent the true variability facing individual farms; consequently, they do not accurately depict farm risk. The distribution of average annual regional yields over time eliminates the individual farm highs and lows experienced in any given year, hence, reducing the real variability that an individual producer takes into account when making production decisions. This would therefore understate the potential for an indemnity payment. This report found that using average annual yields, CRAM would underestimate indemnity payments. To correct this problem, the annual yield distributions are shifted to the left as explained in Appendix A. The result is an increase in the estimated net indemnity payments such that net indemnities calculated by subtracting farm premiums from indemnities approximate the 20-year (1977–1996) long term average net indemnities of $196 million. By shifting the yield distribution, CRAM estimates an expected net indemnity payout of $182 million, $14 million less than the 20-year average.

Section 4: Impact of Crop Insurance on Resource Utilization and Production

Analysis of Crop Insurance

This section explores the impact of CI on tillage practices, crop production, and land use. This is a static analysis where the risk component and the government payment component in CRAM's objective function (Eq. (3.5)) are altered. The reference solution is obtained by finding an optimal solution without CI where the covariance matrix W is based on a farm revenue stream that does not include CI. Without CI, farm revenue will fluctuate more than with CI resulting in a higher covariance matrix which would increase the risk premium as determined by the last term in Eq. (3.5). The government payment component will equal zero since no CI indemnities are received and no premiums are paid, and no other government programs are included in the crop sector of the model. For this analysis other safety net programs have been set to zero

With CI, the covariance matrix W is recalculated based on a farm revenue stream that includes CI. CI reduces the variability of the farm revenue streams since indemnities are paid out when actual yields fall below 70% of long term average yields. Consequently, the covariance matrix will be smaller with CI. Government payments G for each activity x will equal the expected indemnity payment minus the premiums. Government payments will generally be positive since indemnity payments are larger than the producer premiums as discussed above.

A decision rule was added to the model to simulate the fact that not all farmers in Canada are enrolled in the CI program. It was assumed that farmers that did not expect to receive an indemnity payment would not buy CI. Consequently, when the calculated expected net indemnity payments are less than zero, it is assumed that producers do not participate in the CI program for that crop in that region. This represents zero participation. When expected net indemnity payments are greater than zero, this represents 100% participation for that crop in that region. The enrolment rate will depend on the level of expected net indemnities; for example, with net indemnities of $183M the model estimated 78% of the land planted to insurable crops would be covered by CI.

As discussed above, the effect of CI on farm management practices are two-fold. First, reducing the risk component will be equivalent to shifting the supply curve to the right as the risk premium is reduced. Relative improvement in the objective function between the different crops will cause the model to reallocate production among the crops. Second, positive government payments will have an additional positive effect, further increasing total production. The analysis compares estimates obtained with no CI to those with CI. The initial scenario assumes moderate levels of risk aversion with the current CI program reflected in the model. This is followed by a discussion of several scenarios where key parameter assumptions are altered.

Impact of CI with Moderate Aversion to Risk

This central reference scenario is based on an assumption of moderate aversion to risk which has been defined for this analysis as a willingness to accept a crop failure (negative net returns) one year in seven. As indicated above, 1994 is the base year and CRAM was calibrated to 1994 based on observed land allocation and expected prices and yields. In the model there are two specific types of land use. The first is for field crops which include grains, oilseeds, potatoes, field peas, beans, lentils and corn silage. The second land use is for tame hay and pasture that produces forage. Hay and pasture production are less factor intensive land utilization activities and in this analysis it is assumed that economically marginal land that cannot produce field crops at a profit will revert to producing tame hay as the next best alternative. A significant amount of information is generated by the economic analysis. The focus will be on how CI affects resource utilization in terms of land seeded to field crops, which crops are grown, and rotational decisions related to the use of summerfallow in Western Canada.

The overall impact of CI on land use is shown in Table 1. The decision rule in the model to insure only crops in regions with positive expected net indemnities results in 78% of the land planted to insurable crops actually being insured (20.3 million hectares out of 25.9 million hectares)[5]. CI increases land seeded to grains, oilseeds, and potatoes across Canada by 2% (685,000 ha) as land is shifted from less intensive uses such as tame hay production. CI was found to impact Saskatchewan the most by increasing land devoted to field crop production by 530,000 ha. Besides having the largest arable land base of any province, Saskatchewan has the largest number of insured hectares, a high participation rate, and receives the largest proportion of indemnity payments (Figures 1 and 2). Within Saskatchewan, CI would have an impact on total land use in only five regions as seen in Table 2. Figure 9 indicates where the Prairie crop regions are located. Except in Ontario, the impact of CI in Eastern Canada is negligible.

Structurally, this non-continuous response arises from the way CRAM deals with total available land in each region and how the regional supply functions are derived. This is most easily explained with the aid of Figures 10 and 11. In the base period in each crop district, Q^* land is planted to field crops which, given expected prices and yields, implies some positive return to land depicted by the distance *ab*. Other agricultural land is generally used to produce forage. A marginal decrease in farm revenues may not be sufficient to shift land from field crop production to less intensive forage production. However, at some point further reductions in farm revenues would result in land shifting out of grain and oilseed production.

5. This land does not include summerfallow and non-insurable crops (‘Other Crops’ in Table 3).

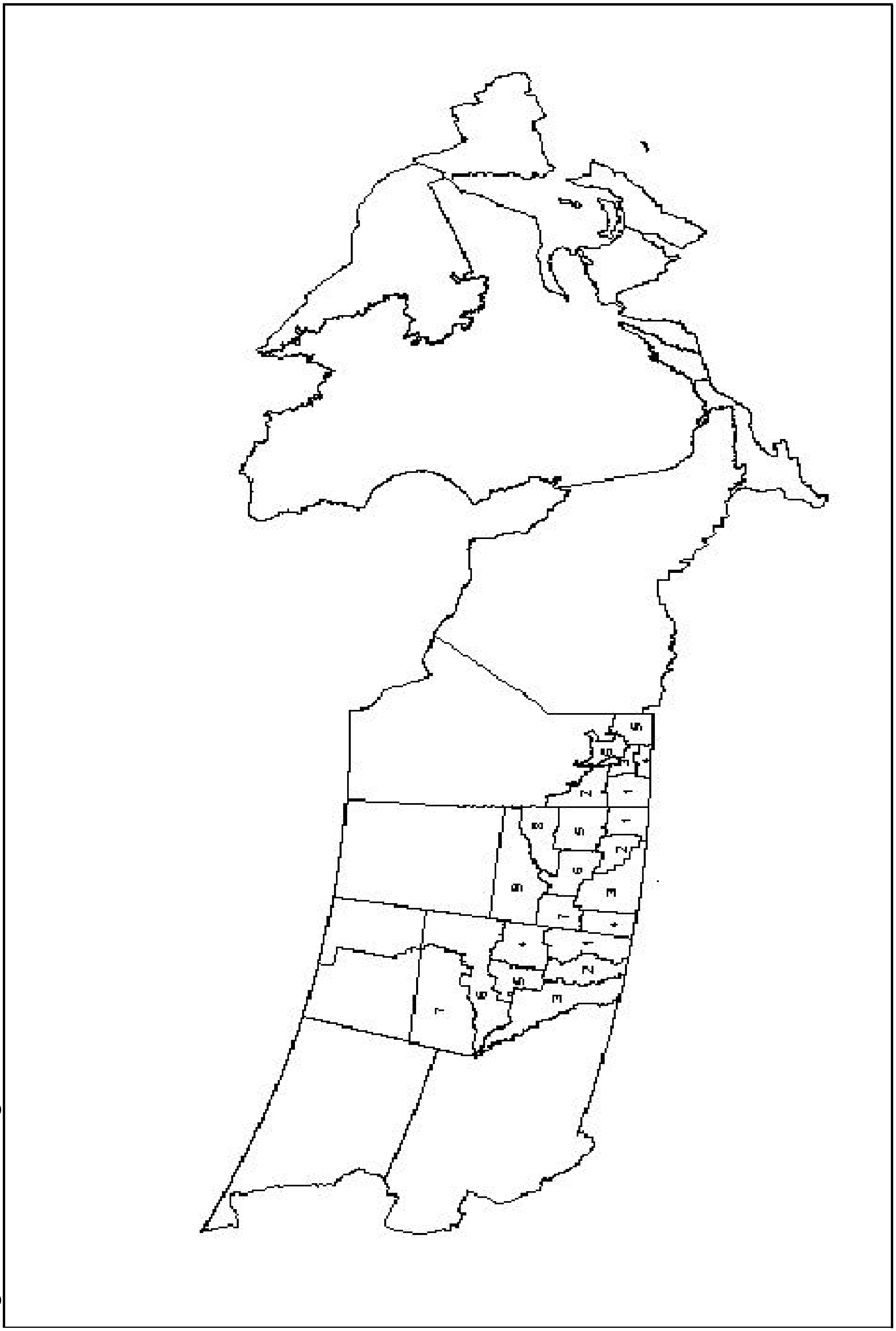


Figure 9: CRAM Regions

In Figure 10 if revenues are reduced to *c,* this would result in *Q** - *Q* land shifting to forage production. At an aggregate level, this model structure results in a non-linear crop supply function as shown in Figure 11.

Figure 10: Supply Response at Crop District

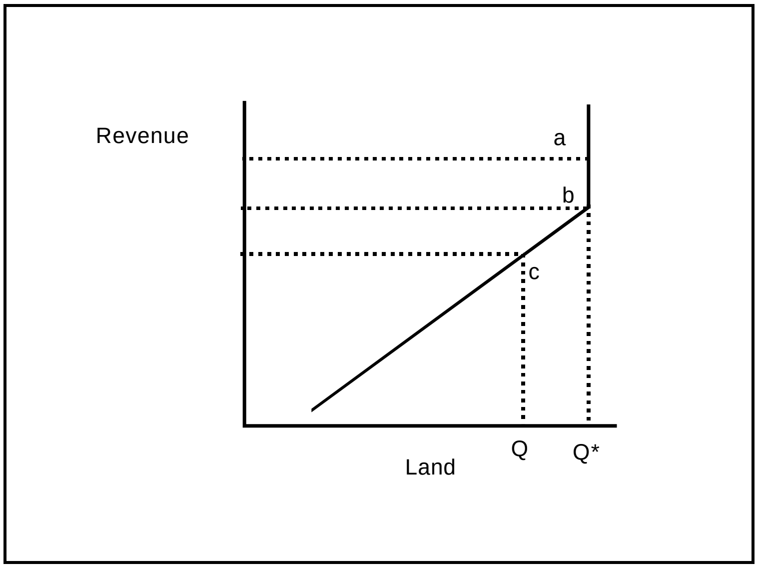
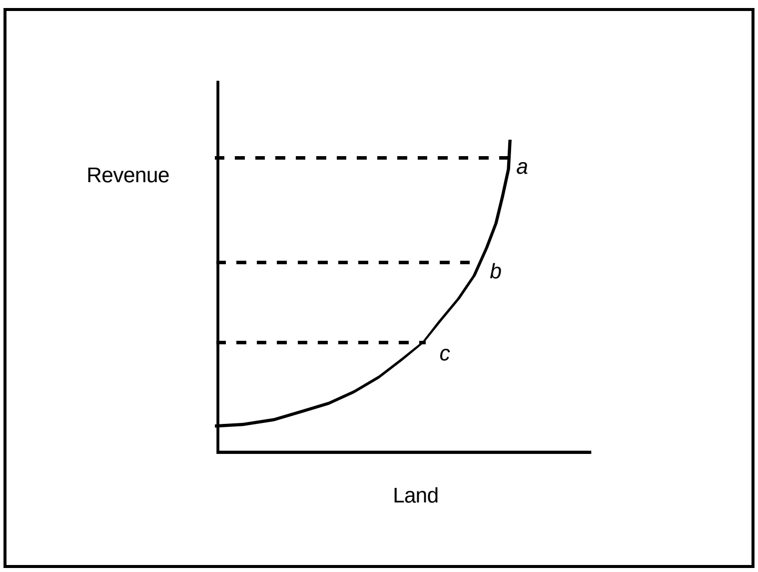


Figure 11: Aggregate Supply Response for Canada



CI would be expected to impact the selection of crops seeded in response to the expected net indemnity payments and the reduction in the risk premium as captured by the variance-covariance matrix. As demonstrated in Table 3, CI was found to be non-neutral with respect to crop selection. Reflected in the simulation results, CI would increase the amount of land seeded to hard red spring (HRS) wheat, barley, oats, flax, and soybeans. In part this is the result of 685,000 ha of economically marginal land being brought into grain and oilseed production, but also as a result of shifting land from non-insurable crops to crops apparently favoured by CI. Changes in the cropping pattern are similar between Eastern and Western Canada. Through a combination of reduced risk and subsidization, CI appears to favour some crops which may have been relatively more risky without the CI program. This does not imply that CI introduces a distortion in terms of which crops are grown, similar to the argument made that additional land being brought into production does not necessarily indicate any loss in efficiency if market failure existed previous to the introduction of CI by the government.

Summerfallow area increased in some crop districts while declining in others in Western Canada (Table 4). It increased approximately 0.1% (5,000 hectares) with CI (Table 5). At the provincial level, summerfallow increases in all provinces except Alberta. There are a variety of factors affecting decisions related to the use of summerfallow. First, summerfallowing can reduce risk for subsequent crops by building soil moisture reserves and can also reduce the need for purchased inputs (MacGregor and Graham 1988). If CI reduces the risk related to moisture deficits causing poor yields, continuous cropping would be encouraged by CI. Subsidization that improves overall returns to land would also encourage more intensive production practices as found with continuous cropping. On the other hand, CI could affect crop selection and it appears to favour crops where summerfallowing is more important. An increase in total land used for grain and oilseed production would be expected to result in an increase in summerfallow somewhat in proportion to land use prior to the introduction of CI. Depending on the weight of these factors, summerfallowing could either increase or decrease. In Saskatchewan and Manitoba with about 637,000 ha brought into grain and oilseed production, this factor would seem to be determining the increase in summerfallow area.

As shown in Table 6, HRS wheat exports increased by 681 kilotonnes (kt), durum exports 1kt, barley exports 357kt, oat exports 124kt, and flax exports by 53kt with CI. These shifts would have little impact on domestic prices as Canada is assumed to be a price taker in the world markets and with or without CI, Canada remains an exporter.

In summary, if grain and oilseed producers can be characterized as moderately risk averse, CI would have a relatively small impact on farm management decisions and resource utilization. As suggested by theory, resource utilization increases, as does output, leading to increased exports of roughly 1.2 million tonnes or 4% (Table 6).

Table 1: Impact of Crop Insurance with Moderate Risk Aversion on Total Land Use for Field Crops (′000 ha)

Regions	Without Crop Insurance	With Crop Insurance	Land Transferred from Forages and Pasture to Field Crops (% Change)	Difference
Canada	34,412	35,096	2.0	685
BC	209	209	0.0	0
AL	9,116	9,116	0.0	0
SA	17,750	18,280	3.0	530
MA	4,204	4,311	2.5	107
WEST	31,279	31,915	2.0	637
ON	2,252	2,300	2.1	48
QU	712	712	0.0	0
NB	53	53	0.0	0
PE	98	98	0.0	0
NS	18	18	0.0	0
NF	0	0	0.0	0
EAST	3,133	3,180	1.5	48

Source: Simulation results from CRAM.
*See Figure 9.

Table 2: Regional Impact of Crop Insurance with Moderate Risk Aversion on Land Use for Field Crops (´000 ha)

Western Crop District*	Without Crop Insurance	With Crop Insurance	Land Transferred from Forages and Pasture to Field Crops (% Change)	Difference
AL 1	1,080	1,080	0.0	0
AL 2	1,757	1,757	0.0	0
AL 3	908	908	0.0	0
AL 4	2,232	2,232	0.0	0
AL 5	898	898	0.0	0
AL 6	711	712	0.0	0
AL 7	1,529	1,529	0.0	0
SA 1	1,210	1,255	3.7	45
SA 2	1,671	1,671	0.0	0
SA 3	3,030	3,174	4.8	144
SA 4	1,002	1,002	0.0	0
SA 5	2,366	2,596	9.7	230
SA 6	2,344	2,344	0.0	0
SA 7	1,914	1,914	0.0	0
SA 8	1,861	1,898	2.0	38
SA 9	2,351	2,425	3.1	74
MA 1	1,333	1,439	7.9	106
MA 2	747	747	0.0	0
MA 3	638	638	0.0	0
MA 4	741	745	0.5	3
MA 5	360	360	0.0	0
MA 6	386	382	-0.8	-3

Source: Simulation results from CRAM.
*See Figure 9.

Table 3: National Impact of Crop Insurance with Moderate Risk Aversion on Crops Planted (´000 ha)

Crops	Without Crop Insurance	With Crop Insurance	Changes in Crops Planted (% Change)	Difference
Wheat	8,237	8,634	4.8	397
Durum	2,339	2,346	0.3	6
Barley	4,820	4,967	3.0	147
Oats	1,591	1,658	4.2	67
Flax	662	712	7.6	50
Canola	5,769	5,773	0.1	4
Lentils	402	399	-0.9	-4
Field Peas	697	696	-0.1	-1
Soybeans	778	820	5.4	42
Corn Grain	927	929	0.2	2
Corn Silage	151	151	0.0	0
Potatoes	124	126	1.9	2
Other Crops	1,098	1,068	-2.8	-31

Source: Simulation results from CRAM.

Table 4: CRAM Regions, Impact of Crop Insurance with Moderate Risk Aversion on Land Use for Summerfallow (´000 ha)

Regions*	Without Crop Insurance	With Crop Insurance	Change in Summerfallow Area (% Change)	Difference
AL 1	402.8	399.1	-0.9	-3.7
AL 2	535.8	474.0	-11.5	-61.7
AL 3	76.6	72.3	-5.6	-4.3
AL 4	250.3	256.0	2.3	5.7
AL 5	46.0	47.2	2.5	1.1
AL 6	70.9	70.9	0.0	0.0
AL 7	176.2	176.2	0.0	0.0
SA 1	381.4	393.2	3.1	11.8
SA 2	542.2	541.8	-0.1	-0.4
SA 3	1,250.3	1,284.5	2.7	34.2
SA 4	423.0	415.2	-1.8	-7.8
SA 5	489.8	514.5	5.0	24.7
SA 6	728.2	718.7	-1.3	-9.5
SA 7	675.7	665.1	-1.6	-10.6
SA 8	234.3	236.4	0.9	2.1
SA 9	279.0	290.3	4.1	11.3
MA 1	102.5	110.6	7.9	8.1
MA 2	65.7	69.0	5.0	3.3
MA 3	14.0	13.7	-2.3	-0.3
MA 4	8.2	8.3	0.9	0.1
MA 5	15.3	15.4	0.8	0.1
MA 6	26.4	26.4	0.0	0.0

Source: Simulation results from CRAM.
*See Figure 9.

Table 5: Regional Impact of Crop Insurance with Moderate Risk Aversion on Land Use for Summerfallow (′000 ha)

Regions	Without Crop Insurance	With Crop Insurance	Change in Summerfallow Area (% Change)	Difference
Canada	6,812	6,817	0.1	5
BC Total	18	18	2.7	0
AL Total	1,559	1,496	-4.0	-63
SA Total	5,004	5,060	1.1	56
MA Total	232	243	4.8	11

Source: Simulation results from CRAM.

Table 6: National Impact of Crop Insurance with Moderate Risk Aversion Grain and Oilseed Exports (′000 tonnes)

Crops	Without Crop Insurance	With Crop Insurance	Changes in Crops Exported (% Change)	Difference
Wheat West	12,128	12,809	5.6	681
Wheat East	327	327	0.00	0
Durum	4,058	4,059	0.0	1
Barley	2,587	2,944	13.8	357
Oats	2,015	2,139	6.2	124
Flax	706	759	7.4	53
Canola	5,687	5,687	0.00	0
Lentils	391	387	-1.1	-4
Field Peas	918	916	-0.3	-2
Total	28,817	30,027	4.2	1,210

Source: Simulation results from CRAM.

Sensitivity Analysis

In conducting the above analysis, many assumptions had to be made. With any analysis of this sort a question arises as to how some of the more important assumptions might have affected the results. Several scenarios are run to determine how sensitive the results are to these assumptions and also to test the structural robustness of how CI has been modelled in CRAM through the expected net indemnity payments and the risk term. The scenarios are presented in Table 7. Normally when carrying out scenarios, a baseline is established and held constant and all comparisons are made to this base. For this analysis this was not the correct approach. For most scenarios, the behavioural parameter φ, the risk adversion coefficient, was adjusted and then held constant between the with and without CI runs[6].

Scenario 1, discussed above, assumes that individual producers are moderately risk averse since they are willing to accept a crop failure every seven years. Scenarios 2, 3 and 4 examine the impact of altering risk preferences by changing the risk aversion coefficient φ to reflect extremes in risk preferences. The less risk averse individuals are, the less CI would be expected to influence their decision. *A priori*, it is expected that CI would have the most impact if the industry could be characterized as highly risk averse as reflected in Scenario 3, and the least if risk neutrality holds as in Scenario 4. In Scenarios 5 and 6 the impact of CI is evaluated at higher and lower crop returns as determined by either market prices or government deficiency payments. The expected implication of this was demonstrated in Figure 11. Point *b* represents expected crop revenue and intersects the aggregate supply function in a relatively inelastic area. At higher expected revenues, CI would be expected to play a much smaller role in land use decisions as indicated by point *a.* At low returns such as point *c* in Figure 11, CI would be expected to have a bigger impact. In Scenario 7, the implication of increased yield variability is examined. In this run, a mean-preserving spread is applied to the yield distribution as outlined in Appendix A, and the increased variability is used both in the calculation of net indemnities and in the risk component of the model. Finally, Scenario 8 assumes higher net indemnities ($902M) while holding the producer premiums constant. The increase in net indemnities results in 100% of acres insured compared with 78% in Scenario 1.

Table 8 indicates how overall land use in terms of area seeded to grains and oilseeds is affected by these various assumptions. The results of Scenario 1 are repeated for comparison purposes. At the national level the impact of producers' attitude to risk (as implemented through different values for φ) on land use ranges between an increase of 0.1% for risk neutral to a high as 2.6% for highly risk averse behaviour. By comparison, in Scenario 1 the impact is 2%. These results are consistent with *a priori* expectations. Obviously, if producers are risk neutral, the availability of CI would be of little interest as a risk management tool. As risk aversion increases, which increases the risk premium producers incorporate into their production decisions, the availability of CI has a stronger positive impact on output, although the absolute impact remains relatively small. Another interesting finding occurs when φ is set equal to 0, equivalent to risk neutral behaviour. This sets the risk term in Eq. (3.5) to zero in Scenario 4. The only component of CI remaining is the government

6. This means calibrating a new baseline for each scenario which will have small impacts on the positive mathematical programming (PMP) process that calculates the marginal factor cost functions for all cropping activities. In essence, the elasticity on the underlying crop supply functions will vary slightly as a result of this approach.

subsidization as captured by expected net indemnity payments. The impact of CI on land use is very small at an aggregate level which suggest that the reduction in risk provided by CI plays a major role in how CI affects resource use decisions.

When tested under conditions of high and low crop returns, the impact of a CI program were also as expected, *a priori*. In Scenario 6 expected GRIP payments for 1994 were incorporated into government payments in addition to crop returns. This is the only scenario examined that included any government crop subsidies other than CI. The impact of including GRIP is to move the response to CI into a relatively more inelastic portion of the supply curve (Figure 11) and the impact of CI is substantially less than in Scenario 1. Scenario 6 could also be viewed as a high price market situation. Scenario 5 examines the impact of lowering market prices by 5%, a low price situation. The purpose of this run is to demonstrate the impact of CI when a situation of lower profitability of producing grains and oilseeds exists. This would tend to make a greater proportion of land economically marginal and increase the incentive to look for alternative uses, such as forage production. It is estimated that CI would result in a 3.6% increase in the quantity of land used for producing grains and oilseeds when weak market conditions prevail.

In Scenario 7, the increased yield variability incorporated into the variance-covariance matrix through a mean preserving spread applied to the yield distribution intensifies the impact of the CI program as compared to Scenario 1. The key role played by the risk premium is again demonstrated in this scenario. Although the overall level of subsidization is maintained at $180 million, the impact on land use more than doubles to 4.3%.

In Scenario 8, the formula used in CRAM to calculate indemnities is altered to increase expected net coverage. A payout would be triggered more often but producer premiums are held constant. As indicated in Table 7, this would dramatically increase the cost of the program for the government, as well as the subsidy transfer to producers from roughly $180 million per year to $900 million. At this level of subsidization all insurable crops in the model have positive expected net indemnities, therefore, participation reached 100%. CI has the largest impact on land use of all scenarios at 5.6%, not unexpected given the dramatic rise in subsidization to obtain 100% participation.

As discussed in Scenario 1, two opposing responses are seen in the model. As more land switches from less intensive forage production to grains and oilseeds, the amount of summerfallow increases as part of the normal rotation. On existing land planted to grains and oilseeds there is a tendency to reduce the amount of summerfallow in the rotation and opt for more continuous cropping if CI is available to help deal with the added risk. As seen in Table 9, in Alberta in all scenarios the use of summerfallow decreases as the shift to more continuous cropping is the most important influence. In Saskatchewan, the shift of economically marginal land to grain and oilseed production generally results in an overall increase in summerfallow, except in Scenario 4 (risk neutrality) where the incentive to increase continuous cropping is greater and very little marginal land is affected. For the Prairies as a whole the impact of CI on summerfallow area across the various scenarios analysed is generally small, increasing as risk aversion and riskiness increase or as returns fall.

Table 7: Sensitivity Analysis, the Underlying Assumptions for Each Scenario

Scenario 1 Moderately risk averse	Scenario 2 Slightly risk averse	Scenario 3 Highly risk averse	Scenario 4 Risk neutral	Scenario 5 Lower Crop Returns	Scenario 6 Higher Crop Returns	Scenario 7 Increased Yield Variability	Scenario 8 High net indemnities
Assume a risk acceptance level of a crop loss every seven years	Assume a risk acceptance level of a crop loss every three years	Assume a risk acceptance level of a crop loss every ten years	Assume individual's decision process is not influenced by risk	Assume a risk acceptance level of a crop loss every seven years	Assume a risk acceptance level of a crop loss every seven years	Assume a risk acceptance level of a crop loss every seven years	Assume a risk acceptance level of a crop loss every seven years
φ =2.05273e-6	φ =8.24929e-7	φ =2.45560e-6	φ =0	φ =2.05273e-6	φ =2.05273e-6	φ =1.2133e-6*	φ=2.05273e-6
No GRIP	No GRIP	No GRIP	No GRIP	No GRIP	**With GRIP**	No GRIP	No GRIP
Market returns set at 1994 levels	Market returns set at 1994 levela	Market returns set at 1994 levels	Market returns set at 1994 levels	Lower market prices by 5%	Market returns set at 1994 levels	Market returns set at 1994 levels	Market returns set at 1994 levels
Net indemnities $183M	Net indemnities $183M	Net indemnities $183M	Net indemnities $183M	Net indemnities $182M	Net indemnities $850M (including-GRIP payments)	Net indemnities $180M	Net indemnities $902M

*In Scenario 7, the risk aversion coefficient will change even though risk preferences are held constant because the variance-covariance matrix is altered, see Eq. (3.9).

Table 8: Impact of Crop Insurance on Total Land Use for Grains and Oilseeds Production (Percent Change with Crop Insurance)

Regions	Scenario 1 Moderate risk averse	Scenario 2 Slightly risk averse	Scenario 3 Highly risk averse	Scenario 4 Risk neutral	Scenario 5 Lower crop returns	Scenario 6 Higher crop returns	Scenario 7 Increased Yield Variability	Scenario 8 High net indemnities
Canada	2.0	1.0	2.6	0.1	3.6	1.1	4.3	5.6
BC	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0
AL	0.0	0.0	0.6	0.0	1.7	0.0	1.3	2.4
SA	3.0	1.4	3.8	0.2	2.2	2.0	5.6	7.3
MA	2.5	1.7	3.1	0.0	5.0	0.4	2.4	10.1
WEST	2.0	1.1	2.7	0.1	3.6	1.2	3.9	6.2
ON	2.1	0.0	1.9	0.0	1.9	0.0	11.8	0.0
QU	0.0	0.0	0.2	0.0	8.2	0.0	0.2	0.3
NB	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PE	0.0	0.0	0.0	0.0	3.1	0.0	0.0	4.8
NS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EAST	1.5	0.0	1.5	0.0	3.2	0.0	8.4	0.2

Source: Simulation results from CRAM.

Table 9: Impact of Crop Insurance on Summerfallow Area (Percent Change with Crop Insurance

Regions	Scenario 1 Moderately risk averse	Scenario 2 Slightly risk averse	Scenario 3 Highly risk averse	Scenario 4 Risk neutral	Scenario 5 Lower crop returns	Scenario 6 Higher crop returns	Scenario 7 Increased Yield	Variability
Canada	0.1	-0.3	0.3	-0.8	1.2	-0.1	3.3	0.6
BC	2.7	2.7	2.7	2.7	3.6	1.3	10.6	20.0
AL	-4.0	-3.2	-4.0	-2.6	-1.7	-2.5	-3.1	-3.6
SA	1.1	0.4	1.4	-0.4	1.8	0.5	5.0	1.6
MA	4.8	3.1	5.3	1.3	6.6	2.0	5.3	7.1

Source: Simulation results from CRAM.

Table 10: National Impact of Crop Insurance on Crops Planted (Percent Change with Crop Insurance)

Crops	Scenario 1 Moderate risk averse	Scenario 2 Slightly risk averse	Scenario 3 Highly risk averse	Scenario 4 Risk neutral	Scenario 5 Lower crop returns	Scenario 6 Higher crop returns	Scenario 7 Increased Yield Variability	Scenario 8 High net indemnities
Wheat	4.8	2.9	5.9	1.3	7.3	2.8	7.2	11.7
Durum	0.3	0.2	0.3	-0.5	1.3	0.4	4.1	1.5
Barley	3.0	2.0	5.2	1.0	5.5	2.3	5.8	10.3
Oats	4.2	1.9	5.4	0.4	5.2	2.7	4.1	13.7
Flax	7.6	4.2	9.6	1.8	11.5	6.1	12.6	19.4
Canola	0.1	-0.5	0.5	-0.8	1.1	-0.4	0.9	3.1
Lentils	-0.9	-0.7	-0.9	-0.7	-0.6	-1.1	-0.2	4.5
Field Peas	-0.1	-0.7	0.4	-0.8	1.0	-0.6	0.0	2.9
Soybeans	5.4	3.1	5.3	2.9	6.2	4.7	10.3	9.0
Corn Grain	0.2	0.2	0.2	0.3	0.3	-0.2	1.8	0.9
Corn Silage	0.0	-4.8	-1.4	-5.5	-0.4	-4.7	-2.1	-20.2
Potatoes	1.9	2.3	1.8	2.5	2.5	1.9	4.9	2.6
Other Crops	-2.8	-3.1	-2.5	-3.1	-1.8	-3.9	-2.0	-12.4

Source: Simulation results from CRAM.

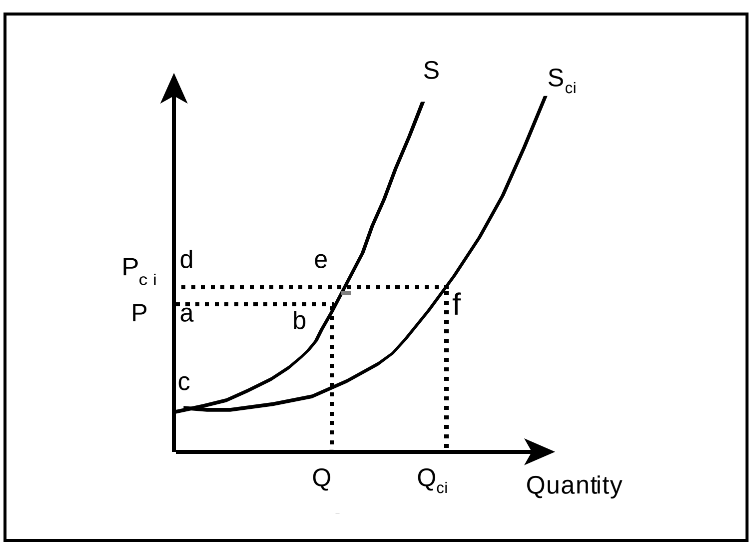
The impact of CI on crop selection is in part influenced by decisions related to use of summerfallow, and also by the crop districts where overall land use is most affected by CI. In the Prairies, hard red spring wheat, flax, barley and oats are favoured relative to the other crops based on the estimates provided in Table 10. Flax, barley and oats are generally planted into stubble. CI is estimated to have little impact on plantings of durum, canola, lentils and field peas, an indication of a relatively inelastic supply response for these crops in CRAM and that CI generally provided a lower level of risk reduction, and/or subsidization for these crops. In Eastern Canada soybeans appear to be favoured by CI, increasing acreage by 3–10%. 'Other Crops' is a composite for all other field crops produced that are not explicitly modelled in CRAM. They are treated as a non-insured crop in this analysis. The area devoted to these remaining crops is generally small so this is not expected to have much impact on the overall results. However, some of the crops in this aggregate do have CI programs which means that the estimated negative impact of CI on 'Other Crops' in Table 10 needs to be qualified.

Impact of Crop Insurance on Producer Income

CRAM solves for a competitive equilibrium by maximizing aggregate producer surplus and aggregate consumer surplus. The aggregate producer surplus or aggregate profit, when firms face a situation with no CI is depicted by the area *abc* in Figure 12. CI shifts the aggregate supply curve S to the right to S_{ci}, by reducing producer risk. Farm revenues increase from PQ to $P_{ci}Q_{ci}$ by subsidizing premiums. The aggregate producer surplus with CI is depicted by the area *dfc* in Figure 12.

In a small open agricultural economy, commodity prices are determined by international market conditions. A shift in the domestic supply curve to the right would not significantly reduce domestic prices. Therefore, producers would capture most of the risk reduction benefits and subsidy benefits. CI insurance increases producer surplus, in this case aggregate profits, 8% or $220 million in Scenario 1 (moderately risk averse) as shown in Table 11. The actual subsidy component was estimated by the expected net indemnity of $183 million (Table 7).

Figure 12: Estimate of Producer Income



With the risk term included in the objective function Eq. (3.5), it is the utility of expected income that is being maximized taking into account the cost associated with risk. Part of the difference between the $220 million increase in producer surplus and the $183 million expected subsidy would be the reduction in the risk premium as expected income becomes less variable which encourages producers to plant economically marginal land to grains and oilseeds. Overall supply is increased which increases exports 4% (1.2 million tonnes). In terms of transfer efficiency (Deloitte & Touche 1993), CI would appear to be a very efficient program in that producers obtain a benefit that exceeds the amount transferred by government through their share of the premiums. However, this does not account for administrative costs shared by the federal and provincial governments, nor the costs associated with raising the tax dollars allocated to the CI program.

Table 11: National Impact of Crop Insurance with Moderate Risk Aversion on Aggregate Producer Surplus ($000)

Regions	Without Crop Insurance	With Crop Insurance	Change (%)	Difference
Canada	2,594,935	2,815,025	8	220,090
BC	8,912	9,176	3	264
AL	598,377	665,970	11	67,593
SA	1,417,913	1,506,321	6	88,408
MA	287,899	308,972	7	21,073
WEST	2,313,101	2,490,440	8	177,339
ON	176,635	196,255	11	19,620
QU	57,096	75,287	32	18,191
NB	20,149	21,414	6	1,265
PE	26,745	30,207	13	3,462
NS	1,172	1,387	18	215
NF	37	37	0	0
EAST	281,834	324,586	15	42,752

Source: Simulation results from CRAM.

Section 5: Environmental Assessment

Introduction

The economic analysis in the previous section provides estimates of the extent to which CI affects producers decisions with respect to land use and crops grown under a wide variety of circumstances. This is measured at a regional or provincial level. In this section the implications that changes in land use have for resources employed or affected by field crop production will be discussed. To the extent possible, environmental impacts of CI will be quantified. Where it is not yet possible to measure the impact, qualitative assessments will be provided. This will provide us with some understanding of the degree to which environmental costs (or benefits) have been left out of the process of designing programs such as CI and how outcomes might change if they are taken into account in the future.

The methods presented below may be used for analyses of other agricultural policies, as well as non-policy changes in the agricultural sector, such as changes in markets or technology. As indicators of agri-environmental performance are further developed, the reliability of this kind of analysis will increase, as will its usefulness for policy formation.

Scope

This analysis covers resources that may be affected by agricultural activities, and that provide significant benefits to the agricultural sector or the public. It focuses on attributes of resources for which information is available on their state and their link to agriculture. This includes:

- soil erosion from wind and water,
- soil salinization,
- water quality, and
- wildlife habitat.

This report does not analyse the impact of the program on the atmosphere. Given that the changes in cropping patterns imputed to CI programs are relatively small, the atmospheric implications of the program are also likely to be small, and would not significantly affect the overall assessment.

Methodology

This analysis searched for geographical areas where there are both:

- changes in producer decisions attributable to CI and
- significant environmental risks related to those producer decisions.

Geographical information is essential for environmental analysis of agricultural policies because both policy impacts and environmental risks vary widely from area to area. Similar policies can lead to different producer decisions, depending on the local conditions. For example, CRAM estimates in Section 4 indicate that CI would lead to increases in summerfallow in areas of Manitoba and Saskatchewan, but decreases in Alberta. Similarly, most environmental risks are not evenly distributed across the country, but rather are concentrated in small geographical areas with particularly sensitive resources. For example, the risk of soil salinization due to farming practices is high on only about 10% of prairie agricultural land (Eilers et al. 1996).

CRAM results described in Section 4 provide regional information on how CI would affect producer decisions. The following analysis uses these results to assess the impacts of these changes on natural resources. In areas where CI influences decisions, information on environmental risks and public benefits is used to determine how much the resource is affected.

Environmental risks are evaluated with geographical information from CRAM, the Census of Canada, AAFC's Soil Landscapes of Canada database, Ducks Unlimited and other sources. For soil erosion, the CRAM model provides changes in land use that are used to provide quantitative estimates of changes in erosion levels by crop district. The other sources are used in a more qualitative manner to identify agricultural areas that are highly susceptible to resource degradation, and evaluate CI's contribution to degradation risk. While the basic approach is the same for all resources, different sources of information and methods are used in each section. The analysis pays particular attention to decisions that may affect natural resources, particularly tillage methods, allocations of land between crops and pasture, and levels of summerfallow.

This analysis requires the interpretation of maps based on two different geographic information systems, CRAM regions (Figure 9) and Soil Landscape Polygons (AAFC 1996). The impacts of the CI program on producer decisions are estimated for CRAM regions, which include 22 regions of the Prairie provinces, and provincial estimates outside the Prairies, as described in Section 4. Erosion risk, salinity risk, wildlife habitat on farms and waterfowl habitat value are evaluated at the soil polygon level. There may be several hundred soil polygons in a particular CRAM region or province.

The use of different geographical classification systems requires caution because the borders and the scale of detail vary between systems. The simplest way to apply the economic results at the CRAM region level to the environmental information at the soil polygon level is to assume that changes predicted by CRAM would apply equally to all soil polygons within the CRAM region. The following analysis tempers this simplification with qualitative judgements in order to estimate better the impact of CI on natural resources.

Impact of Crop Insurance on Soil Erosion

Erosion is a process by which soil is moved from one area to another. The main natural agents of erosion are wind and water. Erosion also removes organic matter from the soil which in turn affects soil fertility and crop yields. Yields from severely eroded soils may be 50–100% lower than those from stable soil in the same field (Wall et al. 1995). In this analysis, the impact of CI on production decisions is determined and the environmental implications are measured by the estimated annual rate of wind and water erosion for each crop district and/or province.

The methodology to estimate the rate of wind and water erosion is described in detail in Appendix B. Wind and water erosion rates are estimated for the moderately risk averse scenario (Scenario 1, Table 7) and high net indemnities scenario (Scenario 8, Table 7) (as described in Section 4). CRAM is run with and without CI . Output from CRAM is used to obtain the estimates of wind and water erosion for the CRAM regions. The water erosion rates are calculated for all the CRAM regions except Newfoundland. The actual erosion rates reported here should be interpreted with caution because the universal soil loss equation (USLE) is an empirical model which does not measure erosion but estimates 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 be used qualitatively to compare polygons by erosion risk class and not quantitatively. The risk of soil erosion by wind on agricultural land is a concern in many regions of Canada. However, wind erosion is by far the most extensive and damaging in the Prairie provinces where the climate is dry and large expanses of fields lie unprotected under various management regimes. Wind erosion rates are calculated for the Prairie provinces only because wind erosion is not a serious problem in eastern provinces. This section describes how estimates of wind and water erosion rates could be affected by CI.

Water Erosion Results for Moderately Risk Averse (Scenario 1, Table 7)

The risk of soil erosion by water is a concern in all of Canada's agricultural regions. Fine textured, erodible soils are exposed to erosion by rainfall and runoff in many areas. The risk of water erosion is usually greatest on inherently erodible landscapes under intensive cultivation (Wall et al. 1995). The estimates for water erosion for different CRAM regions are presented in Table 12 and Figure 13. A more detailed description of type of land use changes that result from changes in CI are provided in Section 4.

On average, tolerable soil losses (4.8 tonnes per hectare per year (Table 12))[7] occurred at the provincial level in Alberta without CI. The water erosion rate decreases by about 2% with CI at the provincial level. In region AL1, low soil losses (6.1 tonnes per hectare per year) occur without CI. Soil losses in regions AL 2–7 are tolerable (i.e. less than 6 tonnes per hectare per year) without CI. There is a 4% decrease in the water erosion rates for region AL 2 with CI. This decrease in the water erosion rate is largely due to a 12% decrease in the summerfallow area. For region AL 3, there is 1.8% decrease in water erosion rates with CI, also resulting

7. Soil erosion risk classes of very low, low, moderate, high and severe are discussed in Appendix B. Risk of erosion classed as very low (less than 6 tonnes per hectare per year) is felt to represent a tolerable risk where soil formation is equal to soil loss.

from a 5.5% decrease in the summerfallow area along with changes in the areas under different crops. For regions AL 1, 4, 5, 6 and 7 there is no measurable change in water erosion rates with CI at the crop district level.

On average, tolerable soil losses (2.9 tonnes per hectare per year) would occur at the provincial level in Saskatchewan without CI. Water erosion losses range from 2.3 tonnes per hectare per year (region SA 6) to 3.5 tonnes per hectare per year (region SA 3). The water erosion rate increases by 3.6% with CI at the provincial level. For regions SA 1, 3, 5 and 8, water erosion rates increase 4, 3, 10 and 4%, respectively, with CI due to an increase in the summerfallow area of 3–4% and a decrease in hay area of 23–50% as this land is shifted into grain and oilseed production. For regions SA 2, 4, 6, 7 and 9 there is no measurable change in the estimated water erosion rates with CI at the crop district level.

On average tolerable soil losses (3.5 tonnes per hectare per year) would occur at the provincial level in Manitoba without CI. There is no change in the water erosion rates with CI in Manitoba at the provincial level. Regionally, the estimated water erosion losses are tolerable (i.e. less than 6 tonnes per hectare per year) without CI. There is no change in the water erosion rates for regions MA 3, 4, 5 and 6 when CI is introduced. In regions MA 1 and 2 water erosion rates increase 4% and 2%, respectively, with CI. An increase in the water erosion rate in region MA 1 relates to an increase in the summerfallow area of 8% and decrease in the hay area of 31%. An increase in the water erosion rate in region MA 2 is due to the combined effects of an increase in the wheat area of 2%, an increase in the summerfallow area of 5%, and decrease in barley area of about 9%.

In British Colombia water erosion losses are low (6.3 tonnes per hectare per year) without CI and there is no change in the water erosion rate with CI. In Ontario low soil losses (8.6 tonnes per hectare per year) occur without CI. The water erosion increases 4.7% with the CI scenario due to the combined effects of an increase in potato, wheat, barley and soybean areas of 3%, 2%, 5% and 5%, respectively, and a decrease in hay area of 4%. In Quebec tolerable water erosion losses (3.9 tonnes per hectare per year) occur without CI. There is no change in the water erosion rate with CI measured at the provincial level.

In New Brunswick moderate soil losses (14.3 tonnes per hectare per year) occur without CI. The water erosion increases slightly by 0.7% with the CI scenario. This slight increase in the water erosion rates is connected to a 2.4% increase in potato area. In Prince Edward Island low soil losses (7.4 tonnes per hectare per year) occur without CI. There is no change in the water erosion rates with the CI scenario. In Nova Scotia soil losses are tolerable (4.2 tonnes per hectare per year) without CI. The water erosion increases 2.4% with CI scenario. This increase in the water erosion rate relates to an increase in corn grain area of 11%.

These relatively small changes in the water erosion rates are due to several factors including changes in the distribution of different crops grown, and the summerfallow and hay areas. The C values[8] are weighted for the proportion of total cropland area, summerfallow area and hayland areas. A significant increase or decrease in the land area in a region under a particular use may result in an increase or decrease in the water erosion rates in that region. Provincial water erosion increases range from negligible to a high of about 4.7% in Ontario. These increases in soil loss are the result of the combined effects of changes in cropland areas

8. A C value is a ratio comparing the soil eroded under a specific crop and management system to a cultivated continuous fallow system. See Appendix B for details.

and shifts in the types of crops grown. In the Prairies the impact is also due to adjustment between conventional, conservation, and no-till cultivation practices. Based on the soil erosion risk classes as defined in *The Health of Our Soils* (Wall et al. 1995), no change occurs between the with and without CI scenarios when evaluated at the CRAM region or provincial level.

Water Erosion Results for High Net Indemnities (Scenario 8, Table 7)

In case of the high net indemnities scenario, the formula used in CRAM to calculate indemnities is altered, increasing the coverage level such that a payout would be triggered more often while producer premiums are held constant. The high net indemnities scenario results in 100% of hectares being insured as compared with 78% with the moderately risk averse scenario (Scenario 1). With the high net indemnities, CI has the largest impact on total land use. Grain and oilseed acreage increases 5.6% as compared with the moderately risk averse scenario at 2%. The impact of CI on water erosion is expected to be higher in the case of the high net indemnities scenario as compared with the moderately risk averse scenario. The results for water erosion for the high net indemnities scenario for different CRAM regions are presented in Table 13 and Figure 14.

On average, tolerable soil losses (4.7 tonnes per hectare per year (Table 13)) occur at the provincial level in Alberta without CI. There is no change in the water erosion rate with CI in Alberta at the provincial level. Soil losses in Alberta regions AL 2 to 7 are tolerable. The decrease in the water erosion rate in regions AL 2 and 3 is due to a 10% decrease in the summerfallow area. The decrease in the water erosion rate in region AL 6 is again due to a decrease in summerfallow area of 13%. In region AL 7, with CI, the water erosion rate would increase 12.5% due to an increase in the summerfallow area of 29% and a decrease in hay area of 30%.

On average, tolerable soil losses (2.7 tonnes per hectare per year) would occur at the provincial level in Saskatchewan without crop insurance. The water erosion rates would increase 7.4% with CI at the provincial level. In regions SA 3, 4, 5, 8 and 9, CI would increase the rate of erosion as marginal land that is seeded to hay without CI, is used to produce grains and oilseeds. In regions SA 6 and 7 the water erosion rates would decrease 4% due to a decrease in summerfallow area of 3.8% and 2.3%, respectively.

On average, tolerable soil losses (3.4 tonnes per hectare per year) would occur at the provincial level in Manitoba without CI. Water erosion rates increase about 6% with CI at the provincial level. In regions MA 1, 2 and 4, the water erosion rates would increase 4–12% due to a shift to more intensive grain and oilseed production from forage in all three regions.

In British Colombia, Quebec and Nova Scotia, there would be no change in the rate of water erosion with CI. In Ontario, low soil losses (8.7 tonnes per hectare per year) occur without CI and would increase about 3.5% with CI. This relates to increase in soybean area of 8% and a decrease in grain corn area of 2%.

In New Brunswick moderate soil losses (14.3 tonnes per hectare per year) occur without CI and would increase slightly by 1.4% with CI due to increase in potato area of 4%. Similarly, in Prince Edward Island low soil losses (7.3 tonnes per hectare per year) occur without CI and would increase 4.2% with CI due to an increase in potato area of 5% and a decrease in hay area of 8.5% as land is shifted to more intensive field crop production.

The increase in the water erosion rates for most of the regions are due to several factors including changes in the crops grown, an increase in the summerfallow area and an incentive to shift marginal land from hay production. At the level reported here, changes in land due to CI do not change the soil erosion risk classes as defined in *The Health of Our Soils* (Wall et al. 1995).

Soil Erosion Risk Analysis

The averaging of erosion rates across CRAM regions may hide the impact of CI on erosion risk in small areas within regions. If a crop region has low erosion risk in most areas, but high erosion risk in a small number of soil polygons, the average erosion rate for the region will be low. However, CI may have the effect of increasing cropped acres across the entire region, including in high-risk areas. This could cause some land to shift from a moderate risk category into a high risk category, thus contributing to excessive soil erosion.

To assess this possibility, the CRAM regions were overlaid with maps of soil polygons with a high risk of water erosion under 1991 management practices. Analysis concentrated on the Prairies, Ontario, Nova Scotia and New Brunswick, where erosion is estimated to increase slightly as a result of the existence of CI (Table 12). These maps may over-estimate the area at high risk of erosion due to the increase in low-till and no-till cultivation since 1991 (see Figures 15, 16 and 17).

In Alberta, erosion is estimated to decrease in crop districts AL 2 and 3 (Table 12) due to a reduction in the area of summerfallow. AL 3 contains a significant area of highly erodible soil in the foothills area, which may experience slightly lower erosion if the use of summerfallow due to CI declines in this area. In Saskatchewan, erosion is estimated to increase slightly in districts SA 1, 3, 5 and 8. There are very few areas within these districts that have a high or severe risk of water erosion under 1991 management practices. In Manitoba, erosion is estimated to increase slightly in districts MA 1 and 2. These areas contain significant areas of high water erosion risk, particularly the Riding Mountain upland area. Since this is not an intensively farmed area, it is unlikely, but possible, that increases in erosion due to CI could occur in this area.

There are several areas of Central Ontario, New Brunswick and Nova Scotia that have high or severe risk of water erosion under 1991 management practices. It is not known which areas of these provinces are most affected by the CI program. If the increases in erosion attributable to CI (Table 12) are distributed evenly across the agricultural areas of the province, CI could increase the amount of high-risk land under cultivation by a similar amount. This effect would be less if CI has more effect on low-risk areas, which would occur if marginally profitable land occurs in areas of low erosion risk. The effect would be larger if marginally profitable land is concentrated in areas of high erosion risk. With available information, it is impossible to tell how large the effect is, or where it would occur. In general, CI would appear to have little effect on increasing the risk of water erosion on land with a high water erosion risk.

Table 12: Water Erosion Results for Moderately Risk Averse Scenario (tonnes per hectares per year) for CRAM regions

Region	Soil Erosion Risk Class*	Without Crop Insurance	With Crop Insurance	% Change
AL 1	Low	6.2	6.2	0.0
AL 2	Tolerable	5.1	4.9	-3.9
AL 3	Tolerable	5.7	5.6	-1.8
AL 4	Tolerable	4.9	4.9	0.0
AL 5	Tolerable	4.5	4.5	0.0
AL 6	Tolerable	3.8	3.8	0.0
AL 7	Tolerable	4.5	4.5	0.0
Alberta	Tolerable	4.8	4.7	-2.1
SA 1	Tolerable	2.5	2.6	4.0
SA 2	Tolerable	2.6	2.6	0.0
SA 3	Tolerable	3.5	3.6	2.9
SA 4	Tolerable	2.4	2.4	0.0
SA 5	Tolerable	3.0	3.3	10.0
SA 6	Tolerable	2.3	2.3	0.0
SA 7	Tolerable	2.4	2.4	0.0
SA 8	Tolerable	2.5	2.6	4.0
SA 9	Tolerable	2.4	2.4	0.0
Saskatchewan	Tolerable	2.8	2.9	3.6
MA 1	Tolerable	4.5	4.7	4.4
MA 2	Tolerable	5.7	5.8	1.8
MA 3	Tolerable	2.1	2.1	0.0
MA 4	Tolerable	2.8	2.8	0.0
MA 5	Tolerable	1.3	1.3	0.0
MA 6	Tolerable	1.0	1.0	0.0
Manitoba	Tolerable	3.5	3.5	0.0
British Columbia	Low	6.3	6.3	0.0
Ontario	Low	8.6	9.0	4.7
Quebec	Tolerable	3.9	3.9	0.0
New Brunswick	Moderate	14.3	14.4	0.7
P.E.I	Low	7.4	7.4	0.0
Nova Scotia	Tolerable	4.2	4.3	2.4

Source: Calculated (see Appendix B).
*Soil Erosion Risk Classes do not change with and without CI scenarios.

Figure 13: Water Erosion Results for Moderately Risk Averse Scenario

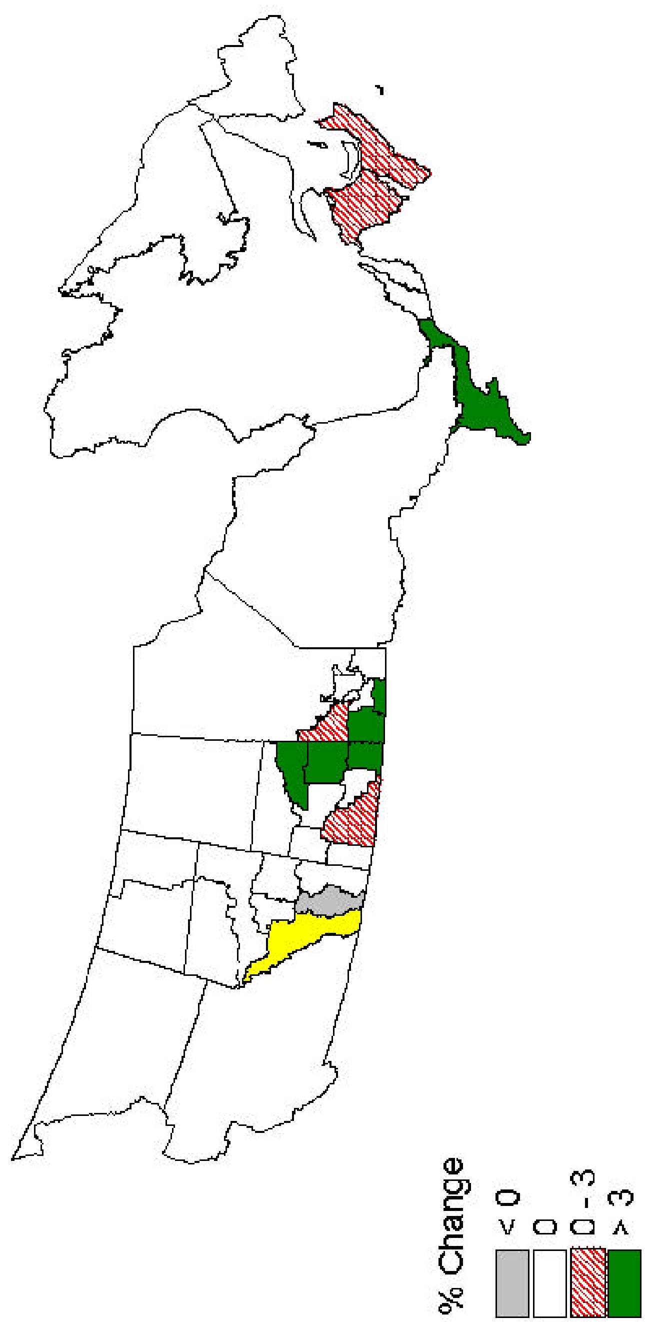
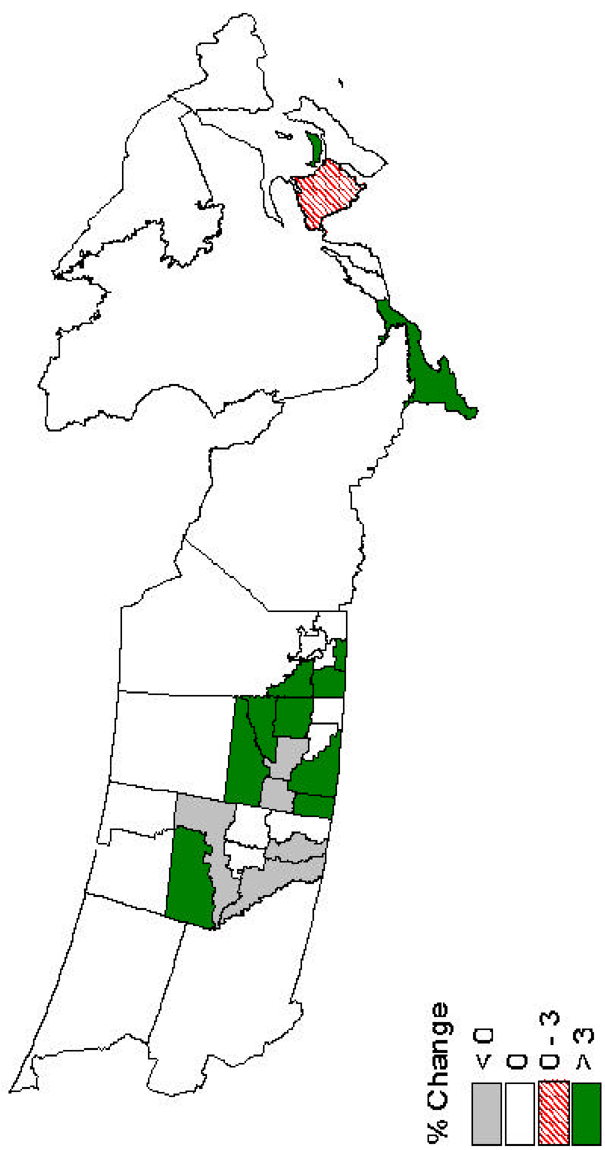


Table 13: Water Erosion Results for High Net Indemnities Scenario (tonnes per hectare per year) for CRAM regions

Region	Soil Erosion Risk Class	Without Crop Insurance	With Crop Insurance	% Change
AL 1	Low	6.2	6.2	0.0
AL 2	Tolerable	5.1	4.9	-3.9
AL 3	Tolerable	5.7	5.6	-1.8
AL 4	Tolerable	4.9	4.9	0.0
AL 5	Tolerable	4.5	4.5	0.0
AL 6	Tolerable	3.9	3.8	-2.6
AL 7	Tolerable	4.0	4.5	12.5
Alberta	Tolerable	4.7	4.7	0.0
SA 1	Tolerable	2.6	2.6	0.0
SA 2	Tolerable	2.6	2.6	0.0
SA 3	Tolerable	3.5	3.7	5.7
SA 4	Tolerable	2.2	2.4	9.1
SA 5	Tolerable	2.7	3.3	22.2
SA 6	Tolerable	2.4	2.3	-4.2
SA 7	Tolerable	2.5	2.4	-4.0
SA 8	Tolerable	2.2	2.6	18.2
SA 9	Tolerable	2.3	2.4	4.3
Saskatchewan	Tolerable	2.7	2.9	7.4
MA 1	Tolerable	4.3	4.8	11.6
MA 2	Tolerable	5.2	5.8	11.5
MA 3	Tolerable	2.1	2.1	0.0
MA 4	Tolerable	2.7	2.8	3.7
MA 5	Tolerable	1.3	1.3	0.0
MA 6	Tolerable	1.0	1.0	0.0
Manitoba	Tolerable	3.4	3.6	5.9
British Columbia	Low	6.3	6.3	0.0
Ontario	Low	8.7	9.0	3.4
Quebec	Tolerable	3.9	3.9	0.0
New Brunswick	Moderate	14.2	14.4	1.4
P.E.I.	Low	7.1	7.4	4.2
Nova Scotia	Tolerable	4.3	4.3	0.0

Source: Calculated.
*Soil Erosion Risk Classes do not change with and without CI scenarios.

Figure 14: Water Erosion Results for High Net Indemnities Scenario



Wind Erosion Results for Moderately Risk Averse Behaviour

The estimated wind erosion rates for each of the CRAM regions for the Prairie provinces, both with and without CI are obtained by adjusting the bare soil erosion rate by the weighted wind erosion reduction value (RED value). The RED value is the ability to reduce wind erosion based on the prevailing land use and management practices, such as crop type and tillage regime. To calculate the weighted RED value for each CRAM region, crops are aggregated into five categories: cereals, oilseeds, summerfallow, pulses, and forage. See Appendix B for a detailed description of the methodology. The estimated wind erosion rates for each CRAM region are presented in Table 14 and Figure 18.

The wind erosion rates without CI, both at the provincial as well as at the CRAM region level, are in the tolerable erosion risk class which is defined as a very low level of soil erosion for sustainable crop production (Wall et al. 1995). The wind erosion rates range from a low of 0.2 tonne per hectare per year for Alberta region AL 6 (Northern Alberta) to a high of 2.1 tonnes per hectare per year for region AL 2 and Saskatchewan region SA 3 in the Brown Soil Zone. There is no measurable change in the wind erosion rates at the provincial level or at the CRAM district level for Alberta with CI. Changes in the weighted RED values, with and without CI, were negligible due to small percentage shifts in the areas across various crop categories (cereals, oilseeds, summerfallow, pulses and forage).

There is no change in the wind erosion rates at the provincial level for Saskatchewan with CI. In region SA 5, the wind erosion rate would increase 11% with CI due to a decrease in hay area of 50% as marginal land is brought into grain and oilseed production and the related increase in summerfallow area of 5%. The wind erosion rate increases 9% for Manitoba at the provincial level with CI. In region MA 1, the wind erosion rate increases 11% due to a decrease in hay area of 31% as land is shifted to grains and oilseeds with a related increase in summerfallow area of 8%. In region MA 3, the wind erosion rate would fall 7.7% due to decrease in summerfallow area of 2.2% along with small changes in the areas across cereals, oilseeds and pulses.

Wind Erosion Results for High Net Indemnities (Scenario 8, Table 7)

The wind erosion rates for each CRAM region for the high net indemnities scenario are presented in Table 15 and Figure 19. There would be no change in the wind erosion rate at the provincial level for Alberta. However, in region AL 7 the wind erosion rate would increase 20% due to a decrease in hay area of 30% and an increase in summerfallow area of 29% along with small changes in areas for cereals, oilseeds and pulses.

In Saskatchewan, the wind erosion rate would increase 8% at the provincial level. In regions SA 4, 5 and 8, the wind erosion rates increases by 6%, 11% and 10%, respectively, due to a decrease in hay areas and an increase in summerfallow areas.

In Manitoba, the wind erosion rate would increase 9%. In regions MA 1 and 2, the wind erosion rates increased 11% due to a decrease in hay areas and an increase in summerfallow areas. In region MA 3, the wind erosion rate would fall 7.7% due to a 2.2% decrease in summerfallow area along with small changes in the areas of cereals, oilseeds and pulses.

Figure 15: Risk of Water Erosion in the Prairie Provinces, 1991

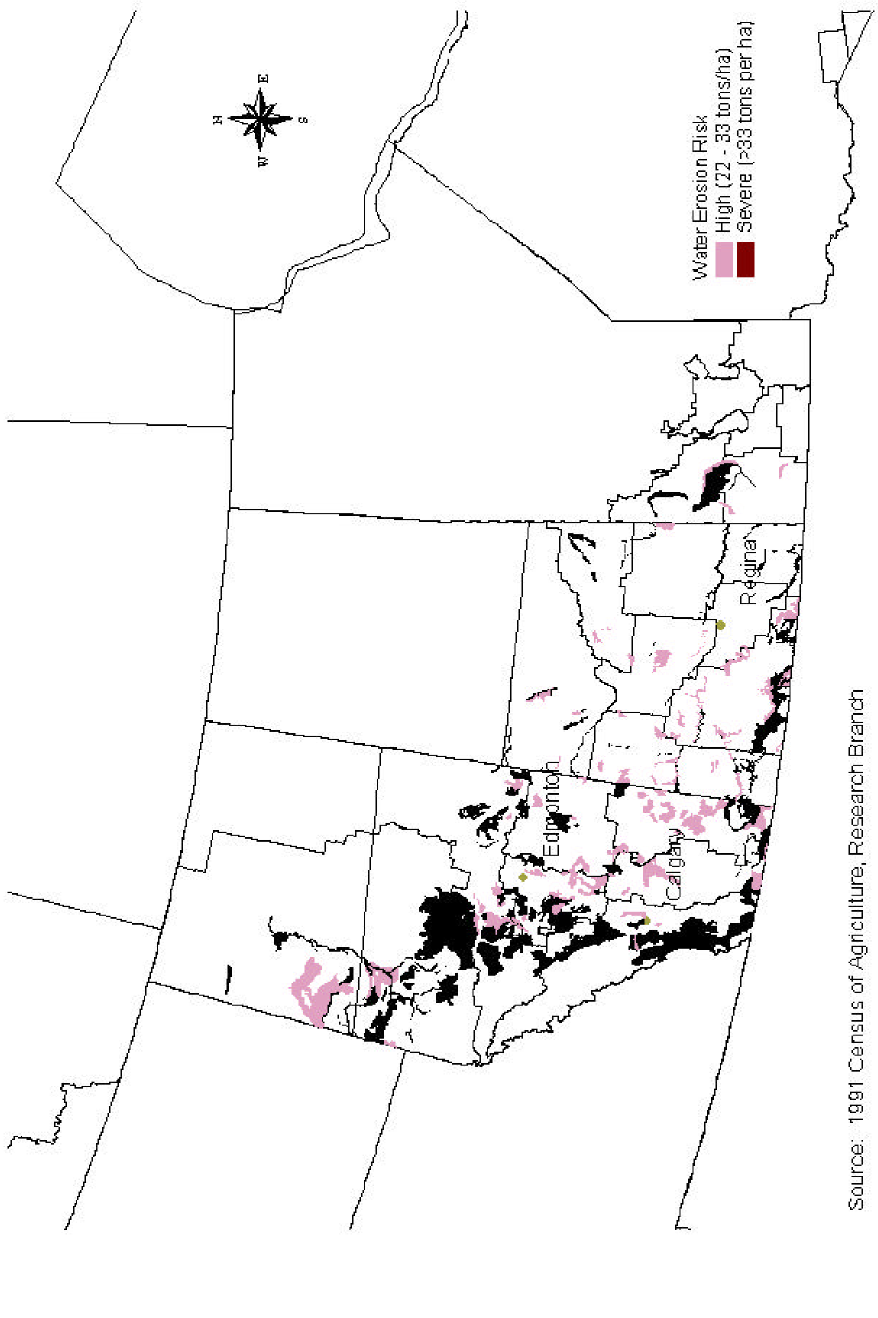
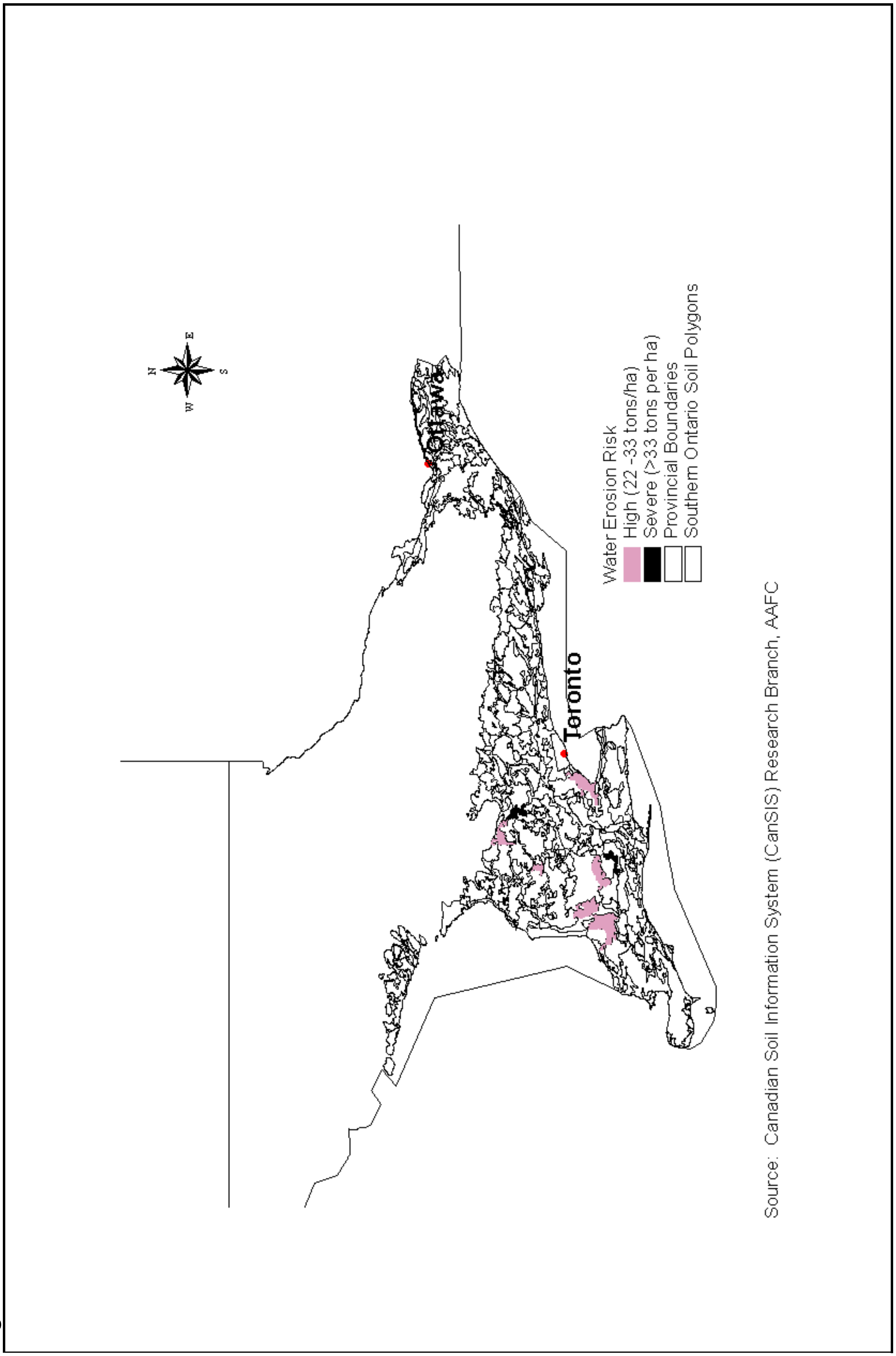
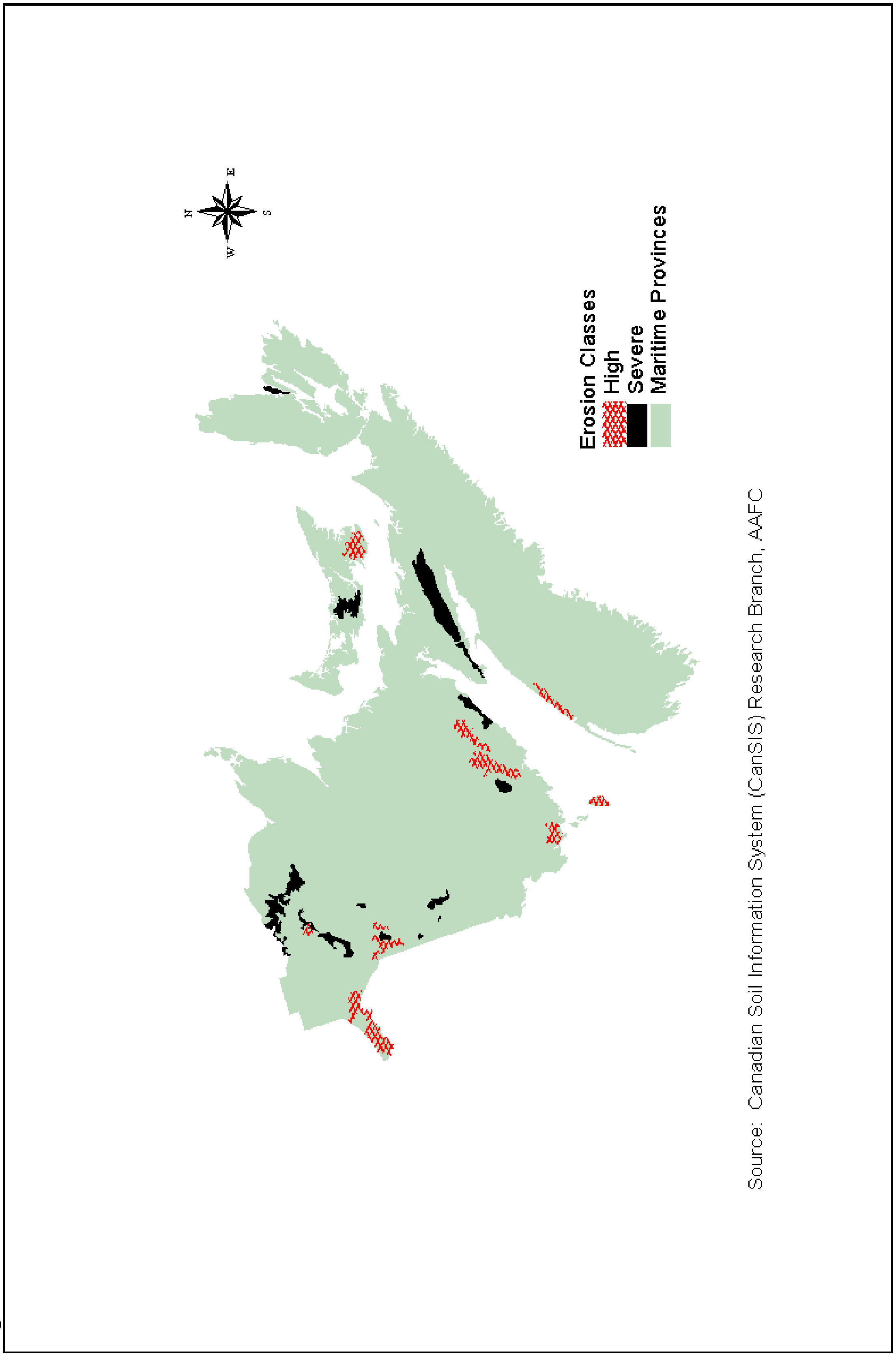


Figure 16: Risk of Water Erosion in Southern Ontario



Source: Canadian Soil Information System (CanSIS) Research Branch, AAFC

Figure 17: Risk of Water Erosion in the Atlantic Provinces



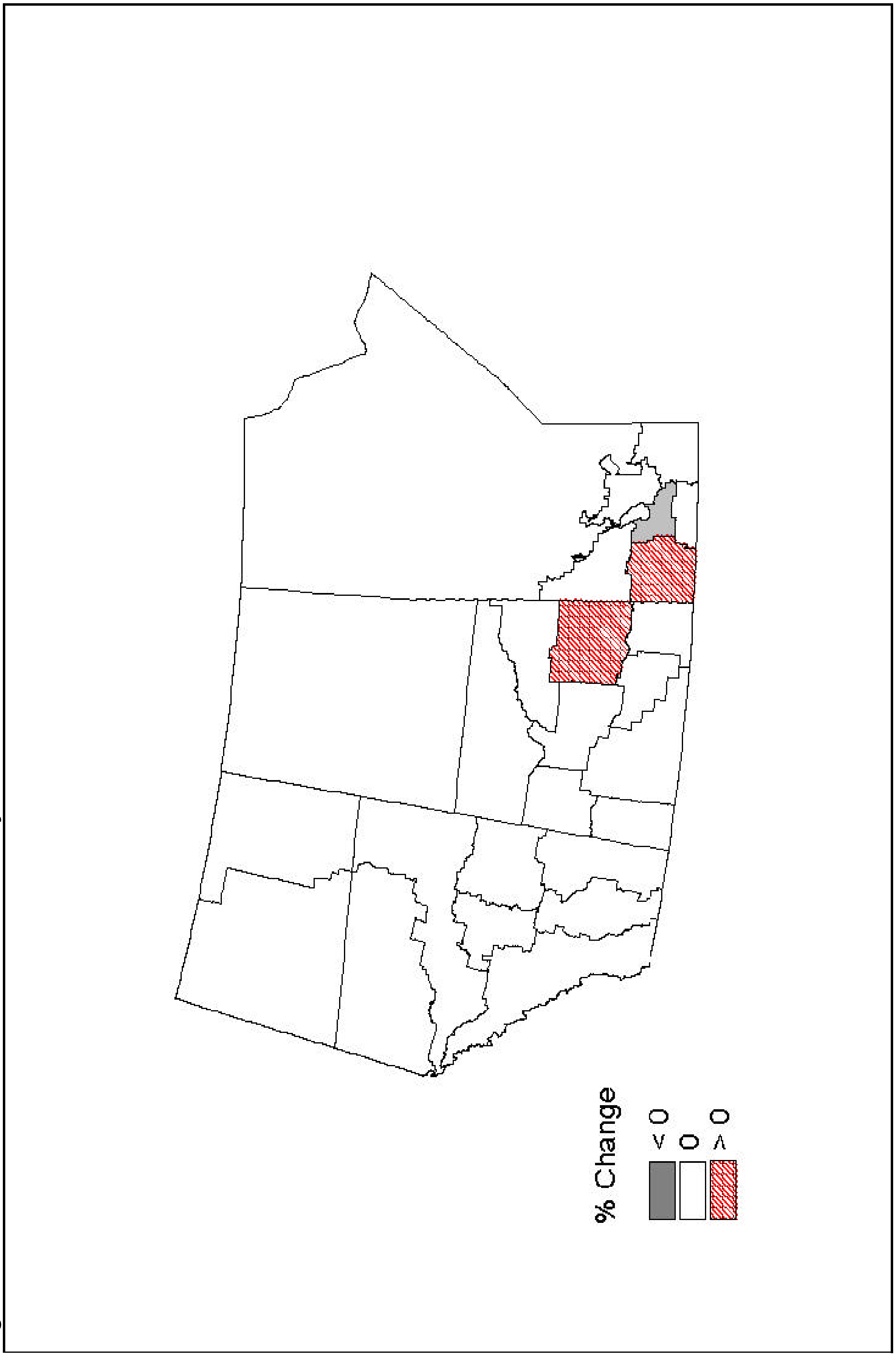


Figure 18: Wind Erosion Results for Moderately Risk Averse Scenario

Table 14: Wind Erosion Results for Moderately Risk Averse Scenario by CRAM region (tonnes per hectare per year)

Region	Soil Erosion Risk Class	Without Crop Insurance	With Crop Insurance	% Change
AL 1	Tolerable	1.5	1.5	0.0
AL 2	Tolerable	2.1	2.1	0.0
AL 3	Tolerable	1.0	1.0	0.0
AL 4	Tolerable	1.2	1.2	0.0
AL 5	Tolerable	0.4	0.4	0.0
AL 6	Tolerable	0.2	0.2	0.0
AL 7	Tolerable	0.6	0.6	0.0
Alberta	Tolerable	1.0	1.0	0.0
SA 1	Tolerable	1.1	1.1	0.0
SA 2	Tolerable	1.5	1.5	0.0
SA 3	Tolerable	2.0	2.0	0.0
SA 4	Tolerable	1.7	1.7	0.0
SA 5	Tolerable	0.9	1.0	11.1
SA 6	Tolerable	1.7	1.7	0.0
SA 7	Tolerable	1.5	1.5	0.0
SA 8	Tolerable	1.1	1.1	0.0
SA 9	Tolerable	1.1	1.1	0.0
Saskatchewan	Tolerable	1.2	1.2	0.0
MA 1	Tolerable	0.9	1.0	11.1
MA 2	Tolerable	1.0	1.0	0.0
MA 3	Tolerable	1.3	1.2	-7.7
MA 4	Tolerable	1.2	1.2	0.0
MA 5	Tolerable	1.1	1.1	0.0
MA 6	Tolerable	0.9	0.9	0.0
Manitoba	Tolerable	1.1	1.2	9.1

Source: Calculated.

Summary on Soil Erosion

Changes in the estimated soil erosion rates between the with and without CI scenarios can be attributed largely to the following: a) CI increases the rate of erosion as marginal cropland that would be seeded to hay without CI is used to produce grains and oilseeds, and b) an increase (decrease) in use of summerfallow would result in an increase (decrease) on erosion rates. This analysis indicates that CI would likely have small impacts on soil erosion rates. However, there would be some regional differences as erosion rates generally decrease slightly in Alberta and increase slightly in Saskatchewan, Manitoba, Ontario, New Brunswick and Nova Scotia.

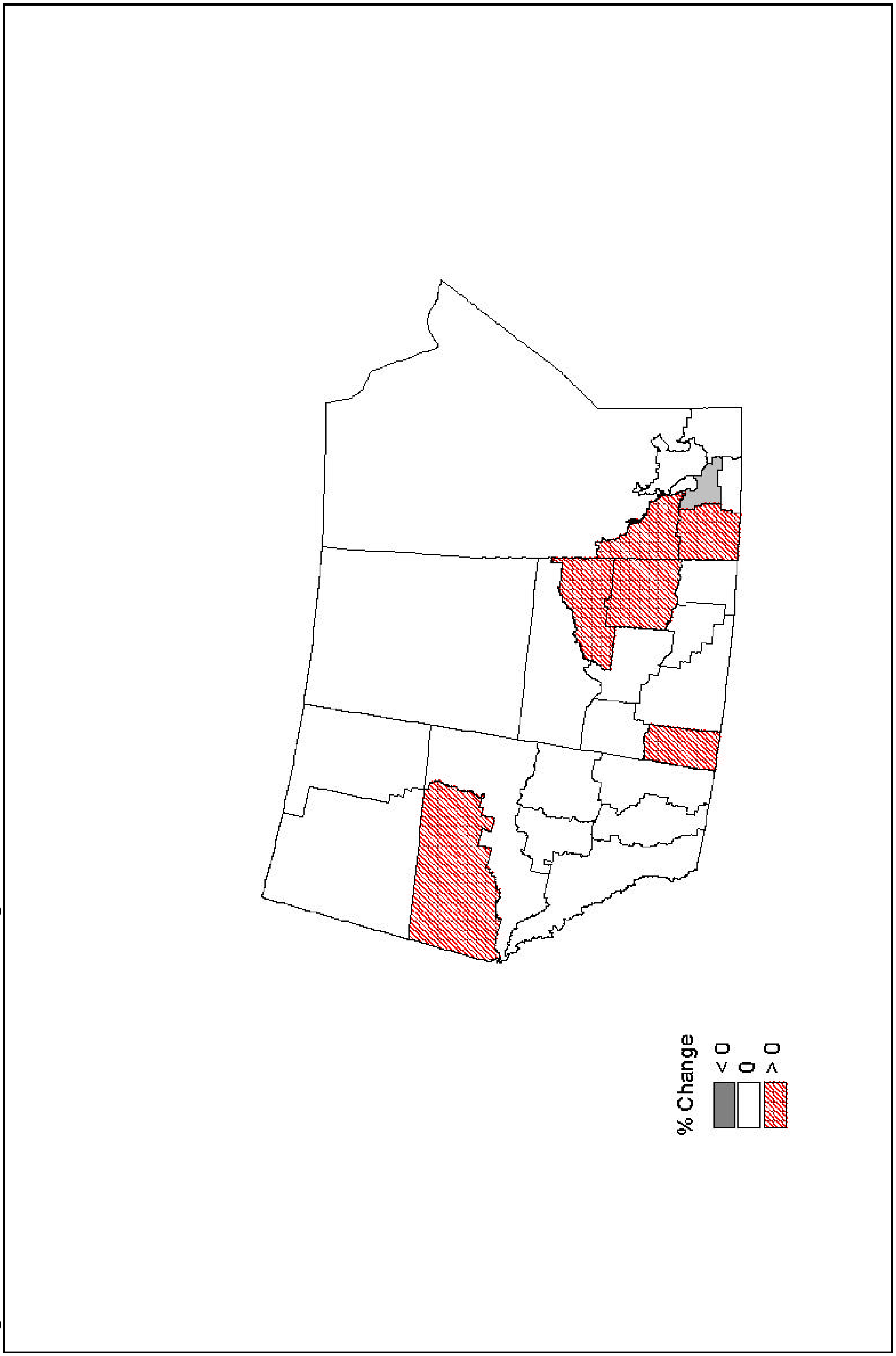
The soil erosion analysis was also conducted using the CRAM–EPIC modelling system for the Prairies (Bouzaher et al. 1993, 1994 and 1995). CRAM–EPIC is an integrated agro-ecological economic modelling system. It incorporates a multidisciplinary approach that can be used to assess quantitatively the regional soil erosion impacts of agricultural policies on the Prairies. The CRAM–EPIC modelling system estimates small impacts on the soil erosion rates due to CI. Percentage shifts in estimated soil erosion rates due to wind and water were similar to those already reported. In the following section a more qualitative environmental assessment of CI is provided using the quantitative assessment as a baseline from which to extrapolate.

Table 15: Wind Erosion Results for High Net Indemnities Scenario (tonnes/hectares/year) for CRAM regions

Region	Soil Erosion Risk Class	Without Crop Insurance	With Crop Insurance	% Change
AL 1	Tolerable	1.5	1.5	0.0
AL 2	Tolerable	2.1	2.1	0.0
AL 3	Tolerable	1.0	1.0	0.0
AL 4	Tolerable	1.2	1.2	0.0
AL 5	Tolerable	0.4	0.4	0.0
AL 6	Tolerable	0.2	0.2	0.0
AL 7	Tolerable	0.5	0.6	20.0
Alberta	Tolerable	1.0	1.0	0.0
SA 1	Tolerable	1.1	1.1	0.0
SA 2	Tolerable	1.5	1.5	0.0
SA 3	Tolerable	2.0	2.0	0.0
SA 4	Tolerable	1.6	1.7	6.3
SA 5	Tolerable	0.9	1.0	11.1
SA 6	Tolerable	1.7	1.7	0.0
SA 7	Tolerable	1.5	1.5	0.0
SA 8	Tolerable	1.0	1.1	10.0
SA 9	Tolerable	1.1	1.1	0.0
Saskatchewan	Tolerable	1.2	1.3	8.3
MA 1	Tolerable	0.9	1.0	11.1
MA 2	Tolerable	0.9	1.0	11.1
MA 3	Tolerable	1.3	1.2	-7.7
MA 4	Tolerable	1.2	1.2	0.0
MA 5	Tolerable	1.1	1.1	0.0
MA 6	Tolerable	0.9	0.9	0.0
Manitoba	Tolerable	1.1	1.2	9.1

Source: Calculated.

Figure 19: Wind Erosion Results for High Net Indemnities Scenario



Soil Degradation: Salinization

Salinization is the process by which salts accumulate in the soil, hindering the growth of crops by limiting their ability to take up water. It occurs naturally in some soils, but is often caused by agricultural activities such as summerfallow, traditional tillage and tight rotations in susceptible areas, particularly in the Prairies. Recent research estimates that about 7% of prairie agricultural land is at a high risk of increasing salinity under 1991 cropping practices. These high-risk areas are found mainly in central Manitoba, central Saskatchewan and southern Alberta, as shown on Figure 20 (Eilers et al. 1995). Reductions in summerfallow and increases in no-till cropping may have reduced the size of these areas since 1991. CI programs may contribute to salinity risk by favouring cropping practices that tend to raise the risk of salinisation, particularly summerfallow.[9]

Methodology

The impact of CI on soil salinity risk was assessed by comparing the crop districts where CI changes the levels of summerfallow (as discussed in Section 4) with soil polygons with a high risk of increased salinity due to agricultural practices. The analysis focuses on the following crop regions where summerfallow is estimated to change more than 10,000 hectares:

AL 2: - 61,700 ha
SA 1: +11,800 ha
SA 3: +34,200 ha
SA 5: +24,700 ha
SA 7: -10,600 ha
SA 9: +11,300 ha

It is not known whether the change in summerfallow within a crop district occurs in areas of high salinity risk. Producers in these areas may use preventative practices that reduce this risk.

Results and Interpretation

In Alberta, district AL 2 contains most of the soils at high risk due to salinity in the province, and is the district where summerfallow is estimated to decrease the most due to CI program. It appears that the program may reduce the risk of salinization by reducing the level of summerfallow in this area. Of the districts in Saskatchewan where summerfallow would increase due to CI, SA 5 and 9 have virtually no soil polygons at high risk of increased salinity due to agricultural practices. SA 1 and 3 each contain several polygons that have a high salinity risk. This risk may increase as a result of an increase in summerfallow that is attributable to the CI program. On the other hand, salinity risk may decrease in SA 7 due to a CI-induced drop in summerfallow.

9. The choice of traditional over low-till or no-till cultivation may also contribute to salinization. However, CRAM estimates found that CI had no significant impact on the choice of tillage method, so this variable was not analysed further.

Water Quality

Through its influence on cropping decisions, CI may influence water quality by affecting siltation and eutrophication. It does not appear to affect other water quality risks that are sometimes associated with agriculture, such as bacterial contamination and pesticide contamination. Bacterial contamination from livestock wastes is a significant problem for well water in many humid agricultural regions, but is not influenced by CI.

Pesticide contamination rarely occurs in water in agricultural regions of Canada, and is not connected to CI. Most pesticides used in Canada degrade quickly, and do not accumulate in the environment. Pesticides are rarely detected in Canadian surface or ground water. When detected, they are generally found in concentrations below limits recommended in the *Canadian Water Quality Guidelines*. A survey of 1300 Ontario farm wells detected pesticides exceeding acceptable concentrations in only two wells, which were attributed to improper storage and products no longer in use (Reynolds et al. 1995). Pest management choices are mainly determined by available techniques, prices, local and seasonal conditions, and producer knowledge. The existence of CI may influence pest management choices, but due to moral hazard the direction of the impact is indeterminate.

Eutrophication

Eutrophication occurs when excess nutrients enter watercourses, decreasing the value of the water for drinking, industrial uses, fish or recreation. In some areas of the Atlantic provinces, Quebec, Ontario and British Columbia, agriculture is a major contributor to eutrophication through leaching of excess soil nutrients from fertilizer and manure. The contribution of agriculture to eutrophication is less clear in the Prairies, and may be restricted to small water bodies (Harker 1997).

CI has no effect on the amount of manure from livestock. However, since CI increases crop acreage in Ontario by about 2%, it probably increases the level of fertilizer applied to crops by a similar amount. This may contribute to excessive nitrogen levels if it occurs in southwestern Ontario, where nitrogen concentrations exceed drinking water standards in over 20% of the region (MacDonald and Gleig 1996). In other regions of the province, excessive nitrogen from agriculture is not so common.

Sedimentation

CI may contribute to sedimentation by increasing erosion. The following discussion focuses on Ontario, where CI appears to increase water erosion by about 4.6% (Table 12), and where silt is a significant problem. Silt damage to waterways is not a significant problem in the dry, sparsely populated prairie region. It is estimated that about 5% of eroded soil in the Prairies ends up in water courses, and that it does not significantly affect turbidity levels or water use values (Harker 1997). Studies in the U.S. found that off-site damages attributable to eroded soil in the northern plains were minimal, at about US$0.66/ton, compared to over US$8/ton in the northeastern region (Ribaudo 1989).

While there is currently no estimate of the amount of eroded soil that moves from fields to water courses as a result of CI, several studies are have been done on the total off-site cost of agricultural soil erosion (Fox et al. 1989; van Vuuren et al. 1997). The estimates of erosion changes due to CI from Section 5 are applied to these costs to give a rough estimate of the sedimentation costs attributable to CI. This assumes that the costs of siltation increase proportionally to an increase in erosion.

The off-farm costs of agricultural erosion in Ontario were estimated to be $91 million in 1985, due to reduced recreational fishing, increased dredging in harbours, sediment removal from drains and ditches, and municipal and industrial water treatment costs (Fox et al. 1989). A U.S. study estimated off-farm erosion costs at $46 per hectare of row crop, which would imply total costs of about $67 million when applied to Ontario cropland in row crops. (corn, soybeans, other beans). Another U.S. study estimated that off-site damage per ton of erosion in the Lake States was about US$4.32 (Faeth et al. 1991). When converted to tonnes of soil in Canadian dollars, it yields an estimate of erosion of C$111 million.[10] Taken together, these studies indicate that the costs of siltation due to agriculture in Ontario range from $60–110 million.

Table 12 estimates that water erosion from agriculture in Ontario increases 4.6% as a result of changes induced by CI. Applying this to the estimates of the off-farm costs of soil erosion, it appears that CI increases the costs of sedimentation in Ontario about $3–5 million.

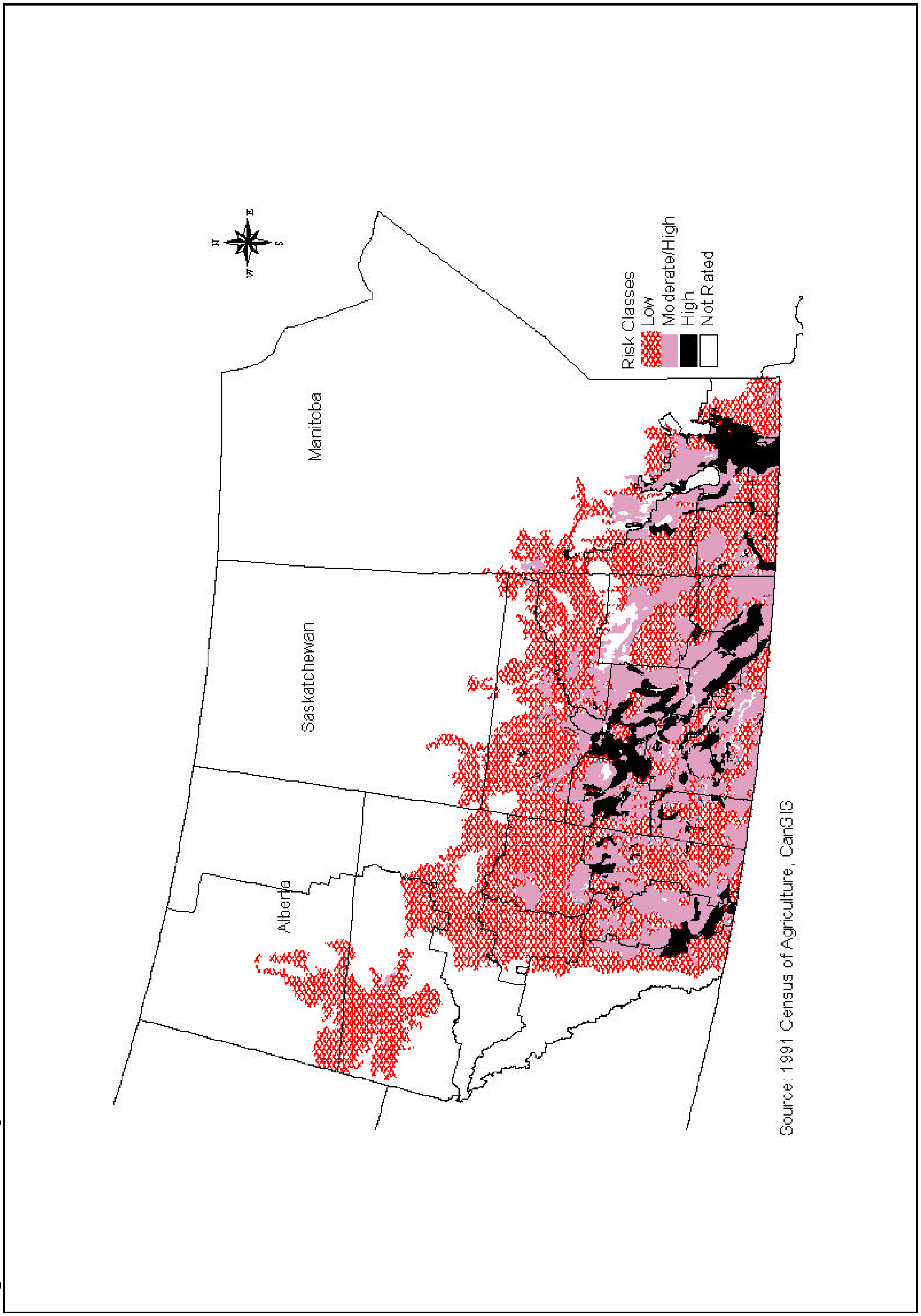
A similar range is obtained using a 1990 study of erosion in southern Ontario, which estimated off-farm damage from lost fishing opportunities, increased water treatment and dredging at $25–100/hectare of land cultivated with a mould-board plough (Fox 1992). Applied to the 48,000-hectare increase in Ontario cropland attributable to CI (Table 1), this leads to a range of $1.2–4.8 million.

This estimate should be treated with a large degree of caution. It is difficult to estimate the monetary value of lost recreational activities, such as lower quality fishing. Also, low-till and no-till cultivation have become much more common since these studies were done, helping to reduce the level of erosion.

In the context of its total costs of erosion, CI plays a small, indirect role in sedimentation. Changes to the CI program are unlikely to be an efficient instrument to reduce this impact. It would likely be more efficient to use measures directly related to tillage practices targeted to erosive soils in areas with valuable water resources, in order to reduce sedimentation.

10. (US$4.32 /ton)*(.72 C$ /US$) * (.907 Tonnes/ton) * (8.9 tonnes/hectare) * 2,299,000 hectares

Figure 20: Salinity Risk Index Based on 1991 Land Use in the Canadian Prairies



Wildlife Habitat

The value of wildlife habitat comes from both its quantity and its variety. Higher quantities of habitat provide more opportunities for nature-related recreational opportunities, wild harvests and other benefits. Wetlands provide added benefits such as flood control and water purification. More variety in habitat provides biodiversity and protects rare and endangered species that are important to the public.

When wildlife habitat is converted to use for annual crops, most of these values are lost. CI provides a benefit to annual cropping activities from reduced income risk and subsidy that is not available to other land uses, such as pasture, agri-forestry, tourism, native cover, or wetland. This benefit could lead to land use shifts, such as conversion of pasture to crops, reductions in shelterbelts and grassed wetland margins, conversion of bushland and woodlots to crops, and draining of potholes and wetlands. This section assesses the size of these shifts, and the value of the lost benefits to society.

Methodology

The analysis uses the amount of land transferred from forage and pasture to cropland as a proxy for the effect of CI on wildlife habitat. While this is a gross simplification, it is the best indicator currently available.[11]

The results presented in Section 4 estimate that CI would shift about 685,000 hectares from forages and pasture to field crops. This estimate does not explicitly account for unbroken woodland or wetland being brought into agricultural production, although large increases in cropland may indicate areas where breaking of new land could occur. Available data indicate that large-scale land conversion is not occurring, since total agricultural land has remained stable over the past 20 years (Acton 1995). In particular, total cropland and summerfallow acreage on the Prairies appears to have decreased slightly over the past 10 years (Statistics Canada 1997). However, the draining of wetlands or breaking of new land may occur in some areas. Further research is needed to measure long-term trends in prairie land use and their effect on wildlife populations.

The diversity of wildlife habitat is evaluated by comparing maps of changes estimated by CRAM with maps of agricultural land use derived from the Census of Agriculture. High-value wildlife habitat available on agricultural land is defined as the Census category including unimproved pasture or other unimproved land, such as woodlots, brush and wetlands. This category also includes laneways and farmyards, so it may overestimate habitat area (Neave 1997). Diversity is assumed to be threatened in soil polygons where less than 10% of the agricultural land is available for habitat. Crop insurance is assumed to decrease diversity if it increases cropland in areas with a low level of habitat.

Habitat value is also evaluated with maps of high potential waterfowl habitat provided by Ducks Unlimited (DU) because of the particular importance of Canadian wetlands for migratory waterfowl in North America. While this measure does not include all forms of habitat, many important species in addition to waterfowl are concentrated in or near wetlands. Furthermore, DU focuses its efforts in regions where habitat is most affected by

11. An indicator of the value of different agricultural land uses for different species is being developed as part of AAFC's Agri-Environmental Indicator Project.

agriculture. These maps identify soil polygons that contain at least 1% of upland and wetland areas that have been secured by DU for waterfowl and other species. These DU areas indicate regions with high concentrations of waterfowl habitat that may be under pressure from agricultural development. DU priority regions include wetlands and adjacent feeding areas that support wildlife populations, for both nesting and migratory staging. CI is assumed to decrease habitat for waterfowl and other species if it increases crop acreage in areas which include wetland margins and uplands adjacent to wetlands.

Results and Interpretation

The estimates of land use shifts due to CI are negligible in the Atlantic provinces, Quebec, Alberta, British Columbia and many crop districts in Manitoba and Saskatchewan. In these areas, it appears that CI does not decrease the quantity or variety of wildlife habitat. Shifts from forage and pasture to field crops are concentrated in Saskatchewan districts SA 5 (+230,000 ha) and SA 3 (+144,000 ha), and Manitoba district MA 1 (+106,000 ha). Smaller shifts occur in SA 1 (+45,000 ha), SA 8 (+38,000 ha), SA 9 (+74,000 ha) and Ontario (+48,000 ha). The estimated shifts of 3,000 hectares in MA 4 and MA 6 are considered too small to be of significance.

CI does not appear to be threatening habitat diversity in the most intensively agricultural areas of the Prairies. As shown in Figure 21, polygons where habitat is most threatened are concentrated in the area south of Winnipeg and in the SA 2 region south of Regina, where land use is not affected by CI. CI tends to have more impact in less intensive crop districts where most of the polygons have more than 10% habitat. The increase of 2% in Ontario cropland may decrease the habitat diversity if increases occur in the extreme south-west of the province, where habitat accounts for less than 10% of agricultural land (Figure 22).

CI does appear to reduce the quantity of valuable wildlife habitat by increasing cropped land by 685,000 ha. Much of this increase occurs in regions SA 5 and MA 1, which contain high concentrations of high-value waterfowl habitat (Figure 23). In these areas, the land use shift is a significant 8–10%, implying that CI is a significant contributor to cropped acreage, and reductions in wildlife habitat. CI may contribute to the cultivation of nesting and feeding grounds adjacent to wetlands that would not otherwise occur. CI is unlikely to significantly reduce waterfowl habitat in Ontario, as most concentrations of waterfowl habitat are in northern regions of the province where little agriculture is practiced (Figure 24).

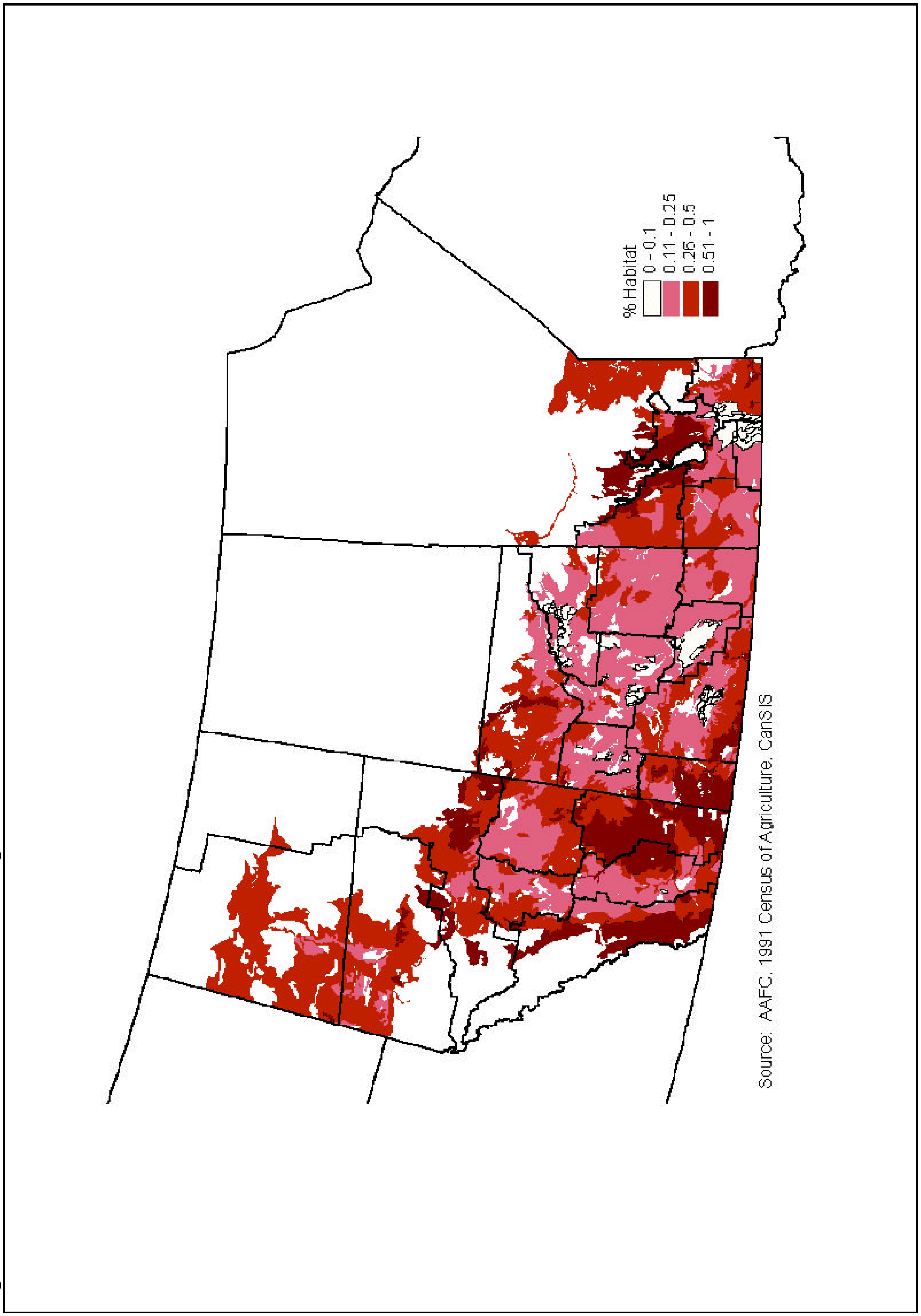


Figure 21: Available Wildlife Habitat on Agricultural Land in the Prairie Provinces

Figure 22: Available Wildlife Habitat on Agriculture Land (Mixed WoodPlains)

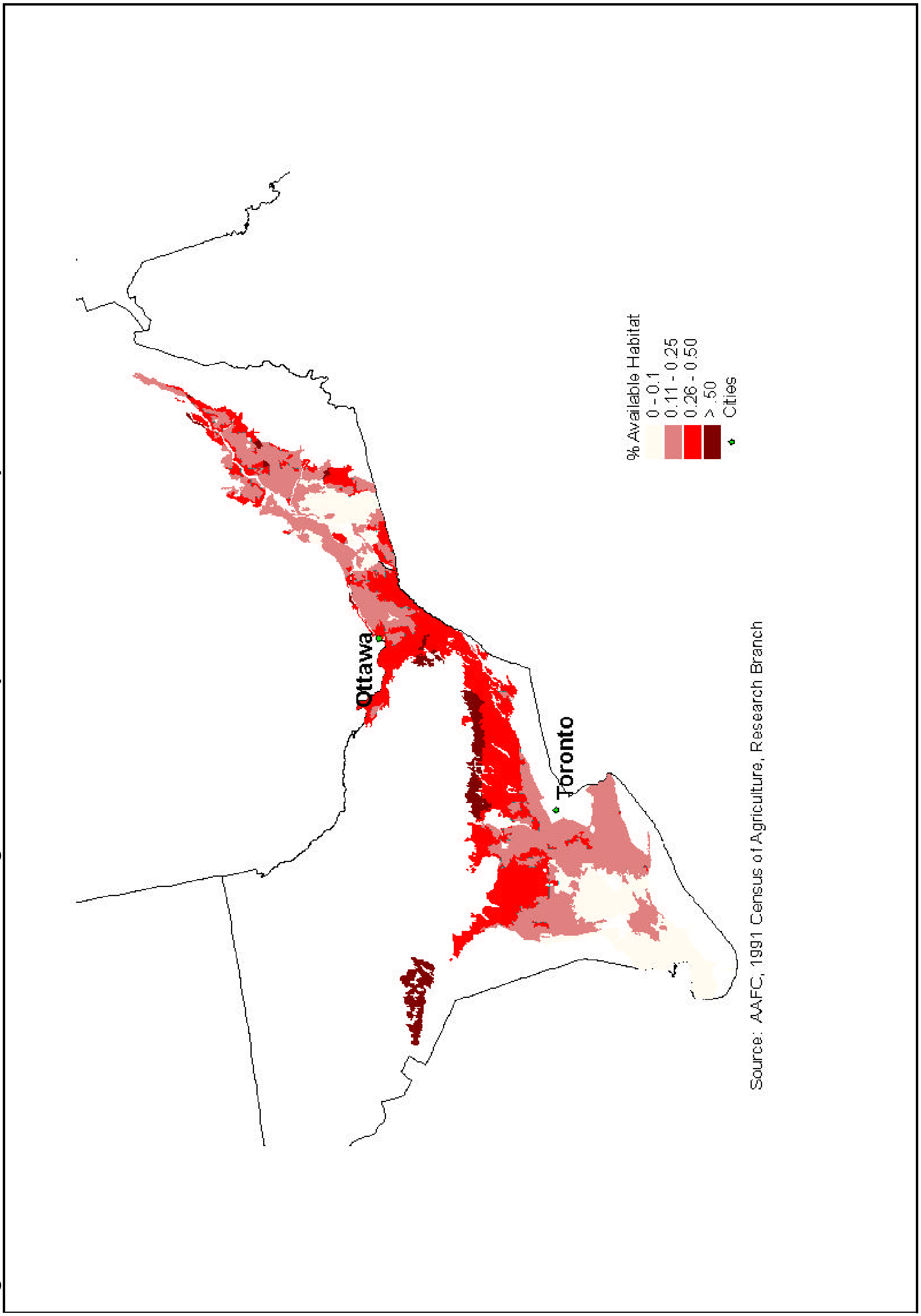
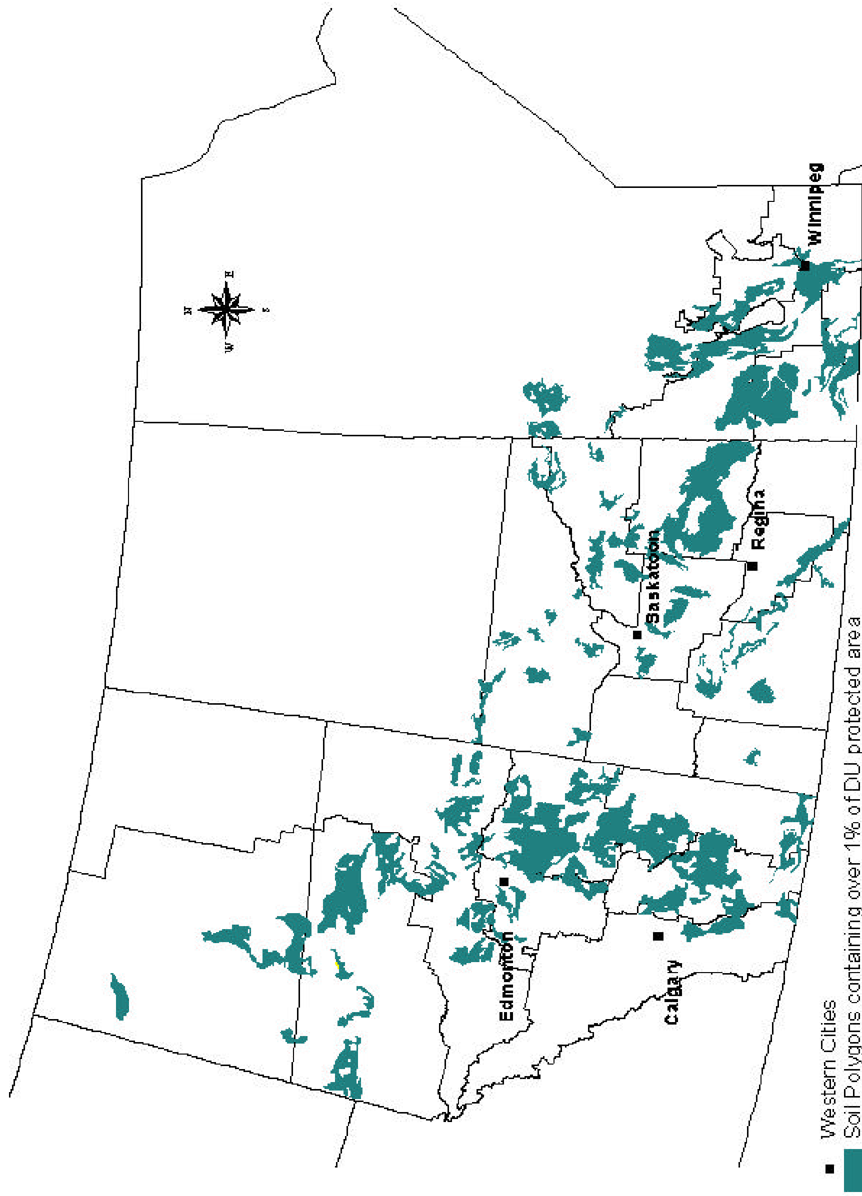
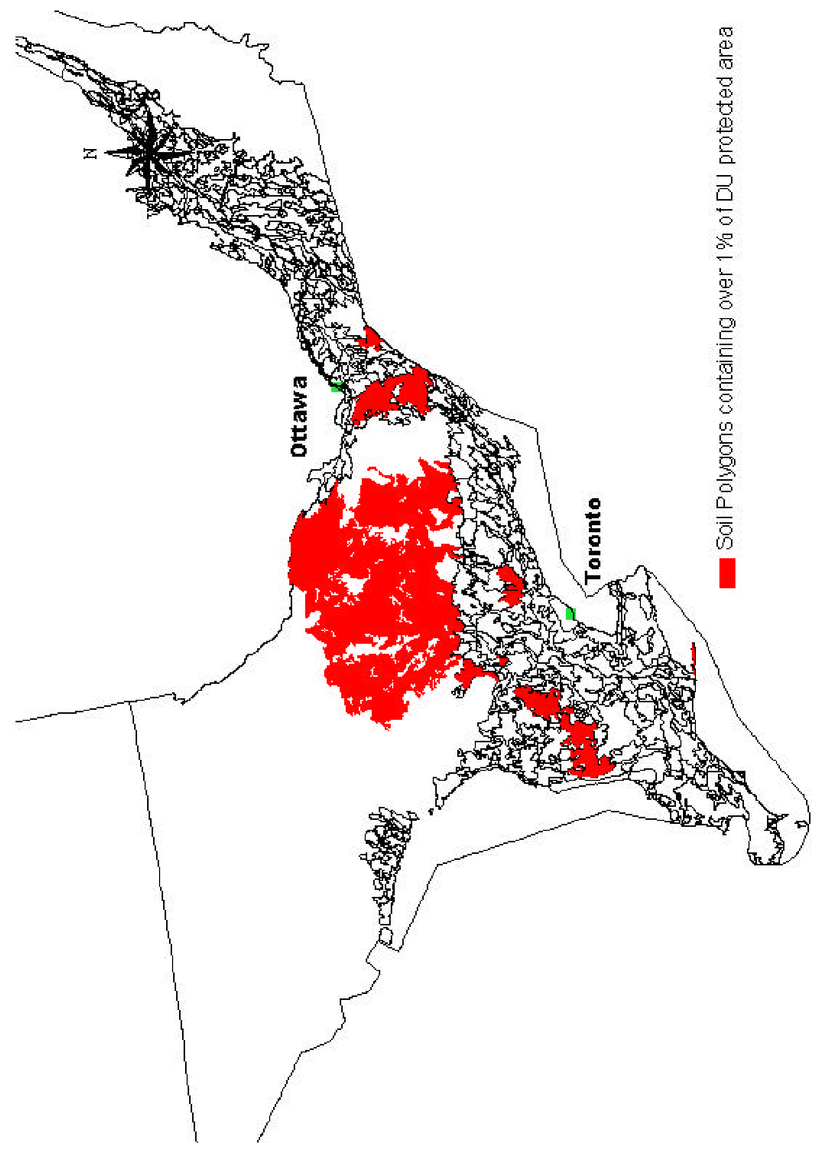


Figure 23: Concentrations of Waterfowl Habitat in Western Canada



Source: Ducks Unlimited, 1991 Census of Agriculture,

Figure 24: Concentration of Waterfowl Habitat in Eastern Canada



Source: Ducks Unlimited Canada, 1991 Census of Agriculture

Sensitivity Analysis

The previous three sections are based on the economic and behavioural assumptions outlined in Section 3. This section discusses how the environmental impacts would change under different assumptions, as represented by the scenarios in Tables 7 and 8.

Most of the potential environmental impacts of CI are related to the shifting of land from pasture to annual crops, such as increased erosion, reduced water quality and reduced wildlife habitat. These impacts would be somewhat larger if more land were shifted to crops, and smaller if less land were shifted to crops. There may be small regional variations in impacts, depending on the state of natural resources in the region.

Given the projected changes in total land use in Table 8, one would expect larger environmental impacts from CI under the following situations:

- higher risk aversion (Scenario 3)
- lower crop returns (Scenario 5)
- increased yield variability (Scenario 7)
- higher net indemnities (Scenario 8).

The estimates in Tables 12 and 13 confirm this situation for water and wind erosion for the most extreme scenario (Scenario 8). In all provinces except Ontario, water erosion is estimated to be higher with high net indemnities than in the reference scenario of moderate risk aversion (Scenario 1). In all Prairie provinces, wind erosion is estimated to be higher with high net indemnities than in the reference scenario.

One would expect smaller environmental impacts arising from CI in situations of:

- lower risk aversion (Scenario 2)
- no risk aversion (Scenario 4)
- ligher crop returns (Scenario 6).

In general, these results support the general conclusion that CI does not cause large changes in land use by producers, and hence does not have a large impact on the environment. Even under the extreme case of Scenario 8, where net indemnities increase five-fold to $900 million, land in annual crops would increase by only 5.6% compared to assumptions of moderate risk aversion and relatively poor market returns as reflected in 1994 prices.

These results show that CI would have a more substantial effect if market conditions deteriorate further relative to 1994, holding about 3.6% of land in annual crops that would otherwise shift to hay or pasture production. If pressures to decrease silt in waterways or increase wildlife habitat become more significant at the same time as crop returns are falling, there may be justification to review the CI program in some areas to achieve better management of natural resources.

On the other hand, if crop returns improve, the small impacts of CI on natural resources would be even smaller, and modifications to CI would have negligible affects on the state of natural resources.

Summary of Environmental Impacts of Crop Insurance

Table 16 summarizes the environmental impacts analysed in this section. Regions where no significant effect (NSE) occur are indicated.

Table 16: Summary of Environmental Impacts

Region:	B.C.	Prairies	Ontario	Quebec	Atlantic
Water erosion	NSE	No general effect, but possible improvement in south-western Alberta	No general effect, but possible deterioration in high-risk areas	NSE	NSE
Wind erosion	NSE	NSE	NSE	NSE	NSE
Salinisation	NSE	Possible improvement in central Alberta and deterioration in southern Saskatchewan	NSE	NSE	NSE
Water quality	NSE	NSE	Silt damage to waterways (up about 5%), possible increased risk of eutrophication in south-western Ontario	NSE	NSE
Wildlife habitat	NSE	Reductions in wildlife habitat value of farm-land in regions SA 5 and MA 3, with high concen-trations of waterfowl habitat	Possible decrease in rare habitat in south-western region	NSE	NSE

In summary, the response to CI estimated in this report may slightly increase the risk of environmental degradation in Saskatchewan, Manitoba and Ontario. It has no significant effects in British Columbia, Alberta, Quebec or the Atlantic provides. All of the possible increases in risks to natural resources due to CI are relatively small in the context of the total area at risk due to agricultural activities.

In the Prairies, the program may lead to reductions in the risk of water erosion and salinity in some areas of Alberta, and increases in some areas of Saskatchewan. These changes in risk depend on whether cropping patterns that are generally influenced by CI affect particular tracts of soil with a high risk of erosion or salinity. If they occur, the changes due to CI are relatively small in the context of all prairie land that has a high risk of soil degradation due to agricultural activities. The program may also reduce wildlife habitat in the area on the Manitoba and Saskatchewan border.

In Ontario, CI would seem to lead to increases in water erosion of about 5%, which would in turn likely increase siltation of waterways by a similar amount. It may also cause a small drop in the amount of wildlife habitat on agricultural land, some of which may be in areas with little remaining native cover. The possible risks identified above occur in provinces or regions where there is known to be some risk to natural resources from agricultural activities. CI may increase these risks if it affects particularly sensitive areas of a region. Detailed local studies would be required to determine whether this is the case.

Section 6: Summary and Conclusions

The Federal-Provincial Crop Insurance program was established in response to the failure of the market place to provide appropriate risk management instruments that the industry could use to deal with production risks inherent in growing crops. Lack of access to appropriate risk management tools would lead to a misallocation of resources and economic efficiency losses if producers are risk averse. Variations in farm revenues caused by natural hazards (weather, pests or disease) would force some farmers into bankruptcy, in the short run, whereas they would be viable in the long run if they had access to a financial instrument that would see them through those periods when yields fall well below expected normal levels.

The objective of this report is to estimate the regional and national impact that CI has on supply and resource use, and to evaluate the subsequent environmental consequences. To quantify the impact, CRAM (Horner et al. 1992) is employed to estimate the behavioural response with wind and water erosion models used to estimate the impact on top soil. Other environmental factors are largely dealt with using data from Geographical Information Systems (GIS).

Expected utility theory under uncertainty suggests that CI would shift aggregate supply to the right as producers respond to reduced income variability and an increase in overall farm income, at least for those producers who choose to participate in the program and benefit from the government subsidization of premiums. The effects of CI on land use are estimated with CRAM. This model is able to predict the impact of CI on total land use, cropping patterns, summerfallow, exports, and producer income. CI is integrated into the model through the objective function by adding two components: (i) a quadratic risk term which determines the risk premium; and (ii) expected net indemnities realized from the government subsidization of CI premiums. The risk term reflects producers' risk preferences and the relative risk of producing alternative crops based on realized yields over time. In this report producers are assumed to be risk averse. Government subsidization is calculated as expected indemnities minus producer premiums averaged over the proceeding 10 years. The analysis is comparative static, comparing a base run without CI to one with CI. Assumptions related to key parameters in CRAM are evaluated through an extensive sensitivity analysis.

Summary of Findings on Impact of Crop Insurance

The impacts of CI on the agricultural sector are estimated in Scenario 1, which assumes a moderate level of risk aversion and relatively weak market conditions that existed in 1994. This scenario is used as a benchmark for this report. The results are as follows:

- Marginal land shifts from less intensive uses such as hay production to grain and oilseed production in response to CI. Roughly 685,000 ha are affected (2% of the arable land base). The impact is mainly felt in Western Canada where most of the insured crops are grown.

- Cropping patterns are altered slightly, increasing the relative production of hard red spring wheat, barley, flax, soybeans, and oats. In absolute terms hard red spring wheat area increases the most, almost 400,000 ha.

- Summerfallow area in Western Canada is estimated to change very little. In Alberta where overall land use did not change, summerfallow area actually decreases 63,000 ha as producers opt for the riskier option of seeding more crops on stubble. In Saskatchewan and Manitoba the area of summerfallow increases 67,000 ha as part of the rotation for the 637,000 ha of marginal land brought into grain and oilseed production.

- Exports are estimated to increase 4.2% (1.2 million tonnes) and producer income[12] 8% ($220 million) with CI due to the overall increase in land seeded to grains and oilseeds.

- CI has a minimal impact on the risk of water erosion related to land use or crops grown as measured at the crop district or provincial level. The change in the rate of erosion varies from a reduction of 2% in Alberta to an increase of 5% in Ontario when measured at the provincial level. In no instance did the rate of water erosion increase sufficiently to change a region’s risk rating. The wind erosion model estimated that CI would have a minimal impact on the risk of wind erosion measured at this scale. At the provincial level the rate of erosion due to wind would increase only in Manitoba, reflecting an actual estimated increase of only 0.1 tonne per hectare per year. Although of minimal impact at the provincial level, CI may contribute to soil salinity risk in sensitive areas of Saskatchewan and water erosion risk in sensitive areas of Ontario. Also, CI may lead to improvements in areas of south-western Alberta that have a high risk of water erosion or salinity.

- Other environmental impacts of CI are limited. Some habitat loss is expected from bringing marginal land into field crop production and the risk to water quality is expected to increase slightly because of an increase in the risk of soil erosion in some regions. CI may contribute to problems of siltation and eutrophication in Ontario, due to the small increases in water erosion attributable to the program. It does not affect water quality in other regions.

- CI decreases the area available for habitat in the waterfowl rich region on the Manitoba and Saskatchewan border and may decrease wildlife habitat in south-western Ontario.

12. More accurately, this is producer surplus which is a measure of net cash income, including expected net indemnities from the CI program.

To put this in perspective, CI is only one of many factors that affect producers' decisions related to resource utilization, and is probably of relatively minor importance compared to factors such as market prices, technological change, structural change, direct government support programs, land set-aside schemes, trade policy, and tax policy. From an environmental point of view, CI makes a small contribution to increasing risk to some environmental resources. For example, it is estimated to increase siltation of Ontario waterways 5%. Without CI, the vast majority of silt from agricultural sources would continue to flow into waterways.

Sensitivity Analysis

These general conclusions held over reasonable ranges for key parameters such as market performance, degree of risk aversion and risk level. The estimated impacts of CI to variations in these key parameters are evaluated through extensive sensitivity analysis. The direction of change in estimated impacts is as expected, *a priori*. An important finding is that the response to CI is much more inelastic when market returns (or equivalently government direct support levels) are relatively high. When expected market prices are high, producers are going to seed more marginal land to grains and oilseeds with CI having a much smaller impact on land allocation decisions. If producers in the sector are characterized as being highly risk averse, CI has a slightly larger impact on output, as it would if expected yield variability increases.

An important finding from this report is that the two components of CI, the subsidy component as well as the reduced risk premium that risk averse producers attach to production decisions with CI, are not simply additive, in that taken individually it is estimated that they have almost no impact on production decisions. If producers are characterized as risk neutral, the impact of CI virtually disappears although the subsidy remains. Due to small changes in resource use found in the sensitivity analysis, only the results from the relatively extreme Scenario 8 (high net indemnities) are evaluated for the impact on erosion rates. Generally, provincial estimates of the rate of water and wind erosion increase slightly, but not enough to increase the overall risk to sustained farming activity.

Comparison to Previous Findings

In the literature of quantitative estimates of the impact of CI on resource utilization at an aggregate level, none could be found for Canada. The results from this report support the qualitative conclusions drawn in the previous analysis of CI based on a series of farm level models (PW 1994a) and assessments by Fulton et al. (1989) and Weisensel et al. (1990) that resource use and crop selection are affected marginally by the CI program. A detailed comparison with the 1994 PW study is included in Appendix C. Gardner and Kramer (1986) conclude for the U.S. that CI appears to encourage crop production in marginal areas and other risk taking but these impacts are not dramatic. More recent research has focused on the issue of moral hazard which can have an offsetting negative impact on output if producers have an incentive to apply less than optimal levels of inputs on insured crops that would increase the probability of indemnity payments (Ramaswami 1993; Babcock and Hennessy 1996; Smith and Goodwin 1996). The implications of moral hazard related to input use have not been assessed, but if they were, they would tend to reduce the supply enhancing impact of CI estimated in this report.

Quantitative impacts of CI on soil erosion rates were not reported in the literature surveyed. The estimates provided by this report indicate that when measured at an aggregated level (i.e. provincial) the impacts are small. Even at more disaggregate levels (i.e. crop districts) the estimated absolute changes in erosion rates are small, even if the percentage changes are sometimes large due to the small absolute values.

Limitations

This report is based on assumptions that the industry response to risk, and to the CI program, can be adequately characterized with a few simplifying assumptions that treat all producers in a region as having the same economic response to risk. For example, it is assumed that all farmers will insure crops only in a region with a positive expected net indemnity and all producers are subject to the same expected variability in income in a region. No attempt has been made to segment a regional population into different behavioural or managerial categories to develop distributional estimates of the response to risk. This simplification arises by treating each region as a single 'representative' producer. Land in each region is treated as a heterogenous resource as reflected in the upward-sloping marginal factor cost curves specified for each crop in relation to a fixed yield with a known distribution. In the version of the model used for this analysis purchased inputs are held in fixed proportion to land (MacGregor 1995). Another limitation is that an upper limit for arable cropland is specified in each region which limits the quantity of grains and oilseeds that can be produced.

The application of land use estimates for CRAM regions to environmental information at the detailed soil polygon level also creates limitations. The interpretation of these estimates required the assumption that changes at the CRAM region level would be reflected in all soil polygons contained within the region. This simplification may lead to misleading conclusions, so conclusions drawn at the soil polygon level must be treated with caution.

Yield data is a major concern with this report. Data that provide information on the distribution of yields by crop and by region over time using different production systems are not available which meant that data generated by models (EPIC) or average annual data for a whole region had to be used to generate data on income variability. As discussed at some length in the report, without further adjustments this data did not generate sufficient indemnity payments or participation to reflect the benefits obtained with CI. Whether the adjustments made to increase income variability, and therefore risk, participation and net indemnities accurately capture the true yield risk faced by producers will only be known if the required data become available. In relaxing some of these assumptions, we are able to test the structural robustness of the model in estimating the impact of CI. However, with the limitations noted, the model remains a highly simplified representation of the complexities of the real world.

Conclusions

CI was found to have an impact on resource utilization in this analysis, increasing the level of production of insured crops. That CI would have a positive impact on supply was expected, *a priori,* as conceptually this government program responds to a market failure that would result in output below an economically optimal level if not addressed. What is apparent from this analysis is that the overall impact of CI on resource utilization and the environment is small. At a regional level, the environmental impact of CI is ambiguous, at least in terms of soil erosion. In some instances the producer response to CI can reduce erosion rates, especially where it encourages less use of summerfallow, but in other regions and situations it can encourage a shift of marginal land from forage production into more erosive grain and oilseed production.

The CI program may have small effects on the risk of environmental degradation of a few key resources in the Prairie provinces and Ontario. It has no significant effects in British Columbia, Quebec or the Atlantic provinces. All of the possible increases in risks to natural resources due to CI are very small in the context of the total area at risk due to agricultural activities.

The new options for CI that are currently being tested in Canada, two-tier insurance and self-directed risk management, would have even less impact on the environment than the current system, as they provide even weaker signals to producers in terms of risk reduction, land use and cropping decisions. Based on this analysis there is no reason for these options to be questioned because of increased environmental risks.

The analysis implies that the environmental effects of CI are too small to justify significant changes in the program. Given that the program decreases environmental risks slightly in some areas and increases them slightly in others indicates that it would be difficult to integrate environmental improvements into the program. In cases where the program seems to contribute marginally to resource degradation, such as siltation in Ontario, the vast majority of the degradation depends on factors unrelated to CI. In such a situation, it would be much more efficient to improve resource use by targeting agricultural practices directly than making adjustments in a small, indirect program such as CI.

There does not seem to be much scope for improving public environmental benefits through the CI program. Public benefits due to wildlife habitat on farmland are not affected by CI in most regions. It appears that direct measures to enhance valuable habitat would be more effective than measures related to the CI program.

This analysis shows that AAFC has developed a set of analytic tools that can take a complex, national program, and trace its impact through producer decisions to their effect on particular environmental resources in all regions of the country. Both the CRAM system and the geographical information on natural resources are accurate enough to give analysts a fair degree of confidence in the results.

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Appendix A : Yield Distributions

Indemnity payments are triggered when a producer's farm yield falls, by a certain percentage, below the regional long-term average yield. Hence, the distribution of the yield data is critical in triggering indemnity payments. Data limitations restrict the yield distributions used in this report to be based on the year to year variability of regional average yields[1]. However, the actual CI program also takes into account the farm to farm variability of yields within a given year.

In order to compare the variability of the regional average yields used in CRAM with the distribution of farm level yields within a year, a special data request was made to Statistics Canada. The means, standard deviations, highs and lows of farm level yields for the crops and regions included in CRAM were provided for 1996. These are the raw data that Statistics Canada uses to estimate regional yields. A summary of the farm level data for 1996 with the 1980 to 1992 average yield data for selected crops and regions is presented in Table A.1. The major conclusions that can be drawn from the comparison are that the difference between the high and low yields is much greater in the farm level data as compared to regional average yields, and the standard deviations are higher for the farm level data[2]. Therefore, using the regional average yields underestimates the farm-to-farm yield variability with the result that the estimated net indemnity payments would be significantly understated. In fact, using the average regional yields in the model to trigger payments resulted in negative net indemnities for most crops, indicating that the program payouts would be less than producer premiums.

This phenomeon is represented in Figure A.1, with curve **A** representing the distribution of annual average regional yields over several years. Curves **B** and **C** represent annual yield distributions for the farm population with **C** representing a very bad year and **B** a very good year. The 70% line represents the trigger for CI payments, i.e. yields lower than 70% of the regional long term average result in a CI payout. Distribution **A** does not pick up the farm

1. Historical information on annual average regional yields are only available by crop. In CRAM, crop yields are required broken down by fallow/stubble cropping and by tillage practices (intensive, moderate and no-till) for the Prairies. Annual yields at this level of detail simulated by EPIC were used to adjust the annual regional average yields used in the model.

2. While Table A.1 presents data only for selected crops and regions, the same general conclusions apply to all crops and all regions.

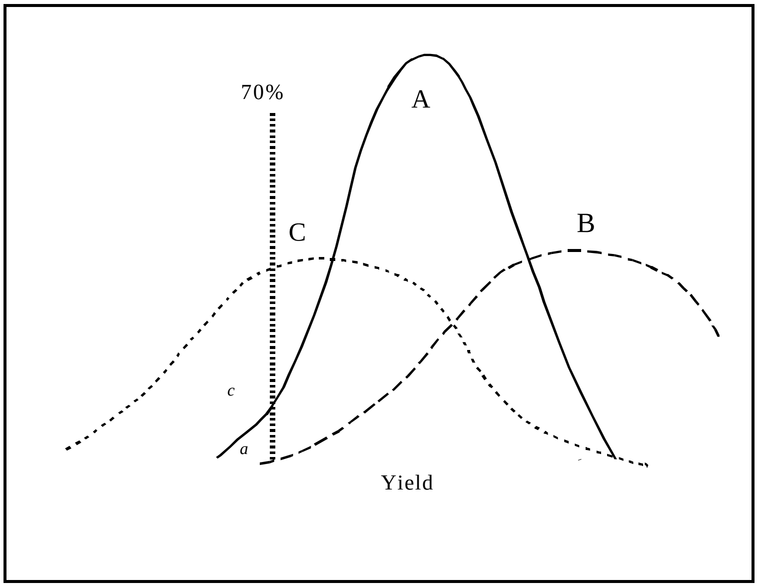
Table A.1: Comparison of Yield Distributions

	Statistics Canada[1] (1996 Crop Survey)				CRAM[2] (1980-1992)					
Province/ Region	Mean Yield (tonnes /ha)	Standard Deviation	Low Yield	High Yield	Fallow/ Stubble	Mean Yield (tonnes /ha)	Standard Deviation	Low Yield	High Yield	Ratio of Standard Devia- tions
Alberta (Region 5)										
Wheat (excl. Durum)	3.92	1.37	n/a	n/a	SF SB	2.91 2.37	0.17 0.09	2.53 2.25	3.25 2.56	8.03
Durum	3.00	0.98	1.68	5.38	SF SB	2.91 2.37	0.17 0.09	2.53 2.25	3.25 2.56	5.78
Barley	3.75	0.87	0.81	5.92	SB	3.31	0.15	3.09	3.60	5.81
Canola	1.83	0.50	0.56	3.08	SF SB	1.44 1.21	0.08 0.05	1.22 1.12	1.57 1.30	6.30
Manitoba (Region 4)										
Wheat (excl. Durum)	2.66	0.44	n/a	n/a	SF SB	2.41 1.96	0.37 0.30	1.66 1.35	2.91 2.38	1.20
Durum	2.53	0.26	2.02	3.03	SF SB	2.41 1.96	0.37 0.30	1.66 1.35	2.91 2.38	0.69
Barley	3.79	0.86	0.36	5.65	SB	2.89	0.54	2.02	3.66	1.58
Canola	1.80	0.37	0.34	2.52	SF SB	1.31 1.08	0.18 0.15	0.90 0.75	1.54 1.28	2.05
Ontario										
Wheat	2.85	0.83	0.74	6.72		3.68	0.40	2.90	4.50	2.06
Barley	3.01	1.31	0.24	6.18		3.12	0.33	2.50	3.60	3.98
Soybeans	2.50	0.87	0.34	4.94		2.37	0.20	2.02	2.76	4.33
Corn Grain	7.17	2.08	0.94	12.35		6.30	0.50	5.31	7.34	4.17
Quebec										
Wheat	2.78	1.03	0.89	7.41		3.01	0.25	2.60	3.50	4.11
Barley	2.89	1.15	0.33	6.67		2.94	0.28	3.50	2.40	4.09
Soybeans	2.74	0.79	0.98	5.18		2.49	0.27	1.91	2.82	2.93
Corn Grain	7.10	1.49	0.24	12.35		5.90	0.52	4.82	6.72	2.87

[1] Based on farm level yields within a single year.
[2] Based on regional average yields over several years.

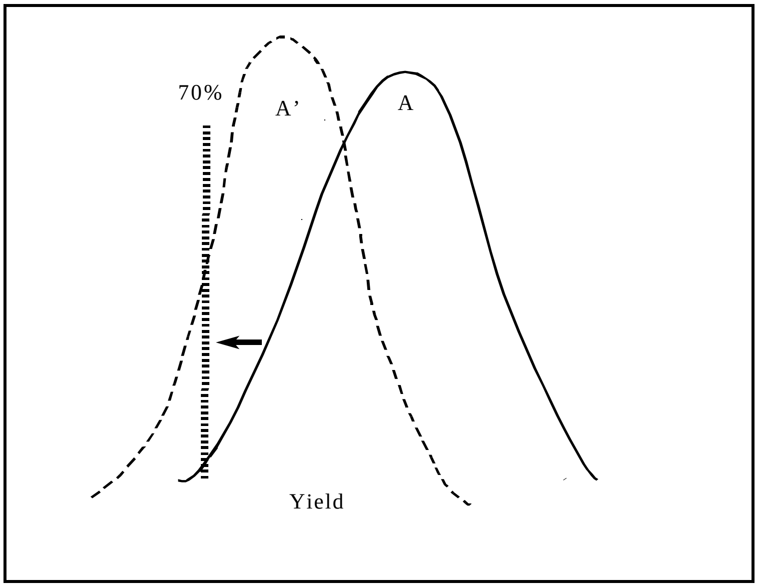
level highs and lows, and if this distribution is used to calculate expected indemnity payments it would underestimate the potential for payments. Only when the yield falls in region *a* would an indemnity payment be triggered. In a relatively poor year such as **C**, where the mean yield still exceeds 70% of the regional long term average yield, a payout would not be triggered. In this case, area *c* represents the actual yields that should trigger a CI payment. In summary, the distribution of average annual regional yield data would tend to underestimate the amount of indemnity payments from the program.

Figure A.1: Crop Yield Distributions



To overcome this problem would require farm level data across time for all the regions and crops. This type of data is not readily available. In its place, the model was calibrated to compensate for this data problem. CRAM was calibrated by applying a proportional shift to the annual average yields; i.e. the average annual yields for each crop within each region were multiplied by some constant less than unity. This results in the distribution **A** in Figure A.2 shifting to the left to **A**'. The constants used varied across regions and crops, and were chosen so that the net indemnity payments generated by CRAM approximated those paid by CI on average over time. This calibration procedure resulted in a more accurate depiction of CI, especially considering the data limitations. It should be noted that the proportional shift in yields was only used to calculate the CI net indemnities over time. The risk component of the model is based on the distributions of regional average yields as proposed by Hazell and Norton (1986) for sector models.

Figure A.2: Proportional Shift of Yield Distribution



Applying proportional shifts to the yield distributions is one of several methods which could be used to calibrate the net indemnities to historical levels. An alternative would be to apply a mean preserving spread to the distribution of regional annual crop yields as illustrated in Figure A.3. In this case, the mean of the yield distribution is held constant, but the variance is increased. The result is that CI payments would be triggered for more years than would be the case if the untransformed distribution of regional average yields is used. This is accomplished by applying the transformation

$$Y_i = \bar{X} + k(X_i - \bar{X}) \qquad (A.1)$$

where

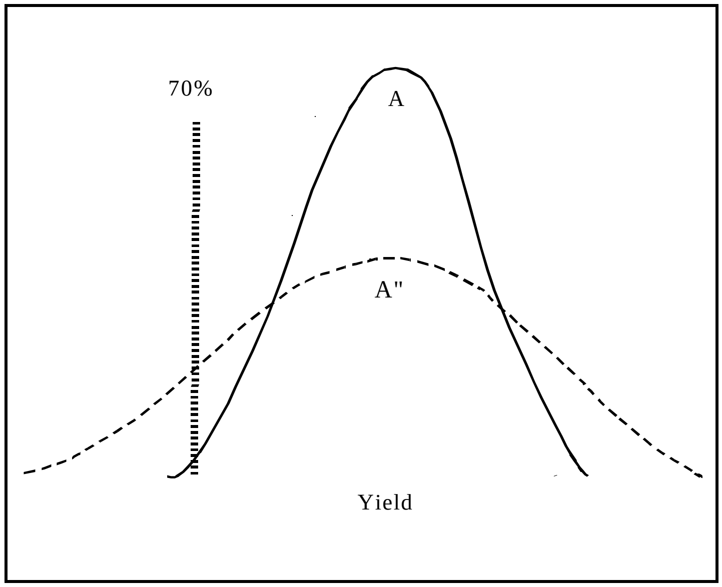
Y_i = transformed crop yield for year *i*,

X_i = regional average crop yield for year *i*,

$\bar{X}$ = average regional crop yield over time, and

k = a constant greater than unity.

Figure A.3: Mean Preserving Spread of Yields



This method is consistent with the observation that the regional average yields underestimate the farm-to-farm variability upon which expected net indemnity payments are based. Shifting the yield distribution from **A** to **A**" will trigger more CI payments. As is the case for the proportional shifts, the values of *k* are chosen so that the indemnity payments generated by the model are consistent with historical levels.

Table A.2 summarizes the results of the two methods of calibrating net indemnities. The results are reasonably consistent, and some of the differences can be explained by the fact that for the proportional shifts the net indemnities are calibrated to crops within regions, whereas the mean-preserving spread method is only calibrated to total provincial net indemnities. The analysis carried out for this report uses the proportional shift approach, with the exception of Scenario 7 which examines the impact of increased variability based on the mean-preserving spread of yield distributions applied to both net indemnities and the risk component of the model.

Table A.2: Impact of Crop Insurance for Different Yield Distribution Shifts (Percent Change with Crop Insurance)

	Total Land Use for Grains and Oilseeds		Crops Planted			Summerfallow Area		
Region	Propor-tional Shift	Mean Preserving Spread	Crop	Propor-tional Shift	Mean Preserving Spread	Region	Propor-tional Shift	Mean Preserving Spread
CANADA	2.0	1.9	Wheat	4.8	5.0	CANADA	0.1	1.0
BC	0.0	0.0	Durum	0.3	1.1	BC	2.7	8.3
AL	0.0	0.0	Barley	3.0	2.2	AL	-4.0	-4.6
SA	3.0	3.6	Oats	4.2	2.5	SA	1.1	2.4
MA	2.5	1.7	Flax	7.6	11.5	MA	4.8	5.1
WEST	2.0	2.3	Canola	0.1	0.7			
ON	2.1	0.0	Lentils	-0.9	-0.7			
QU	0.0	0.0	Field Peas	-0.1	0.0			
NB	0.0	0.0	Soy-beans	5.4	-6.5			
PE	0.0	0.0	Corn Grain	0.2	0.3			
NS	0.0	0.0	Corn Silage	0.0	0.0			
NF	0.0	0.0	Pota-toes	1.9	1.2			
EAST	1.5	0.0	Other	-2.8	-1.7			

Appendix B : Erosion Model

Water Erosion

Soil Landscape of Canada (SLC) maps at a scale of 1:1 million have been published for all of Canada and are available from the Research Branch of Agriculture and Agri-Food Canada in Ottawa (Coote et al. 1992). These are used for the water erosion risk calculations. The SLC polygon database contains information on the inherent characteristics of one or more soils in each SLC polygon in relation to the landscape. Soil and landscape attributes are recorded in the extended legend for the dominant and subdominant soils found in each polygon.

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

$$A = R * K * LS * C * P \tag{B.1}$$

where

A = soil loss rate (tonnes per hectare per year),

R = rainfall erosivity (megajoule-millimeter per hectare-hour-year),

K = soil erodibility (tonne-hour per megajoule-millimeter),

LS = slope length and steepness factor (unitless),

C = crop management factor (unitless),

P = conservation management factor (unitless).

Although newer, more process-based models exist, their data input requirements are much more extensive and some such as EPIC contain the USLE as a component module.

Utilizing Canada's soil and climatic databases, *R, K* and *LS* factors are determined for most of the individual SLC polygons. The average annual sum of all rainfall events is *R*.

$$R = E*I \qquad (B.2)$$

where

E*I = total kinetic energy of a storm multiplied by the maximum 30-minute intensity,

E = volume of rainfall and runoff (kinetic energy in metric-ton metres per hectare per centimetre of rain),

I = prolonged-peak rates of detachment and runoff (intensity in centimetres per hour).

R_t and R_s terms are used interchangeably for *R.* These are the adjusted-*R* values for winter conditions for Eastern Canada and the Prairies, respectively.

$$R_t = R(1+(WP/100)) \text{ (Madramootoo 1988)} \qquad (B.3)$$

where

R_t = average annual erosivity index, adjusted for winter conditions and

WP = percentage of total annual precipitation occurring in winter (December-March),

$$R_s = m\, r_w\, k \text{ (Hayhoe et al. 1992)} \qquad (B.4)$$

where

R_s = rainfall for winter conditions in the Prairies,

m = mean daily winter runoff rate (mm/day),

r_w = mean winter runoff (cm),

k = a constant of 1.

The R_t term represents total erosivity from rainfall *R*, and snowmelt and runoff R_s for areas east of the Rocky Mountains. The Wischmeier and Smith (1978) method was used to determine *R* and Madramootoo's (1988) method was used to calculate R_s. Appropriate R_t values were obtained from interpolation of Madramootoo's isoline maps for individual SLC polygons. For British Columbia, R_s was calculated using the procedure by McCool et al. (1982).

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

The topographic factor *LS* is determined for both the dominant and subdominant soil 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. 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 (van Vliet and Coote 1997; Shelton et al. 1991). The Territories and Newfoundland were excluded because of a very limited agricultural land base.

Identifying the SLC Polygon within each CRAM Region

British Columbia, Ontario, Quebec, New Brunswick, Nova Scotia and Prince Edward Island have only one CRAM region per province. In the determination of one erosion rate for each province, cropland areas and previously-calculated erosion rates for each SLC polygon are used to derive a weighted estimate.

Alberta, Saskatchewan and Manitoba contain seven, nine and six CRAM regions, respectively. Data obtained from the Policy Branch are used to identify the SLC polygons contained within each CRAM region. SLC polygons that overlapped two regions are assumed to have 50% of their cropland area in each region for the purpose of calculating weighted erosion rates. SLC polygons appearing in three regions are assumed to have 33.3% of their cropland area within each region.

Determining Erosion Rates for each CRAM Region

The USLE, as briefly described, is used to estimate erosion risk rates for each SLC polygon. These estimates are based on the inherent rainfall, soil (dominant and subdominant) and landscape characteristics of each polygon (*R,K* and *LS* in the USLE). For each SLC polygon, the calculated soil risk erosion rate (tonnes per hectare per year) is then multiplied by the area of cropland (ha) to estimate annual soil loss (t/y). By summing these annual soil losses for each SLC polygon in a CRAM region, then dividing the total by the total cropland area (ha) in the region, a weighted erosion rate (tonnes per hectare per year) could be determined. This weighted rate reflects the different erosion rates present in a region and the proportion of total cropland on which they occur. Note that this estimate does NOT include the crop and management information which are discussed in the following section.

Compiling Crop and Management Values for Provinces and CRAM Regions

Management values C are obtained from the "Revised Universal Soil Equation For Application in Canada" (RUSLEFAC) manual (Wall et al. 1997), Research Branch, Agriculture and Agri-Food Canada. A weighted C value is calculated for each CRAM region. A C value is assigned to each crop or crop group present in the CRAM region. The crop or crop group C value is multiplied by the proportion of total cropland area in the region occupied by the individual crop. For example, if spring wheat is grown on one quarter of the total CRAM region's cropland, then the C value for spring wheat is multiplied by 0.25 to produce a weighted spring wheat value. The weighted values for all crops in the region are summed to obtain a weighted C value for the region. Support practice factor *P* in the USLE is assumed to be 1.0 (no practice).

Estimating Actual Erosion by Water for the CRAM Area Regions

The actual estimated erosion rate (A = tonnes per hectare per year) for a CRAM region is produced by multiplying the erosion risk rate (*R*K*LS*) by the weighted C value for each CRAM Region. It is assumed that 60% of the soil loss rate applies to the dominant soil and the remaining 40% applies to the subdominant soil.

Soil Erosion Risk Classes

Soil loss rates determined with the USLE are grouped into five erosion risk classes ranging from tolerable to severe (Table B.1). Tolerable losses are defined as less than 6 tonnes per hectare per year. Low rates range from 6.0 to 10.9 tonnes per hectare per year and moderate rates range from 11.0 to 21.9 tonnes per hectare per year. High and severe classes comprise rates of 22.0 to 32.9 and greater than 32.9 tonnes per hectare per year respectively. The lowest class (less than 6 tonnes per hectare per year) is generally considered to represent a tolerable risk of soil erosion for sustainable crop production. Soil formation is generally in equilibrium with soil loss. The other classes of soil erosion represent conditions where the implementation of soil and water conservation practices are required for sustained production of agricultural crops. Since the USLE is an empirical model which does not measure erosion but estimates a potential for loss, and also because it is a field-scale model being used on much larger areas (soil landscape polygons), the actual erosion rates reported here should be interpreted with caution. 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.

Table B.1: Guidelines for Assessing Potential Soil Erosion Classes

Soil Erosion Risk Class	**Potential Soil Loss** (tonnes/hectare/year)
Very low (i.e., tolerable)	<6
Low	6–11
Moderate	11–22
High	22–33
Severe	>33

Source: Adapted from Wall et al. 1997.

Wind Erosion

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

The wind erosion analysis is also based on 1:1 million scale Soil Landscapes of Canada maps for each of the Prairie provinces. Pertinent soil and landscape attributes are recorded for each SLC polygon. Climate and land use parameters are linked to the SLC polygons to provide an integrated land resource digital database to facilitate analysis.

Inherent Erosion Risk

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

$$E = KC(V^2 - \P W^2)^{1.5} \qquad \text{(B.5)}$$

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,

¶ = soil moisture shear resistance, and

W = surface soil moisture content (volumetric).

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

Actual Erosion Risk

The actual erosion risk is 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 residue reduction factor (RED) for wind erosion is based on the amount of surface residue and its effectiveness in controlling erosion. Initial residues, or the residues at harvest, were calculated using 10-year average crop yields, adjusted for soil zone and soil texture, multiplied by a crop conversion factor (unit weight*straw:grain ratio). To calculate the residues for the following April–May period, which coincides with the highest wind erosion risk, initial residues are reduced according to cropping system and type and frequency of tillage.

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 are considered for each region.

(i) Rotation:

% cropland to be fallowed the following year

% cropland to be seeded the following year

% summerfallow to be seeded the following year

(ii) Tillage:

% conventional (fall and spring tillage)

% conservation (spring only)

% no-till (direct seeding)

For cropland to be fallowed the following year, it is 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 cropland that is to be seeded the following year, tillage operations representing conventional, conservation, and no-till systems are considered.

It is assumed also that all cropland reported in the census was seeded the following year, with the exception of spring cereals which is apportioned between fallow and seeded. The area of spring cereals to be fallowed is 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 B.2.

The calculation of the actual amount of residue (RES) for each crop group also requires an estimate of the area in conventional, conservation, and no-till systems as well as the residue reduction associated with each tillage system. The equations are:

(i) Cereals:

$$RES(cereal) = \frac{IRc * Cf * Rcf + IRc * Csv * Rcsv + IRc * Css * Rcss + IRc * Csn * Rcsn}{Ct} \qquad (B.6)$$

where

IRc = initial residue for cereals (kg/ha)

Cf = area of cereals fallowed the following year (ha)

Rcf = reduction for cereals fallowed the following year

Csv = area of cereals seeded the following year under conventional tillage (ha)

Rcsv = reduction for cereals seeded the following year—conventional tillage(%)

Css = area of cereals seeded the following year under conservation tillage (ha)

Rcss = reduction for cereals seeded the following year—conservation tillage(%)

Csn = area of cereals seeded the following year under no-till (ha)

Rcsn = reduction for cereals seeded the following year—no-till(%)

Ct = total area of cereals;

(ii) Oilseeds:

$$RES(oilseed) = \frac{IRo * Ov * Rosv + IRo * Os * Ross + IRo * On * Rosn}{Ot} \quad (B.7)$$

where:

IRo = initial residue (kg/ha)

Ov = area of oilseeds seeded the following year under conventional tillage (ha)

Rosv = reduction for oilseeds seeded the following year—conventional tillage(%)

Os = area of oilseeds seeded the following year under conservation tillage (ha)

Ross = reduction for oilseeds seeded the following year—conservation tillage(%)

On = area of oilseeds to be seeded the following year under no-till (ha)

Rosn = reduction for oilseeds seeded the following year—no-till(%)

Ot = total area of oilseeds (ha);

(iii) Summerfallow:

$$RES(fallow) = \frac{IRc * Fv * Rfv + IRc * Fs * Rfs + IRc * Fn * Rfn}{Ft} \quad (B.8)$$

where

IRc = initial residue (cereals) (kg/ha),

Fv = area of fallow under conventional tillage (ha),

Rfv = reduction for fallow—conventional tillage(%)

Fs = area of fallow under conservation tillage (ha)

Rfs = reduction for fallow—conservation tillage(%)

Fn = area of no-till fallow (ha)

Rfn = reduction for no-till fallow (%)

Ft = total area of fallow (ha);

Table B.2: Crop Residue 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	f-cultivator(2x)	22
		Direct Seeding	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

(iv) Pulses:

$$RES(pulses) = \frac{IRp * Pv * Rpsv + IRp * Ps * Rpss + IRp * Pn * Rpsn}{Pt} \quad \text{(B.9)}$$

where

IRp = initial residue (kg/ha)

Pv = area of pulses seeded the following year under conventional tillage (ha)

Rpsv = reduction for pulses seeded the following year—conventional tillage(%)

Ps = area of pulses seeded the following year under conservation tillage (ha)

Rpss = reduction for pulses seeded the following year—conservation tillage(%)

Pn = area of pulses to be seeded the following year under no-till (ha)

Rpsn = reduction for pulses seeded the following year—no-till(%)

Pt = total area of pulses (ha).

The RED value was calculated for each crop group (cereals, oilseeds, summerfallow, pulses and forage) according to the following equation:

$$RED = a + b(RES) - c(EROS) \quad \text{(B.10)}$$

where

RED = wind erosion reduction factor

a,b,c = coefficients based on crop type (cereal, oilseed, summerfallow, pulses and forages)

RES = amount of residues (kg/ha)

EROS = bare soil erosion rate.

The RED value for each soil type within the polygon is calculated as a weighted average of the crop groups:

$$\frac{RED(cereals)*Area(cereals) + RED(oilseeds)*Area(oilseeds) + RED(fallow)*Area(fallow)}{Cultivated\ Area}$$

$$+ \frac{RED(pulses)*Area(pulses) + RED(forages)*Area(forages).}{Cultivated\ Area} \quad \text{(B.11)}$$

It is assumed that the proportion of cultivated land within the polygon is the same for both the dominant and subdominant components. It is also assumed that the extent of cultivated land and relative extent of the various crops is the same for subdominant landscape as for the dominant landscape. The actual erosion rate is then estimated for each of the dominant and subdominant soil landscapes as follows:

$$NEROS = EROS(1 - RED) \tag{B.12}$$

where

NEROS	=	actual erosion rate
EROS	=	bare soil erosion rate
RED	=	reduction factor.

The output is treated as a dimensionless index denoting the relative erosion risk only. A rating of 100 would correspond to a loss of one tonne per hectare per year, and 200 would be two tonnes per hectare per year.

Appendix C: Update on the 1994 Crop Insurance Environmental Assessment

Introduction

Price Waterhouse conducted the first environmental assessment of CI for AAFC, as required under the Farm Income Protection Act (FIPA). This appendix summarizes progress made in responding to questions that were left unanswered by their 1994 report, *Crop Insurance Environmental Assessment – Synthesis and Recommendations*. It also provides an update on the status of recommendations from the 1994 report.

Unresolved Issues Raised in the 1994 Report

In their 1994 report PW noted several issues that could not be answered without a national, quantitative model, including the impact of CI on summerfallow, potato rotations, and forage crops. These questions have been resolved with the CRAM estimates presented in this report.

(i) Summerfallow

The 1994 report noted conflicting theoretical and empirical evidence on whether CI would increase or decrease the choice of summerfallow in grain rotations (PW 1994a, p. 25). This could have environmental implications, as summerfallow is associated with serious environmental problems in the prairie region such as salinization and erosion.

This report estimates that CI leads to a small increase of 67,000 hectares in summerfallow in Manitoba and Saskatchewan, but a decrease of 63,000 in Alberta. The net result for Canada is an insignificant change +0.1% (Table 5). This mixed result is due to several concurrent influences of CI:

- CI diminishes summerfallow by encouraging higher-risk stubble cropping;
- CI favours summerfallow by favouring wheat production (Table 3), which often includes summerfallow in the rotation, more than canola, which generally does not; and
- CI favours summerfallow by favouring the area used for all annual crops over other land uses (Table 1).

The net impact of these conflicting influences could not be estimated without a multi-product, regional model. The net effect of CI is to increase summerfallow slightly in Manitoba and Saskatchewan, and decrease it in Alberta. In summary, CI has a very small net effect on summerfallow acreage with the direction of change dependent on a number of factors.

(ii) Potatoes

The 1994 report found evidence that CI may tend to increase potato acreage over grains and forage in the potato rotation (PW 1994a, p. 10, 12, 18). This effect could reduce organic matter in the soil and increase the opportunity for soil erosion, reducing soil quality, increase risk of water contamination due to heavy use of pesticides and increasing silt in surface water.

The size of this bias turns out to be fairly small, accounting for about 2,000 hectares, or 2% of potato acreage, according to the estimates presented in Section 4.

(iii) Marginal Land Use

The 1994 report found some evidence that CI may bring marginal or environmentally sensitive land into production, but had no quantitative evidence of the size of the effect (PW 1994a, p. 20-22). Marginal land tends to be more prone to erosion, and sometimes provides habitat for wildlife.

This report found that about 685,000 hectares, or 2% of annual cropland, is transferred from forages or pasture to annual crops as a result of CI. While this land is economically marginal, it is not known how much is environmentally marginal as well. It is likely that CI leads some marginal land to be cultivated, but this effect is unlikely to exceed about 2% of Canada's cropland and the magnitude of the impact depends on a large number of factors, the most important being market performance.

Recommendations

While the 1994 report found little or no environmental impact directly attributable to CI, it nonetheless made several recommendations based on particular problems or opportunities. The status of many of these issues has changed over the past three years, as outlined in the following update:

1. **Good Farming Practices**: *The identification of good farming practices provides the best lever for ensuring that CI does not contribute to environmentally harmful practices. What constitutes 'good farming practices' in terms of environmental sustainability must be clearly defined and formally incorporated into the field level operations of the CI program in every province. This provides an opportunity to establish minimum acceptable guidelines for CI at a national level.*

The definitions of good farming practices within CI are the responsibility of provincial CI officials who develop and administer CI programs across Canada. These definitions are continually adapted, particularly in view of producer and public interest in sustaining agricultural production and decreasing off-farm impacts.

2. **Individual Coverage**: *Complete individual coverage should be adopted as soon as possible. This ensures that incentives for producers to undertake practices which will be harmful to the sustainability of their operation are removed. Individual coverage also provides an opportunity to allow producers to use different practices for sustainability and get coverage which accurately reflects the risk associated with that production. This allows for innovation with suitable coverage.*

All provinces now have implemented CI systems based on individual coverage.

3. **Organic Production***: There should be attempts where possible to improve provisions for organic production.*

The province of Saskatchewan has developed a separate organic CI plan.

The Canadian Food Inspection Agency (CFIA) has been working closely with the organic industry over the past several years to develop standards and a system of organic certification and accreditation. The industry, through the Canadian Organic Advisory Board, is pursuing the development of National Standards for Organic Production under the Standards Council of Canada.

4. **Wildlife and Waterfowl Coverage**: *Coverage for wildlife and waterfowl should be improved.*

As a result of the 1996 Review of CI, the Canadian Federation of Agriculture and Wildlife Habitat Canada initiated a joint examination of instruments to improve coverage for wildlife and waterfowl damage. Their preliminary analysis and recommendations were presented to the Federal and Provincial Ministers of Agriculture in July 1997, with a view to recommending options in 1998.

The provinces of Manitoba and Saskatchewan have initiated joint federal-provincial programs to compensate producers for crop losses due to ungulates (deer, elk, etc.). These programs include measures to encourage prevention of damage.

5. **Testing of New or Altered Provisions**: *All new provisions or significant alterations to the existing provision of the CI program should be tested for environmental soundness before being adopted. A two-step process incorporating the approach used in this assessment would allow for a qualitative assessment of new provisions followed by quantification in any areas identified. This provides a proactive approach to ensuring that CI does not contribute to environmentally harmful practices.*

The only significant alteration to CI programs since 1994 was the introduction of a two-tier insurance option in Manitoba. This change was not specifically tested for environmental soundness prior to its implementation. However, the 1998 environmental assessment of crop insurance covers this option, since two-tier insurance is under serious consideration in several provinces. The analysis in this report concluded that two-tier insurance would have a smaller impact on production decisions, and hence on natural resources, than traditional forms of CI.

6. **Requirements for Ongoing Monitoring**: *In order to streamline and improve the process of environmental assessment of programs, there is an opportunity to identify selected priority data or indicators to monitor changes and provide more detailed impact of programs on producer decisions. Indicators would provide greater information on actual environmental performance and producer practices.*

The Agri-Environmental Indicators project, initiated in 1993, is creating detailed, policy-relevant measures of the impact of agriculture on environmental risks and benefits. Some indicators, such as soil erosion risk and soil salinity risk were released in 1996 and 1997, identifying specific regions that have a high risk of degradation due to agricultural activities. Other indicators are forthcoming, such as water contamination risk and agro-ecosystem biodiversity change, which will enrich the capacity to analyse the impact of programs such as CI on the environment (Banerjee 1997). Several of these indicators are used in this report.

7. **Comprehensive Approach**: *We strongly urge the development of a framework for reviewing the environmental impact of agricultural policies in a comprehensive manner. While it is important to initially review each program in isolation to ensure that there are no negative environmental influences specifically attributable to that program, the comprehensive review is equally important to determine the total effect of programs on producer decisions and the interaction between programs.*

Several recent initiatives have contributed to the creation of a comprehensive system for assessing the environmental impacts of agricultural policies in Canada. The Agri-Environmental Indicators discussed above contribute a necessary ingredient by interpreting nation-wide data on a consistent, scientific basis and identifying possible cases of excess resource use. AAFC is developing a *Guide to the Environmental Evaluation of Agricultural Policies and Programs*, which applies to the full range of agricultural policies, and includes specific reference to the cumulative effects of agricultural policies on producer behaviour and environmental impacts. The department is also enhancing its modelling capability by adding environmental components to the Canadian Regional Agricultural Model (CRAM) which will allow quantitative estimation of the impact of policy instruments on soil erosion, greenhouse gases and other environmental factors.