Quantitative Analysis of the Impact of Agricultural Management Strategies on Environmental Indicators

Agriculture and Agri-Food Canada
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QUANTITATIVE ANALYSIS OF THE IMPACT OF AGRICULTURAL MANAGEMENT STRATEGIES ON ENVIRONMENTAL INDICATORS

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Acronyms

AAFC	Agriculture and Agri-Food Canada
AEI	Agri-Environmental Indicator
APF	Agricultural Policy Framework
BAU	Business as Usual
BMP	Beneficial Management Practice
C	Carbon
CEEMA	Canadian Economic and Emissions Model for Agriculture
CFS	Canadian Forest Service
CH_4	Methane
CO_2	Carbon Dioxide
CRAM	Canadian Regional Agricultural Model
GHG	Greenhouse Gas
HA	Habitat Availability
IROWCN	Indicator for the Risk of Water Contamination by Nitrogen
IPCC	Intergovernmental Panel for Climate Change
K	Potassium
LUAM	Land Use Allocation Model
LULUCF	Land Use, Land Use Change and Forestry
N	Nitrogen
NAHARP	National Agi-Environmental Health Analysis and Reporting Program
N_2O	Nitrous Oxide
RSN	Residual Nitrogen
RUSLEFAC	Revised Universal Soil Loss Equation for Application in Canada
RWDE	Risk of Wind Erosion
RWE	Risk of Water Erosion
SLC	Soil Landscape of Canada Polygon
SOC	Soil Organic Carbon

FOREWORD

Canada's agriculture industry makes an important contribution to national social, economic and ecological welfare, and thus the sustainable development of this sector is important to all Canadians. Concern about the sustainability of agriculture is increasing in Canada and governments have responded by broadening the scope of agricultural policy to include environmental and social issues.

The Agricultural Policy Framework (APF), which was launched in June 2001, is a joint initiative of Canada's federal, provincial and territorial governments. Through it, ministers of agriculture pledged to meet the sector's challenges by jointly developing an agriculture policy that is comprehensive, integrated and ensures that farmers have the tools to address issues, be competitive and capture opportunities in the areas of science, food safety and environmental stewardship. In the case of the APF environment chapter, ministers also requested that measurable goals and targets be specified.

This study uses an integrated economic-environmental modeling system to provide quantitative estimates that were used in the process of setting provincial environmental outcome targets under the APF. The analysis represents a joint effort of the Department's physical scientists, economists and policy analysts. This approach provides the ability to model the impacts of agricultural production and the adoption of Beneficial Management Practices (BMPs) on the Canadian environment. The analysis quantifies the impacts of various management practices on air, soil, and water quality as well as biodiversity through measurable and meaningful indicators. It also assists in identifying appropriate environmental goals by providing an indication of achievable outcomes as a result of adopting environmental management practices.

The results of this study provided policy-makers with information on the levels of environmental improvements that are feasible to obtain and identified options to reach these environmental targets. This quantitative analysis provided a basis for discussions between AAFC and the provincial governments with respect to the inclusion of specific environmental outcome targets in the bilateral APF Implementation Agreements.

This study is based on existing agri-environmental indicators and integrated modeling capacity. The limitations of these analytical tools and results are recognized. Work will continue at Agriculture and Agri-Food Canada (AAFC), through the National Agri-Environmental Health Analysis and Reporting Program (NAHARP) to improve the indicators and modeling capacity described in this study and to apply these analytical tools to policy development, performance monitoring, program evaluation and public reporting. Future development will focus on three particular areas: enhancement of the methodology and data of existing agri-environmental indicators and development of new indicators to address key gaps; improvements in the economic models and their linkages to environmental indicator models; and development of a capacity to understand and quantify the economic costs and benefits of environmental changes due to agriculture. The analysis presented in this study will have to be revisited as the data and models are improved through the NAHARP process and the provincial environmental outcome targets will be adjusted as appropriate.

The proposed advances in methodology will lead to policy benefits such as developing a more precise picture of the change in management practices needed to achieve existing targets, and developing options for revising the targets in the existing Implementation Agreements as we move forward within the APF time frame and beyond.

Executive Summary

In June of 2001, federal, provincial and territorial agriculture ministers met in Whitehorse, Yukon to establish an agreement in principle on a new long term agricultural policy framework and action plan that could take the sector beyond crisis management to become the world leader in food safety, innovation and environmentally responsible production. Five priority areas identified in the framework include food safety, environment, science, renewal and risk management. Over the next five year period (to 2007), policy will be developed for these key areas.

Key elements of the Whitehorse Agreement specify that:

> "Ministers... agree to work towards a comprehensive plan for accelerated environmental action, fully covering all Canadian farms, that will help achieve measurable and meaningful environmental targets in the areas of water, air and soil quality, and bio diversity. Ministers will seek agreement on indicators, targets, timetables and approaches."

The Agricultural Policy Framework (APF) Agreement, with specific environmental goals and targets, was signed by most provinces in Halifax in 2002. It included goals related to water resources, air quality, soil health and biological resources and services as well as environmental farm management. Specific quantitative targets and measures were outlined in bilateral Implementation Agreements that were signed with the provinces in the summer and autumn of 2003.

In an effort to help federal, provincial and territorial ministers come to an agreement on the indicators, targets and approaches, Agriculture and Agri-Food Canada (AAFC) conducted a quantitative analysis. The analytical results of this study were used to inform the process of developing the detailed quantitative outcome goals and targets that were incorporated into the Implementation Agreements.

The analysis used various economic and science-based models to determine the impact of changes in farming practices on production, land use and the agri-environmental indicators (AEI), which are outlined in the environment chapter of the APF. This report briefly summarizes AAFC's analysis and presents the impact on environmental performance as measured by indicators related to water, air and soil quality and biodiversity.

Prior to conducting the analysis, an expert group of scientists, policy-makers and modelers met to discuss alternative ways to provide input into the federal/provincial decision making process for targets and measures. After some discussion of tools, goals and resources, they identified nine environmental management scenarios that would cover the impact of various farming practices related to soil nutrient management, soil management, grazing management, livestock feeding management and afforestation.

The scenarios were chosen based on the following criteria:

- Relevance to the established environmental goals of the APF
- Measurability - application and suitability to existing models
- Level of priority within agriculture
- Feasibility

The nine environmental management scenarios that were chosen include:

- Soil nutrient management: better matching of nitrogen to crop requirements
- Soil management practices: increased use of zero tillage
- Soil management practices: decreased use of summerfallow
- Soil management practices: permanent cover program
- Soil management practices: increased forage in crop rotations
- Soil management practices: terracing
- Grazing management: complementary and rotational grazing
- Combined feeding strategies
- Afforestation: increasing plantations on agricultural lands

The quantitative analysis was completed by integrating an economic model with seven existing AEI models. The AEI models indicate the impacts of various agricultural management strategies on the Canadian environment; specifically air, soil, water and biodiversity. The impact of each environmental management scenario on the AEIs was determined separately and the individual impacts were then aggregated to provide the total impact of all scenarios. Since it was unclear whether the scenario impacts were additive, a combined analysis was conducted to account for possible interactions between scenarios. A comparison of the individual and combined scenario results revealed that the results were essentially additive across scenarios.

The overall results of this analysis reveal that the environmental management scenarios have a desirable impact on the AEIs. Air quality is improved through the reduction of Greenhouse Gas (GHG) emissions by 20% (12.2 Mt CO2 equivalent) from baseline levels. An improvement in soil quality is represented by the reduction in residual nitrogen and risk of wind and water erosion. Residual nitrogen decreases by 11%, and the reductions in risk of wind and water erosion and water contamination vary according to province. Biodiversity, in terms of habitat availability, improves by 6% across Canada. Results were generated for three different levels of adoption in order to provide the sensitivity of results to different adoption rates.

The APF Agreement states that ministers want to "achieve measurable, and meaningful environmental goals in the areas of water, air and soil quality." This analysis demonstrates how we can measure the impacts of agricultural practices on the environment. Therefore, this type of analysis is useful to the APF process for a couple of reasons. First, it quantifies the impact of various management practices on water, air and soil quality and biodiversity through measurable and meaningful indicators. Second, it assists in identifying appropriate environmental targets by providing an indication of achievable outcomes as a result of environmental management practices.

Quantitative assessment of the economic impacts of environmental management scenarios on agricultural production are not included in this study due to time constraints and lack of available and relevant economic information. Some estimates of producers' net margins are available from the scenario runs of the economic model, but this information needs to be supplemented by results from other studies. It is recognized that information regarding the costs and benefits of various environmental management practices is critical to policy development and are therefore a necessary part of future work.

Section 1
Introduction

1.1 Background

In June of 2001, federal, provincial and territorial agriculture ministers met in Whitehorse, Yukon to reach an agreement in principle on a new long-term agricultural policy framework and action plan that would take the sector beyond crisis management to become the world leader in food safety, innovation and environmentally-responsible production. The agreement identifies five priority areas including food safety and quality, environment, science and research, renewal and risk management. Goals, principles, an action plan and next steps will be developed for each priority area and will contribute to policy development over a five year period (to 2007).

Key elements of the Whitehorse Agreement specify that:

> "Ministers... agree to work towards a comprehensive plan for accelerated environmental action, fully covering all Canadian farms, that will help achieve measurable and meaningful environmental goals in the areas of water, air and soil quality, and bio-diversity. Ministers will seek agreement on indicators, targets, timetables and approaches."

Development and implementation of the agreement points to the need for an analytical capacity to help set goals and targets for the environment and for indicators to measure progress toward these objectives. In consultation with the provinces, the federal government worked towards developing specific environmental and farm management targets and approaches for implementation and management that will allow them to achieve these goals. The Agricultural Policy Framework (APF) Agreement, with specific environmental goals and targets, was signed by most provinces in Halifax in 2002. It included goals related to water resources, air quality, soil health and biological resources and services as well as environmental farm management. Specific quantitative targets and measures were outlined in bilateral Implementation Agreements that were signed with the provinces in the summer and autumn of 2003. This development of progressively more detailed environmental outcome goals and targets was informed by the quantitative analysis described in this paper.

This work builds on previous analysis conducted during the Issues Table Process on Climate Change. Representatives from federal and provincial governments, industry groups and academia worked together to develop national and regional estimates of potential greenhouse gas (GHG) reductions and related costs for various mitigation scenarios in agriculture. Many of these same scenarios are used in the current analysis since they have environmental co-benefits for the potential to improve air, soil and water quality and biodiversity.

1.2 Objectives of the Analysis

- To provide scientifically-based quantitative analysis to assist governments in the process of reaching the environmental goals outlined in the environment chapter of the APF
- To establish a prototype for conducting future environmental assessment analysis specific to agriculture

1.3 Report Structure

This report is organized into eight sections. Section two presents a description of the economic and environmental indicator models used in this analysis and section three briefly discusses the baseline that is used for scenario comparisons. Section four provides an overview of the environmental management scenarios and model results by scenario. Section five presents a summary of results for the combined scenario. Section six contains a brief summary and highlights some of the key limitations of this work. The final two sections include the references and appendices containing scenario assumptions, a provincial crosswalk, detailed scenario results and a summary of results by province.

SECTION 2
METHODOLOGY OVERVIEW

Agriculture interacts with and is influenced by a wide array of social, economic and environmental factors. These factors are inextricably linked to one another, interacting and giving rise to various driving forces that influence the nature and direction of agricultural production. In order to improve our understanding of these relationships, quantitative analysis was conducted through the integration of an economic model with seven existing AEI models. The AEIs indicate how the various agricultural management strategies impact the Canadian environment, specifically air, soil, water and biodiversity. This section provides a brief description of the models and some of the key assumptions.

2.1 Canadian Regional Agricultural Model

The economic model used for this study is the Canadian Regional Agricultural Model (CRAM), which has been used for many years in Canada as a policy analysis tool. CRAM is a sector equilibrium model for Canadian agriculture that is disaggregated across both commodities and space (Horner at al. 1992). CRAM is a static, non-linear optimization model that maximizes producer plus consumer surplus. The basic commodity coverage is grains and oilseeds, forage, beef, hogs, dairy and poultry (horticulture is excluded). Spatial features of the model include provincial-level livestock and crop production, with the exception of the Prairie provinces, where crop production is divided into 22 regions based on the Census of Agriculture boundaries. Supply response is determined by the relative profitability of alternative crops. The model allows for both inter-provincial and international trade in primary and processed products. Government policies are incorporated directly through payments and indirectly through policies such as supply management and subsidized input costs. CRAM is capable of estimating the change in resource allocation into various enterprises in response to changes in technology, government programs and policies or market conditions. Analysis is carried out by comparing activity levels for a scenario versus a baseline version of CRAM.

2.2 Linkages Between CRAM and Agri-Environmental Indicators

Over the past few years, a number of Agri-Environmental Indicators (AEI) have been developed for the agricultural sector (McRae et al. 2000). While these indicators are useful for tracking environmental performance over historical periods, predictive models are needed to objectively estimate what the future might look like given the changes in policy today. This predictive capacity has been developed by linking the economic (CRAM) and AEI models. There are substantial spatial implications in doing this type of analysis since environmental impacts vary with local conditions such as climate, soil type and landscape. Policy scenarios are run by linking the crop and livestock activity levels generated by CRAM to the AEIs and assessing changes in the environmental indicators from the baseline. The following presents a brief description of the AEIs that were linked to CRAM to conduct this analysis.

2.3 Environmental Indicator Models

2.3.1 GHG Emissions

The Canadian Economic and Emissions Model for Agriculture (CEEMA) is used to assess GHG emissions (Kulshreshtha et al., 2002). CEEMA consists of a GHG module, which links CRAM output to GHG coefficients to estimate emissions of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Total emissions are calculated on a CO_2 - equivalent basis based on 100-year global warming potential conversion factors of 21 for methane and 310 for nitrous oxide. The model uses the current state-of-the-science of GHG emissions to estimate total emissions from primary agriculture. In order to provide a complete indicator for agricultural systems, the calculations include all of the Intergovernmental Panel for Climate Change (IPCC) sources for the agriculture sector, plus sinks from the land use, land use change and forestry (LULUCF) sector and on-farm fuel use from the transportation sector. A systems approach is taken, meaning both direct and indirect emissions are accounted for in all three major GHGs. This is important since scenarios targeted at increasing soil carbon sequestration may lead to increased emissions of the other gases; hence the net impact needs to be assessed.

2.3.2 Soil Organic Carbon

Agricultural soil organic carbon (SOC) contributes to soil health and can remove carbon from the atmosphere, thus helping reduce net emissions of greenhouse gases from agriculture. The amount of organic carbon held in agricultural soil is the difference between how much is added to the soil (as crop residues, manure, sewage sludge) and how much is lost (through respiration, mineralization or erosion). Certain agricultural management practices, such as zero-till and the inclusion of forage crops in rotations, build up more carbon in agricultural soils. Other practices, such as continuous summerfallow, will reduce soil carbon stocks.

Stocks and changes in agricultural SOC are estimated with CEEMA using a combination of the Century model and expert opinion (based on empirical data) coefficients (Table 1). The Century model is a site-specific computer simulation model that makes use of simplified relationships of soil–plant–climate interactions to describe the dynamics of soil carbon and nitrogen in grasslands, croplands, forests and savannas. It simulates above and below-ground production of plant material as a function of soil temperature, available water and nutrient availability. This model has been extensively evaluated under different soil, climatic and agricultural practices. These practices include planting, fertilizer application, tillage, grazing and organic matter addition. Century has been tested in eastern and western Canada, the United States, northern Europe and under tropical conditions.

On the Prairies where there has been a long history of soil organic carbon research based on well established scientific sampling and measurement protocols, the Century-derived rates of carbon sequestration associated with management practices such as the adoption of zero tillage and elimination of summerfallow were replaced with expert opinion coefficients, which were empirically derived from a number of research findings. Researchers are continuing to validate the Century model and to verify predictions of soil organic carbon (SOC) for adoption of farm management practices that sequester carbon.

Table 1: Carbon Sequestration coefficients (Mg $CO_2 ha^{-1} yr^{-1}$)

Activity	Prairie Region Soil Zones			Non-Prairie
	Brown	Dark Brown	Black	
Adoption of Zero Tillage	**-0.73**	**-0.73**	**-1.34**	-0.54
Reduce summerfallow	**-0.15**	**-0.16**	**-0.08**	--
Increase forages in crop rotation		-0.94	-2.44	-2.44
Permanent cover	-0.88	-1.15	-3.3	-3.3

Notes: (1) The coefficients shown in bold are from empirical data (McConkey et al., 1999).
(2) Other coefficients were derived with the Century model (Smith et al., 2000).

2.3.3 Residual Nitrogen

The residual nitrogen (RSN) indicator is an estimate of the quantity of nitrogen remaining in the field after harvest (McRae et al., 2000 pg.162-163). It is the difference between the amount of nitrogen that is available to the growing crop from all sources and the maximum amount removed in the harvested portion of the crop under average conditions. The crop nitrogen requirement is estimated as the amount recommended for achieving economically optimal production.

The indicator is calculated by:

- Estimating the amount of nitrogen available from the three major agricultural sources of nitrogen: mineral fertilizer, animal manure and legume nitrogen fixation. In the semi-arid regions, inputs also include crop residues and mineralization of soil nitrogen during periods of summerfallow
- Estimating the amount of nitrogen removed in the harvested portion of the crop based on a combination of recommended levels and standard tables of the portion removed in harvest
- Calculating the difference between these two amounts to give a value for residual nitrogen.

Nitrogen levels were determined from recommended rates of fertilizer application rather than from crop yields, to reflect the actual situation in which farmers must decide by an early stage of crop growth how much nitrogen to apply. Crop yield is only partly controlled by management inputs; uncontrollable growing season conditions exert a major influence. Where the levels of available nitrogen are less than or equal to crop recommendations, the ratio of nitrogen remaining to nitrogen available corresponds to standard published information and reflects the overall ability of the crop to use nitrogen. Where nitrogen is present in excess, the ratio increases.

The indicator itself does not give any insight into the environmental effects of various levels of RSN in different agricultural settings. Surplus nitrogen may pose a risk to the environment, but this risk is also sensitive to other factors, such as soil type and climatic conditions. For example, the movement of nitrogen from farmland into the broader environment is related to the movement of water. In the dry regions of the interior British Columbia and the Prairies, the movement of nitrogen in water is limited, occurring mainly during storms and periods of heavy runoff. The environmental risks of having RSN in the soil are greater in humid areas of the country, such as central and eastern Canada. Thus, RSN was also used in the assessment of the next indicator – risk of water contamination by nitrogen.

2.3.4 Risk of Water Contamination by Nitrogen

Contamination of water by nitrogen from farms is a major environmental concern for the agriculture industry. The potential for agricultural nitrogen in the form of nitrate to contaminate water is directly related to two factors: the movement of water off farmland, either in overland flow or by leaching through the soil profile into groundwater and the amount of surplus or residual nitrogen available. The indicator model for the risk of water contamination by nitrogen (IROWCN) measures the risk of water contamination by nitrogen from farmland (McRae et al., 2000 pg.118). The indicator is based on estimates of the potential concentration of nitrate-nitrogen in water leaving farmland.

The potential concentration of nitrogen in water leaving farmland is determined by dividing the amount of nitrogen by the amount of water available to dilute this nitrogen (called excess water). The quantity of nitrogen that is potentially available to move off farmland, called RSN, was calculated as described above for the residual nitrogen indicator.

The amount of water that is potentially available to move off farmland was calculated by devising a moisture budget based on 30 year averages for precipitation (moisture input) and potential evapotranspiration (moisture output). The difference between these two values was used as the estimate of water surplus or water deficit. The capacity of the soil to hold available water was also an important factor in the water budget.

Currently, the IROWCN indicator is only functional for the eastern provinces and the lower mainland of British Columbia; however, work is underway to make this indicator operational for the Prairie provinces and the Peace River region of British Columbia.

2.3.5 Risk of Water Erosion

The risk of water erosion (RWE) indicator is used to estimate the extent of cultivated land at risk of water erosion and to monitor changes in this risk over time, particularly as a result of changes in management practices (McRae et al., 2000 pg.60). The rate of water erosion is estimated using the Revised Universal Soil Loss Equation for Application in Canada (RUSLEFAC) model. Information on factors that influence a soil's vulnerability or resistance to erosion, such as climate, soil and landscape topography, is used to tabulate rainfall, soil, slope gradient and slope length factors for particular agricultural areas. The potential risk of water erosion represented by these factors is then determined for each area and treated as a constant value. The change in erosion risk over time is calculated by considering the effects of changes in agricultural land use and tillage practices across Canada, such as fluctuations in cropland areas, shifts in the types of crops grown and the use of conservation tillage and no-till. This information is obtained from the Census of Agriculture, the CRAM model and input from soil experts. The RUSLEFAC model then estimates the rate of erosion for agricultural cropland in study areas.

Risk is expressed in the following five classes: tolerable (less than 6 tonnes per hectare per year), low (6 to 11 t/ha/yr), moderate (11 to 22 t/ha/yr), high (22 to 33 t/ha/yr) and severe (greater than 33 t/ha/yr). Areas in the lowest class are generally considered at tolerable risk of soil erosion and able to sustain long term crop production. The other four classes represent the risk of conditions that are unsustainable and for which soil conservation practices are needed to support crop production over the long term.

2.3.6 Risk of Wind Erosion

A risk of wind erosion (RWDE) indicator is used to monitor the extent of cultivated land at risk of wind erosion, particularly as a result of changes in management practices (McRae et al., 2000 pg.70). The RWDE is expressed in five categories: negligible, low, moderate, high and severe. The indicator can also be viewed as an indirect measure of a change in soil quality. Because wind erosion is a process of soil degradation resulting in decreased soil quality, a declining erosion risk is considered positive in terms of soil quality. This indicator is only applicable to the Prairie provinces.

2.3.7 Habitat Availability

Agriculture has reduced the quantity of natural habitats, mainly through conversion of the natural landscape and changes in land use, such as the drainage of wetlands and the removal and fragmentation of forest cover. It can also affect the quality of wildlife habitats through various land management practices, such as fertilization, pesticide use and intensive grazing. However, some wildlife species are able to thrive where a native habitat has been replaced by an agricultural habitat, or where agricultural lands contain such habitats as wetlands, grasslands and wooded areas.

To assess agriculture's impacts on wildlife habit, matrices were developed that relate habitat types found on agricultural land (e.g. cropland, pasture, woodlands, wetlands) to the ways in which individual species use agricultural habitats (e.g. for foraging, feeding, nesting, breeding). The matrices were developed from accepted wildlife guidebooks and expert opinion and data on area of agricultural habitats was obtained from the Census of Agriculture. The indicator model used in this analysis can be interpreted as the level of habitat availability (HA) on agricultural lands (adapted from McRae et al., 2000, pg. 145-155).

The types of species and their use of agricultural habitats are essentially constant over time. However, patterns of agricultural land use and cover may evolve over time in response to market conditions and other factors. The habitat index is sensitive to such patterns of agricultural land use as they affect habitats for species.

Section 3

Establishing a 2008 Reference Point

The first step in analyzing the environmental impacts due to changes in on-farm management practices over the next five years was to establish a business as usual (BAU) baseline case for 2008. The year 2008 was chosen since it marks the end of the first APF period for which achievable outcomes must be established. The 2008 BAU baseline for CRAM assumes no increase or decrease in the agricultural land base, with land management practices (e.g. conservation tillage, summerfallow and fertilizer use) continuing to be adopted at rates consistent with historical trends and physical constraints. Growth in various crop and livestock enterprises for 2008 were based on 2001 census information and projections provided by AAFC's September 2002 Medium Term Policy Baseline. Once the CRAM BAU was established, the data was used as input for establishing 2008 baselines for the AEIs. Baseline numbers for CRAM and AEIs are presented in Appendix C.

Baseline numbers for 1996, 2001 and 2008 reveal an increasing trend in cropland, hayland, beef cows and breeding sows whereas summerfallow and native pasture area are declining (Appendix C, Table C.1). Note that tame pasture and native pasture areas are held constant from 2001 to 2008 due to the lack of information on 2008 projections. Trends in land use type, livestock production, fertilizer rates (Table C.2) and zero tillage adoption (Table C.3) are reflected as changes in the AEI baselines. For example, the GHG indicator decreases from 1996 to 2001 and increases from 2001 to 2008. This fluctuation is a result of interactions between the positive impact of increasing SOC sinks (largely influenced by the increase in zero-tillage adoption) with the negative impact of increasing livestock numbers and nitrogen fertilizer rates.

The following section gives a brief overview of the environmental management scenarios included in this analysis. Each of the environmental management scenarios is compared against the 2008 BAU projections for the applicable environmental indicators.

Section 4

Environmental Management Scenarios

In February 2002, a group of scientists, economists and policy analysts from AAFC met to discuss the package of environmental management scenarios that could be used as potential strategies to meet the environmental goals outlined by the APF agreement. The choice of environmental management scenarios was based on the following criteria:

- Relevance to the established environmental goals for the APF
- Measurability – application and suitability to existing models
- Level of priority within agriculture
- Feasibility

Based on the criteria above, nine scenarios were chosen for quantitative analysis. Various scientists and field experts were contacted to provide input into the development of assumptions for each scenario. For each scenario the following set of information was required as input into the economic model (CRAM): applicable regions, current adoption rates, potential future adoption rates, changes in input costs and output. See Appendix A for detailed information on the assumptions for each scenario.

Several management areas identified in the APF goals are not addressed in the selected scenarios due to the lack of existing models for measurement. For example, it was agreed that manure management, specifically storage, handling and application, is an important environmental issue, but it could not be addressed in the current analysis. Integrated pest management and pesticide storage, handling, and application is another area excluded from the analysis. Table 2 provides an overview of the environmental management scenarios included in this analysis and the relevant indicators applied to each scenario.

Table 2: Summary of Indicators Applied to Each Environmental Management Scenario

	Air	Water	Soil			Bio-diversity
Environmental Management Scenario	CEEMA (GHG)	IROWCN	RSN	*RWDE	RWE	HA
Nitrogen Matching	✔	✔	✔			
Conservation Tillage	✔	✔	✔	✔	✔	✔
Reduced Summer-fallow	✔	✔	✔	✔	✔	✔
Permanent Cover	✔	✔	✔	✔	✔	✔
Forage in Crop Rotations	✔	✔	✔	✔	✔	✔
**Terracing						
Rotational & Complementary Grazing	✔	✔	✔	✔	✔	✔
Combined Feeding	✔	✔	✔			
Afforestation	✔	✔	✔	✔	✔	✔

* *Wind erosion model is only applicable for the Prairie provinces.*

** *RWE, RSN and IROWCN are relevant indicators for the terracing scenario, however, due to model structure these indicators could not be applied.*

The impact of the management scenarios on environmental indicators is dependent on the assumed adoption rates. Three adoption rates, low, medium and high, were developed for each scenario based on expert opinion. Low adoption rates are slightly above baseline levels. Medium adoption is reasonably achievable with some promotion of management practices. High adoption rates represent achievable adoption under aggressive promotion of management strategies.

In the following section, scenario results are presented for medium adoption rates only. Results are reported as a percentage change from the 2008 BAU baseline. Changes of less than 0.5% are not presented in the following summary of results. A complete set of model outcomes are contained in Appendix C.

4.1 Comparison to Provincial Measures

Provincial measures and targets, identified by individual provinces during federal/provincial consultations prior to this analysis were grouped according to broader goals identified in the APF framework including: 1) environmental risk assessment and planning goals, 2) nutrient management, 3) pest management, 4) land and water management and 5) nuisance management. The provincial measures were matched with the scenario analysis conducted by AAFC, which is described in this report. The choice of AAFC's environmental management scenarios for the current analysis was limited by the ability of the quantitative economic and scientific models to reflect environmental measures or actions. Most of the scenarios modeled specific actions rather than measures for each of the provinces. For example, the models were capable of estimating the impact of reduced summerfallow, increased conservation tillage and sustainable grazing practices under the land and water management goal. However, goals related to the extent of environmental farm plans in the provinces were more difficult to model, therefore no overlap occurs in this area. The Provincial Crosswalk Table (Appendix B) presents areas of overlap between AAFC's environmental targets analysis and provincial measures and targets.

4.2 Scenario Analysis

4.2.1 Nitrogen Matching

The nitrogen matching scenario assumes better management of the use of nitrogen fertilizer applied to crops in all provinces except Nova Scotia and Newfoundland. In eastern Canada better nitrogen matching to crop requirements is achieved through frequent monitoring of soil nitrogen levels by soil testing resulting in a reduction of fertilizer use. In western Canada nitrogen application in the spring is more efficient than fall application for crop growth, hence the total amount of fertilizer required is lower if some of the fall application is shifted to the spring. Input costs are also adjusted in this scenario since less fertilizer is required, but prices are higher in the spring than in the fall. It is assumed that nitrogen in manure stays constant in this scenario. An adoption rate of 100% is assumed within applicable areas.

This scenario is expected to reduce GHG (N_2O) emissions and excess nitrogen (IROWCN and RSN). Results of this simulation suggest a slight shift in the crop mix, particularly in the reduction of the corn area in eastern Canada due to the cost of soil testing. Livestock production remains virtually unaffected. A small efficiency gain occurs for producers due to a reduction in total fertilizer use in the West as the result of application in the spring being more efficient than in the fall. For example, in British Columbia changing from 70% spring and 30% fall application of fertilizer to 100% spring application results in an 11% decrease in the total amount of fertilizer required (Table A.2).

Scenario Impacts

- The change in the SOC indicator is negligible since land use type or tillage type is unchanged.
- GHG model results indicate a small reduction in emissions in all relevant provinces (Figure 1) with an overall national reduction of 1.4% (0.9 megatonnes (Mt) CO_2 equivalent). The majority of the total reduction is achieved in Ontario due to the magnitude of the corn crop, which requires high fertilizer input. The percentage reduction for Prince Edward Island is large due to the high intensity of fertilizer use for potatoes.
- The nitrogen indicators, IROWCN and RSN, show a decrease in excess nitrogen in water and soil across most provinces (Figure 2). The largest percentage changes occur in Ontario, Quebec, New Brunswick and Prince Edward Island. This is likely due to the greater use of nitrogen in eastern provinces and therefore a greater need for nitrogen matching to crop requirements.
- Nitrogen matching does not affect the RWDE and RWE indicators.
- The HA indicator was unaffected by nitrogen matching since there is little movement in land from one category to another.

Figure 1: Percentage Change in GHG Emissions as a Result of Better Nitrogen Matching

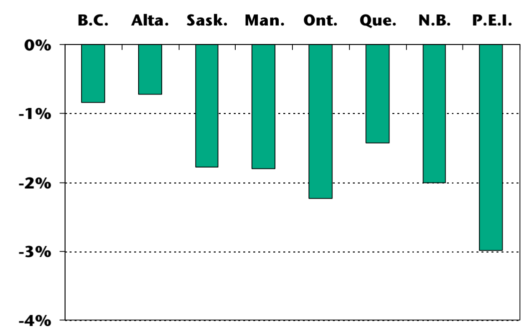
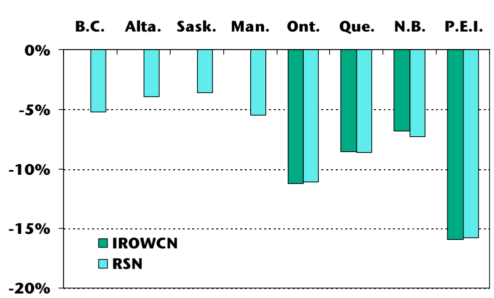


Figure 2: Percentage Change in Nitrogen Indicators as a Result of Better Nitrogen Matching



The nitrogen matching scenario impacts GHG, RSN and IROWCN indicators. GHG emissions are reduced across most provinces with a total national reduction of 0.9 Mt CO_2 equivalent assuming medium adoption. The range of potential reductions is 0.5 Mt CO_2 (0.9%) to 1.1 Mt CO_2 (1.9%) for low and high adoption rates respectively. National reductions in RSN range from 2.3% to 5.6%. For the eastern provinces, reductions in IROWCN vary considerably between low and high adoption rates.

4.2.2 Increase Use of No-till

The increased no-till (zero tillage) scenario is applied to all provinces. Adoption of conservation tillage was assumed to increase to 57% of cropland compared to 32% in the baseline. This represents an increase of 7.1 million hectares over baseline levels with corresponding decreases in minimum and conventional tillage. For provincial adoption rates see the assumptions table in Appendix A. It is expected that increased no-till will result in a reduction in GHG emissions and a decrease in wind and water erosion. A slight change in the crop mix was noted for this scenario, but the livestock impacts were minimal. Recent studies have shown that transition costs of switching to no-till from conventional technology result in lower returns in the first year or two, reaching higher stable levels by year four once the producer has learned how to manage the new production system. However, for many producers, the improved long-run returns are probably not sufficient to provide the incentive needed for change.

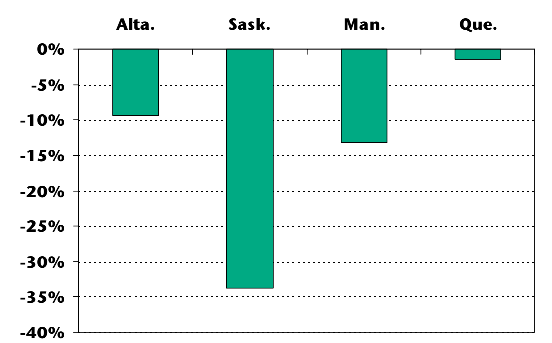
Although this scenario is applicable to all provinces, it should be noted that the current structure of CRAM contains tillage distributions for the Prairie provinces only. Hence, the information that is fed from CRAM to the AEI models is limited for the non-Prairie provinces, and may not be sensitive enough to reflect changes due to improved tillage practices. This was accounted for in the GHG estimates by calculating carbon (C) sequestration for the non-Prairie provinces outside of CEEMA; however, this issue still needs to be addressed for the other indicators.

Scenario Impacts

- Conservation tillage and more specifically, zero tillage enhances soil C sequestration by eliminating soil disturbance and reducing the rate of decomposition of soil organic matter (Janzen et al. 1998). The largest change in SOC occurs in the Prairie provinces. This is due to the relatively high rates of adoption of zero tillage in these areas. Rates of C sequestration in Alberta, Saskatchewan and Manitoba are 0.48 Mt C (1.8 Mt CO_2 equivalent), 0.96 Mt C (3.5 Mt CO_2 equivalent) and 0.33 Mt C (1.2 Mt CO_2 equivalent) respectively.

- The C sequestration in the Prairie provinces is offset slightly by significant increases in N_2O emissions due to increased fertilizer use. The result is a net reduction in GHG that is slightly less than the SOC sink. Figure 3 shows which provinces are impacted and the relative magnitude of change in GHG emissions. The aggregate reduction is 11% (6.5 Mt CO_2 equivalent) of national emissions. Over 50% (3.4 Mt CO_2 equivalent) of this reduction occurs in Saskatchewan due to the large area of land appropriate for conservation tillage.

Figure 3: Percentage Change in GHG Emissions as a Result of Increased Conservation Tillage

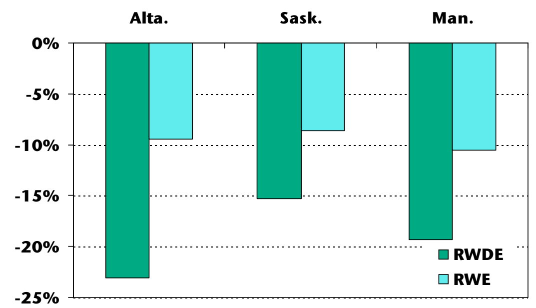


- Increased zero tillage has no impact on IROWCN and minimal impact on RSN (less than 1% increase in several provinces). It should be noted that IROWCN and RSN models do not distinguish between the three methods of tillage. This is likely to result in overstated nitrogen levels for zero tillage. Future work will involve the incorporation of tillage practices into these models.

- In the Prairie provinces, there is an approximate 10% reduction in the RWE indicator and even greater improvements in the RWDE indicator (Figure 4).
- The HA indicator is unaffected by zero tillage since land does not shift from one category to another.

An increase in zero tillage impacts SOC, GHG, RWDE and RWE, particularly in the Prairies. The impact on national GHG emissions may range from 4% (2.5 Mt CO_2 equivalent) to 17% (10.3 Mt CO_2 equivalent) reduction. Sensitivity analysis suggests the impact on RWE and RWDE indicators may vary considerably depending on the assumed adoption rate.

Figure 4: Percentage Change in RWE and RWDE Indicators as a Result of Increased Conservation Tillage



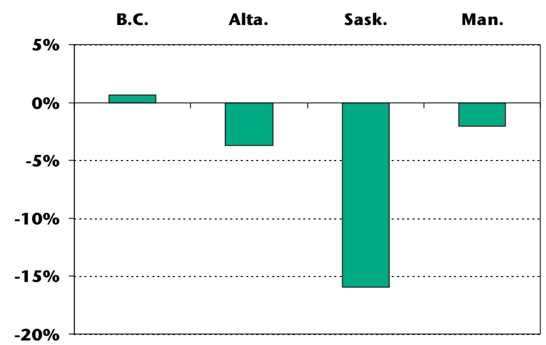
4.2.3 Reduce Summerfallow

Summerfallow is traditionally used in cropping rotations as a method of replenishing moisture in the soil in the Prairie regions. The summerfallow scenario, applied to western Canada only, assumes reduction in the frequency of summerfallow within a cropping rotation. Adoption rates vary by soil zone (see Appendix A). A medium adoption rate is assumed to translate into a 1.5 million hectare reduction in summerfallow relative to baseline levels. A reduction in summerfallow is expected to cause a decrease in GHG emissions, RWE and RWDE and increase HA. Lands converted from summerfallow to cropping leads to increased fertilizer use, which will have an offsetting effect on net GHG emissions. Net revenues for crop producers in this scenario were affected by differences in the costs and yields associated with planting on stubble as opposed to fallow land, and an increase in the land base used for crops. In general, the reduced yields tended to decrease crop net margins. Increased crop production due to the elimination of summerfallow also results in minor crop price reductions, which in turn promotes slight increases in livestock production and revenues due to lower feeding costs.

Scenario Impacts

- Scientific studies indicate that the use of summerfallow, particularly tillage fallow, causes a loss of CO_2 from the soil. A reduction in summerfallow frequency reverses the organic C loss and results in C sequestration. Model results show an increase in SOC of 0.27 Mt C (1.0 Mt CO_2 equivalent) in Alberta, 0.62 Mt C (2.3 Mt CO_2 equivalent) in Saskatchewan and 0.09 Mt C (0.34 Mt CO_2 equivalent) in Manitoba.
- The results indicate that the gains in SOC were partially offset by increased GHG emissions from fertilizer use, livestock production and on-farm fuel use. The net change is a decrease in emissions across all relevant provinces (Figure 5) except British Columbia, where the low rate of C sequestration associated with reduced summerfallow relative to the Prairie provinces is not sufficient to offset increased emissions from fertilizer and livestock. The aggregate level of reduction is 4.1% (2.5 Mt CO_2 equivalent) of national emissions. Approximately 66% (1.6 Mt CO_2 equivalent) of the total reduction is achieved in Saskatchewan.

Figure 5: Percentage Change in GHG Emissions as a Result of Reduced Summerfallow



- Changes in RSN are small – approximately 1% or less (Figure 6).
- A decrease in summerfallow use results in an 11% reduction in the RWDE indicator for Alberta and Saskatchewan and has a lesser impact in Manitoba (Figure 7). Improvements in the RWE (2 to 5%) occur in all western provinces.
- Relative to other agricultural land uses, summerfallow provides the lowest level of wildlife support. The HA indicator suggests that a decrease in summerfallow, and thus an increase in other agricultural land use types, improves biodiversity in western Canada (Figure 8).

Figure 6: Percentage Change in RSN Indicator as a Result of Reduced Summerfallow

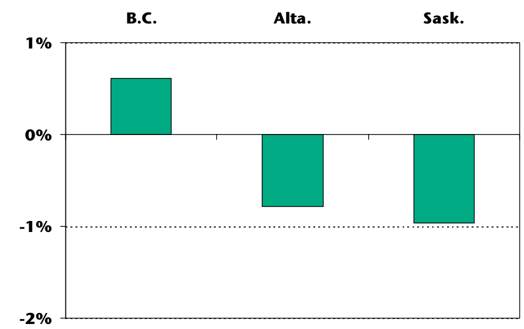


Figure 7: Percentage Change in RWE and RWDE Indicators as a Result of Reduced Summerfallow

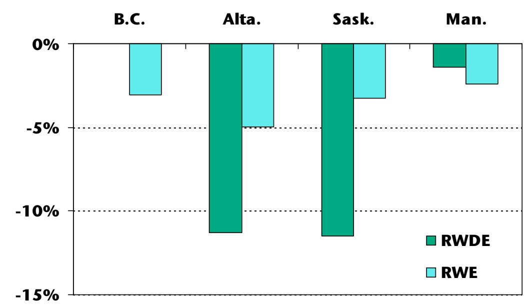
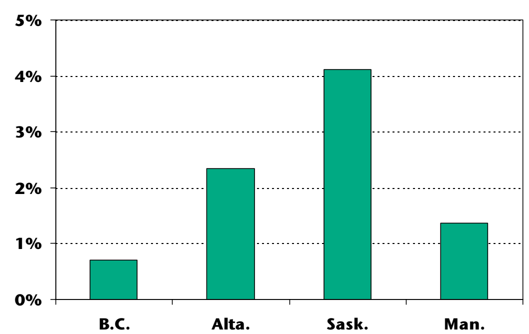


Figure 8: Percentage Change in HA Indicator as a Result of Reduced Summerfallow



Model results indicate that a reduction in summerfallow use will have a positive impact on the environment in western Canada. The AEIs impacted by this scenario are SOC, GHG, RWDE and RWE. The reduction in national level GHG emissions ranges from 2% (1.0 Mt CO_2) to 7% (4.0 Mt CO_2). Sensitivity analysis shows adoption rates have little effect on the RWE indicator. The impact on RWDE varies from 5% to 17% for Alberta and 5% to 18% for Saskatchewan, little change occurs in Manitoba.

4.2.4 Permanent Cover

Assumptions for this scenario were adapted from the existing Permanent Cover Programs. This scenario involves a shift of an additional 600,000 hectares of marginal cropland to permanent cover with perennial crops. Most of the marginal land is converted to improved pasture, with the remainder converted to hayland. Distribution of land converted to improved pasture or hayland varies by region, soil type, actual cultivated marginal lands and the distribution of grazing/hay to support beef animals. The scenario assumes a 2% increase in beef cattle numbers as an outlet for the increased forage production. Based on discussions with provincial experts from Ontario, beef cows are held at a constant level in Ontario in this scenario. Adoption rates for the increased permanent cover scenario are presented in Appendix A. Increased permanent cover is expected to improve biodiversity and reduce soil erosion and GHG emissions. Short-term costs associated with removing land from crop production and seeding it to permanent cover would likely be more than offset by the long term gains of increased beef production (after accounting for the startup costs of increased cattle operations).

Scenario Impacts.

- Permanent cover crops provide C sequestration potential; however, the model results indicate that the amount of C sequestration is relatively small across most provinces.
- The expected impact on GHG is ambiguous since an increase in cattle will likely accompany the increase in permanent cover crops. Permanent cover crops provide C sequestration potential while cattle generate emissions. The simulation indicates that although CH_4 and N_2O emissions increase due to the expanded cattle herd, the C sink is large enough to offset the increase. The result is a net decrease in GHG emissions across all provinces; however, for some the impact is negligible (Figure 9). Across Canada the reduction in GHG emissions is 1% (0.6 Mt CO_2 equivalent).
- Permanent cover results in a minimal impact on IROWCN and RSN indicators for most provinces. Small decreases in RSN occur across all provinces except Nova Scotia. Similar impacts in IROWCN occur in applicable provinces (Figure 10).
- The impact of this scenario on wind and water erosion is small, except in British Columbia where the risk of water erosion is reduced by approximately 5% (Figure 11). These results may be explained by the high concentration of hayland versus cropland in the British Columbia BAU case. Therefore, shifting small amounts of cropland into forage results in a relatively large percentage decrease in cropland, which is more susceptible to erosion than hayland.
- The shift in land types from relatively low to high HA (i.e. less summerfallow and more tame pasture) results in an increase in the AEIs across all provinces, except Newfoundland and Nova Scotia (Figure 12).

The Permanent Cover scenario is applicable to all provinces. In most cases, the indicators are moving in the desired direction; however, the impact is small. Sensitivity analysis indicates that adoption rates have little affect on AEIs.

4.2.5 Forage in Crop Rotations

This scenario assumes an increase in the land in forage production in all regions. It is expected that the rapid expansion of the livestock industry would create a market for the additional forage. To reflect the benefits

Figure 9: Percentage Change in GHG Emissions as a Result of Increased Permanent Cover

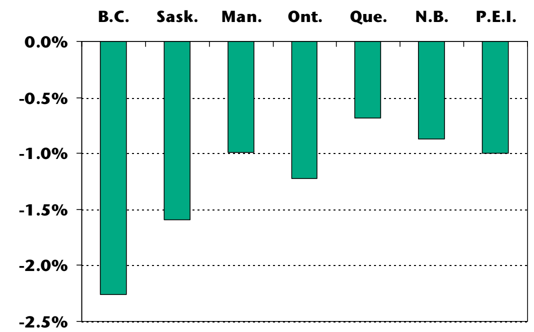


Figure 10: Percentage Change in IROWCN and RSN as a Result of Increased Permanent Cover

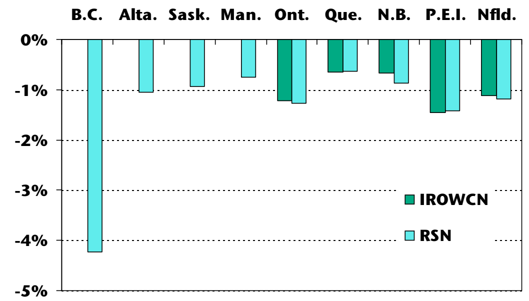


Figure 11: Percentage Change in RWDE and RWE Indicators as a Result of Increased Permanent Cover

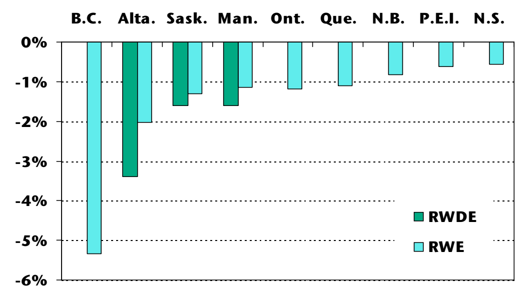
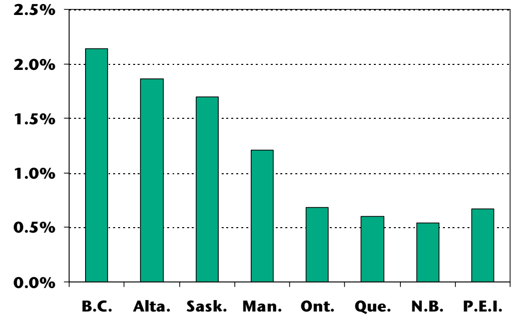


Figure 12: Percentage Change in HA Indicator as a Result of Increased Permanent Cover



of forage in crop rotations, grain and oilseed yields were increased based on the amount of forageproduction in each crop district. (Grain and oilseed yields were assumed to increase more in areas with small forage levels where the benefits of forage in rotations would not yet have been achieved). Similar assumptions were used to estimate the effect of increased forage production on N fertilizer use for grain and oilseed production (see Appendix A). The scenario assumes conversion of 2% of cropland into forage production, with a corresponding 12% increase in the beef herd. The changes in direction of GHG emissions, IROWCN and RSN are ambiguous due to the increased cattle production, whereas the RWDE, RWE, and HA indicators are expected to improve.

Scenario Impacts

- An increase in forage use in crop rotations increases soil C sequestration across most provinces. The greatest impact occurs in the western provinces; however, the amount of C sequestered is more than offset by the increase in GHG emissions from the increase in livestock.
- The increased forage in crop rotations enhances C sequestration and reduces the amount of nitrogen fertilizer required for grain and oilseed production. However, while legume forages reduce fertilizer requirements, they also produce N_2O emissions. The results show an increase in GHG emissions in Alberta and Saskatchewan and slight decreases in some other provinces (Figure 13). The increases in emissions in Alberta and Saskatchewan are due to the rise in livestock numbers, which more than offset the GHG reductions from forage crops. Cattle increases also occur in Manitoba, but the high C sequestration rates in the black soil zone offsets these emissions.
- The RSN indictor decreases in the western provinces, and both RSN and IROWCN indicators decline in three of the four Atlantic Provinces (Figure 14).
- Model results show a small decrease in the RWDE indicator for the applicable provinces and a slight decrease in RWE indicator for the western provinces, Ontario and Quebec (Figure 15).
- Increased use of forage in crop rotations results in a higher HA for most provinces. This is due to the shift in land from summerfallow and cropland to hayland, which provides greater support for wildlife habitat (Figure 16).

Figure 13: Percentage Change in GHG Emissions as a Result of Increased Forage in Crop Rotations

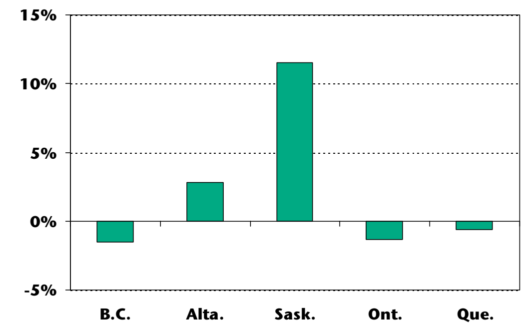


Figure 14: Percentage Change in IROWCN and RSN as a Result of Increased Forage in Crop Rotations

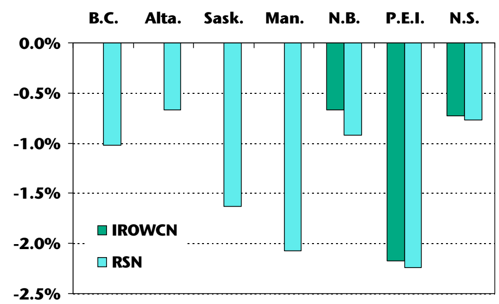


Figure 15: Percentage Change in RWDE and RWE Indicators as a Result of Increased Forage in Crop Rotations

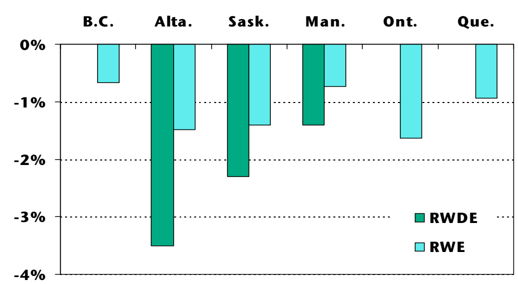
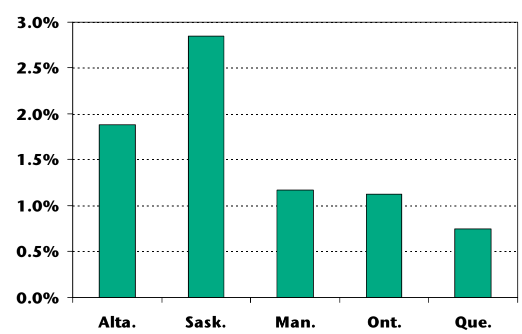


Figure 16: Percentage Change in the HA Indicator as a Result of Increased Forage in Crop Rotations



Increased use of forage in crop rotations has an impact on all AEIs. The impact on GHG is negligible for most provinces. However, in Alberta and Saskatchewan an increase in livestock numbers results in a relatively large increase in GHG emissions. The impact on the RSN and IROWCN indicators is minimal. Likewise, the increase in forage use in crop rotations results in a small improvement in the RWDE, RWE and HA indicators. Sensitivity analysis indicates that the AEI indicators are not greatly affected by varying adoption rates for this management scenario.

4.2.6 Terracing

The terracing scenario is applied to lands in potato rotations in Prince Edward Island and New Brunswick. In the 2000 Agri-Environmental Indicators report both Prince Edward Island and New Brunswick were identified as having areas with unsustainable levels of erosion. This scenario evaluates one strategy for resolving that problem. Terracing results in reduced water and nitrogen run-off as well as a reduction in soil erosion. The benefits of terracing promote more sustainable long-term production. Assumed adoption rates for Prince Edward Island and New Brunswick are 26% and 33% respectively. The expected impact of terracing is a reduction in IROWCN and soil erosion. The impact on RSN is not clear since the reduction in fertilizer applied combined with an increase in crop uptake will likely be offset by less nitrogen lost due to erosion.

Scenario Impacts

- Terracing is not expected to affect the level of SOC.
- Under terracing management, nitrogen application can be reduced by approximately 10% due to less nitrogen run-off. The impact on the GHG indicator is minimal since the decrease applies to a relatively small area of land.
- Up-down slope cultivation has been estimated to cause a 10% reduction in potato yields over a 33 year period (Cao et al., 1994). The use of terracing is expected to improve soil quality (maintaining long-term yields) by decreasing soil erosion by water. However, the impact could not be measured with the existing data structure for the RWE indicator.
- It is expected that terracing will improve water quality through less nitrogen run-off. The impact could not be measured with the IROWCN indicator due to the model structure. Based on unpublished data from Rees (2002), total nitrogen loss can be reduced from 37 kg/ha (15%) on up-down slope cultivation to 2 kg/ha (1%) under terracing.
- Terracing is expected to have no direct impact on the HA indicator.

The terracing scenario is applicable for lands in potato rotations in Prince Edward Island and New Brunswick. The impact of terracing could not be evaluated quantitatively using the models in this analysis due to the structure of the models. Further work may involve adjustment of these models for future measurement of the impacts of terracing on the AEIs.

4.2.7 Grazing Management - Rotational and Complementary Grazing

Rotational and complementary grazing systems decrease grazing intensity on native pastureland by supplementing tame pasture land. This results in an increase in forage quality on native pastureland and a decrease in feed requirements due to higher calf weaning weights. Rotational grazing is applied to moist tame pasture areas in western Canada and tame and native pasture lands in eastern Canada. Complementary grazing is applied to British Columbia, western Manitoba, northern Saskatchewan and northern and western Alberta. Assumed adoption rates for rotational and complementary grazing are 10% above BAU levels (see Appendix A). Grazing management strategies are expected to lead to a reduction in IROWCN and RSN and a decrease in GHG emissions.

Scenario Impacts

- Model results show a slight increase in SOC across most provinces as a result of an improved grazing management scenario.
- The impact of this scenario on GHG emissions is minimal - small decreases occur in western Canada, Ontario, New Brunswick, Nova Scotia and Newfoundland (Figure 17).
- The impact of this scenario on the nitrogen indicators is minimal – the RSN indicator decreases by 4% in British Columbia and less than 1% in Alberta and New Brunswick (Figure 18). The IROWCN indicator is unchanged for all relevant provinces except for a small change in New Brunswick.
- The RWDE indicator declines slightly in western provinces (Figure 19). The impact in other provinces is negligible. The impact on RWE is greater in British Columbia due to a relatively large shift in crop and summerfallow area to tame pasture.
- For the majority of provinces, grazing management strategies have a small impact on the HA indicator (less than 1%). The largest change is a 2% increase in British Columbia.

The grazing management scenario is applied to relevant areas across all provinces. The largest impact on AEIs occurs in British Columbia. Similar to the permanent cover scenario, the high proportion of hayland to cropland mix may explain this result.

Figure 17: Percentage Change in GHG Emissions as a Result of Grazing Management Strategies

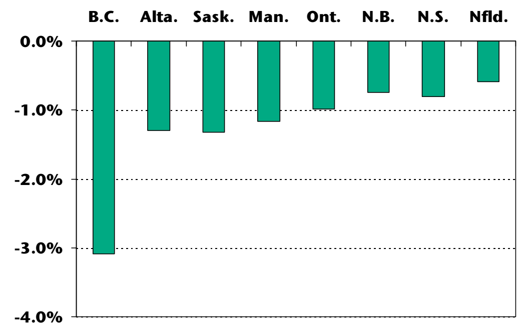


Figure 18: Percentage Change in IROWCN and RSN as a Result of Grazing Management Strategies

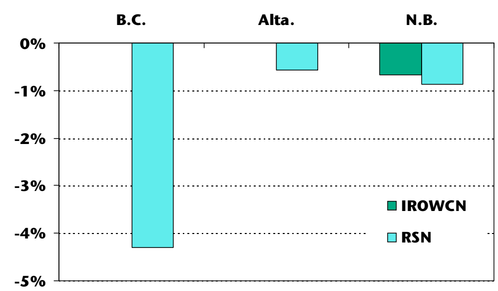
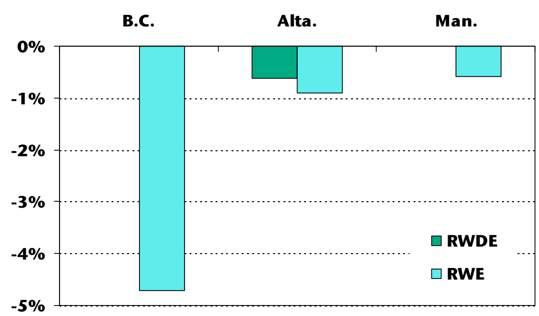


Figure 19: Percentage Change in RWE and RWDE Indicators as a Result of Grazing Management Strategies



4.2.8 Combined Feeding Strategies

In this scenario, a number of feeding strategies are combined to reduce N_20 emissions (and CH_4 to a lesser extent) for manure from pigs, poultry and dairy cows. The simplest way to achieve a nitrogen reduction is to decrease dietary nitrogen (protein) intake. The following strategies apply to all regions of Canada (see Table A.10):

- A 15% decrease in the protein content of feed for hogs with the addition of free amino acids to balance protein results in a 15% increase in the cost per unit of feed.
- The addition of phytase to hog diets improves feeding efficiency by 5% to 10% resulting in a net 5% reduction in the cost per unit of feed.
- A 15% reduction of protein intake for poultry results in a 10% increase in the cost per unit of feed.

- Better matching of protein requirements for dairy cows results in a 10% reduction of nitrogen in the diet and a net cost decrease due to the costs for feed testing being offset by reductions in the use of protein supplements.
- Reducing protein in dairy diets and adding ruminally protected amino acids leads to a 20% reduction of nitrogen in the diet with an added cost for the amino acids.

There is little change in the crop mix for this scenario; however, a small decrease occurs in hog marketings due to slightly higher feed costs leading to a decrease in producer net margins.

Scenario Impacts

- This scenario does not impact the SOC indicator.
- GHG results indicate a national reduction of 1% (0.8 Mt CO_2 equivalent). Ontario and Quebec account for approximately 56% of the total reduction (Figure 20).
- The reduction in the RSN indicator occurs in most provinces (Figure 21). A larger impact is present in the eastern provinces than the western provinces. This may be explained by reduced hog production due to higher feed costs and reduced nitrogen excretion for livestock. A decrease in IROWCN occurs in the eastern provinces, with the greatest percentage change occurring in New Brunswick and Nova Scotia.
- RWDE and RWE models are not applicable for this scenario.
- The combined feeding scenario does not impact the HA indicator.

The combined feeding scenario is applicable to all provinces. The impact of this scenario is limited to the GHG, IROWCN and RSN indicators. Reductions in the GHG and nitrogen indicators are greatest in the eastern provinces.

Figure 20: Percentage Change in GHG Emissions as a Result of Combined Feeding Strategies

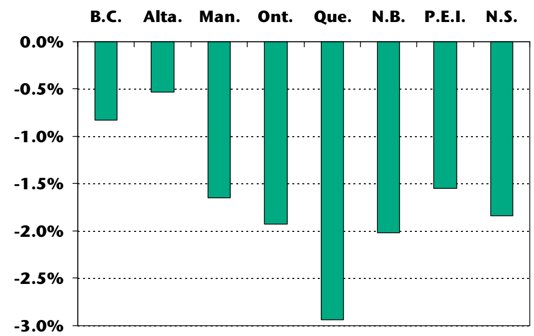
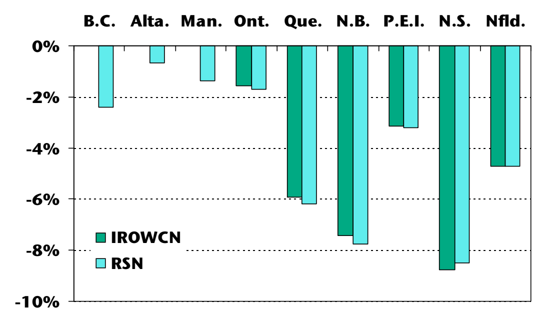


Figure 21: Percentage Change in IROWCN and RSN as a Result of Combined Feeding



4.2.9 Afforestation

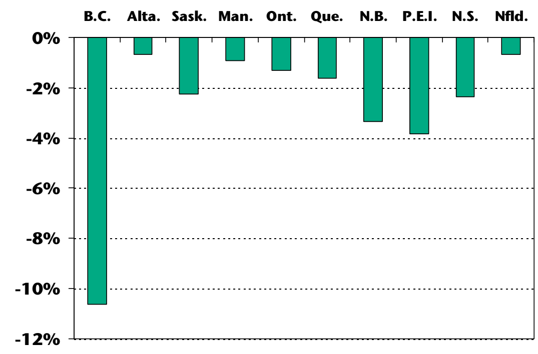
The afforestation scenario assumes an increase in forest plantations on marginal agricultural lands across all provinces. Marginal land may include land unsuitable for agriculture, land too costly to farm, land that is more valuable in a forestry-related use than an agricultural use and/or land that is too environmentally sensitive for intensive agriculture. It is assumed that, if presented with a viable alternative such as forestry, the landowner will make the decision as to which lands are economically suitable for afforestation. An adoption rate of 50,000 hectares is assumed for all of Canada. The provincial share of the 50,000 hectares is given in Appendix A. Afforestation is expected to reduce GHG emissions through C sequestration and improve biodiversity. (Note: other afforestation activities for future analysis might include riparian buffers, windbreaks, shelterbelts, wildlife corridors, biodiversity enhancements plantings, silvopastoral systems and alley cropping.)

Scenario Impacts

- The SOC indicator increases slightly in all provinces. Relatively large increases in British Columbia are caused by the higher proportion of land transferred from traditional agricultural activities to afforestation based on consultations with the Canadian Forest Service.

- Model results show a reduction in GHG emissions across all provinces (Figure 22). The largest reduction occurs in British Columbia for reasons mentioned above. Total national reduction from the afforestation scenario is approximately 1.7% (1.0 Mt CO_2 equivalent).

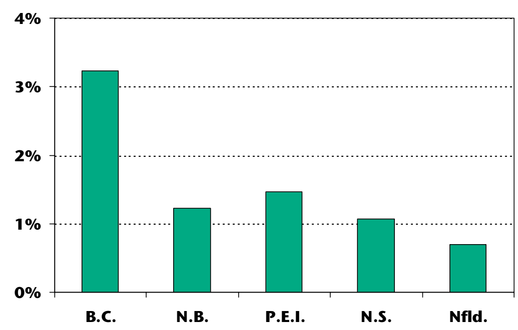
Figure 22: Percentage Change in GHG Emissions as a Result of Afforestation Plantations



- The impact of the afforestation scenario on IROWCN and RSN indicators is limited. Both indicators decrease by approximately 1% in Prince Edward Island and RSN is reduced by approximately 2% in British Columbia.

- This scenario has a negligible impact on water erosion and no impact on wind erosion. The impact on water erosion could not be fully estimated due to the structure of the model not being able to capture forest cover values. While the impacts might be negligible due to the limited areas involved, local conversion of marginal areas to forest plantations may have some significant environmental benefits. Similar to the permanent cover scenario, the afforestation scenario may be dealing with some of the most degradation-prone soils/landscapes.

Figure 23: Percentage Change in HA Indicator as a Result of Afforestation Plantations



- Mixed forests have a higher habitat use associated with them than do agricultural land types (except native pasture), therefore conversion of marginal farmland to forest plantations is expected to have a positive impact on biodiversity. Results show an increase in the HA index for British Columbia and the Atlantic provinces while all other provinces remain relatively unchanged (Figure 23) due to the small proportion of land involved.

The afforestation scenario is applied to all provinces. It has a moderate impact on GHG and a lesser impact on HA, IROWCN and RSN indicators. Sensitivity analysis shows that conversion of between 20,000 and 100,000 hectares of marginal land to forest plantations has the potential to reduce national GHG emissions by 0.7% (0.4 Mt CO_2 equivalent) to 3.4% (2.0 Mt CO_2 equivalent).

SECTION 5

COMBINED SCENARIO RESULTS

5.1 Combined Scenario

The results presented in the previous section were an estimation of the impacts of individual scenarios on the AEIs. To gain a clearer understanding of the overall impact of the suite of management scenarios, a combined scenario analysis was conducted. In the combined scenario, the CRAM optimization model is solved simultaneously for all scenarios, accounting for possible interaction among scenarios. A comparison of the individual and combined scenario results suggests that the impacts on the AEIs are essentially additive across scenarios. This section provides a summary of the combined analysis by indicator followed by a national summary of the combined scenario impacts. Table 3 summarizes the management scenarios included in the combined analysis and the provinces where these scenarios are applicable. Provincial summaries are presented in Appendix D.

Table 3: Summary of Relevant Management Scenarios by Province

	Nitrogen Matching	Zero Tillage	Summer-fallow	Permanent Cover	Forage Use in Crop Rotation	*Terrac-ing	Grazing Manage-ment	Feeding Strate-gies	Agro-for-estry
B.C.	✔	✔	✔	✔	✔		✔	✔	✔
Alta.	✔	✔	✔	✔	✔		✔	✔	✔
Sask.	✔	✔	✔	✔	✔		✔	✔	✔
Man.	✔	✔	✔	✔	✔		✔	✔	✔
Ont.	✔	✔		✔	✔		✔	✔	✔
Que.	✔	✔		✔	✔		✔	✔	✔
N.S.		✔		✔	✔		✔	✔	✔
P.E.I.	✔	✔		✔	✔	✔	✔	✔	✔
N.B.	✔	✔		✔	✔	✔	✔	✔	✔
Nfld.		✔		✔	✔		✔	✔	✔

**Due to the structure of the models, the terracing scenario could not be analyzed using the current models. Therefore, impacts of terracing are not incorporated into the combined scenario results.*

5.2 Results

5.2.1 Soil Organic Carbon

The combined suite of environmental management scenarios results in an increase in the SOC indicator for all provinces (Table 4). Percentage changes are not reported due to sign changes from negative (SOC source) to positive (SOC sink) coefficients and vice versa. Management scenarios that contribute most to the improvement in SOC are conservation tillage, reduced summerfallow, forages in crop rotations, afforestation and to a lesser extent, grazing and permanent cover. Relatively large sinks in the Prairie provinces are due to the effect of conservation tillage and reduced summerfallow scenarios. It should be noted that C sequestration estimates for grazing management and afforestation, as well as for non-Prairie provinces under the zero-till scenario, were calculated external to CEEMA since the current version of the model does not handle these specifications.

The national change in SOC is an increase of 3.8 Mt C (14 Mt CO_2 equivalent). The impact ranges from 1.7 Mt C (6.2 Mt CO_2 equivalent) to 6.4 Mt C (23.4 CO_2 equivalent) for low and high adoption rates respectively.

Table 4: Change in SOC and Net Change in GHG for the Combined Scenario

	SOC		Net GHG Reduction (including SOC sink)
Province	**'000 tonnes Carbon**	**Mt CO_2 equiv.**	**Mt CO_2 equiv.**
B.C.	114	0.42	0.44
Alta.	965	3.53	2.93
Sask.	1966	7.20	5.10
Man.	562	2.06	1.97
Ont.	109	0.40	0.89
Que.	97	0.36	0.72
N.B.	7	0.03	0.04
P.E.I.	8	0.03	0.05
N.S.	6	0.02	0.03
Nfld.	1	0.004	0.004

5.2.2 GHG Emissions

Model results for the combined scenario show a reduction in the GHG indicator for all provinces (Figure 24). Absolute and relative reductions in GHG emissions are greater in western Canada than in eastern Canada. This can be explained by scenarios such as zero tillage and summerfallow, which have relatively large impacts on GHG emissions (via C sequestration) in the Prairies and British Columbia due to high adoption rates and large areas of cropland.

The total national GHG emissions reduction is 20% (12 Mt CO_2 equivalent). The range of GHG reduction is between 9% (5 Mt CO_2 equivalent) and 33% (20 Mt CO_2 equivalent), depending on the assumed adoption rate. Saskatchewan alone accounts for 42% (5.1 Mt CO_2 equivalent) of the national reduction.

Alberta and Manitoba account for another 40% (4.9 Mt CO_2 equivalent). The individual scenario analysis in the previous section, revealed that increased zero tillage, reduced summerfallow and better nitrogen matching contribute the most to the reduction of GHG indicators.

5.2.3 Risk of Water Contamination by Nitrogen and RSN

The suite of environmental management scenarios results in a decrease in IROWCN in the eastern provinces (IROWCN is not applicable for western provinces) and a decrease in the RSN indicator in all provinces (Figure 25). The average change in IROWCN for the eastern provinces is approximately 12% and the national change in RSN is 11%. Sensitivity analysis for RSN indicates a national range of impact between 6% and 15%. Nitrogen matching and combined feeding are the main scenarios driving these changes. These scenarios are targeted specifically at reducing nitrogen use for crops and livestock.

5.2.4 Risk of Wind and Water Erosion

The RWDE indicator is applicable only in the Prairie provinces where the land is relatively flat and there are few trees or obstructions to act as wind barriers. Results indicate that the suite of management scenarios reduce wind erosion in all three Prairie provinces, with the greatest change in Alberta (Figure 26). The main scenarios impacting the RWDE are conservation tillage, reduced summerfallow and increased permanent cover. The range of impact varies considerably depending on adoption rates - a range of 18% to 58% in Alberta, 14% to 44% in Saskatchewan and 11% to 47% in Manitoba.

The RWE indicator is relevant in all provinces except Newfoundland. The impact on the indicator is larger in the western provinces (15% to 19%) than eastern provinces (0.5% to 3%) (Figure 26). This is likely explained by the additional impact in western provinces resulting from the conservation tillage, reduced summerfallow and grazing management scenarios. Other scenarios that impact the RWE in most provinces are permanent cover and increased forage in crop rotation.

Figure 24: Percentage Change in GHG Emissions for the Combined Scenario

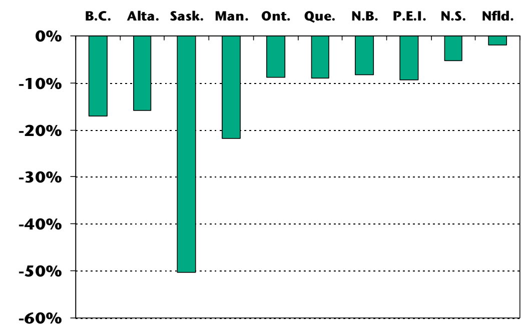


Figure 25: Percentage Change in IROWCN and RSN Indicators for the Combined Scenario

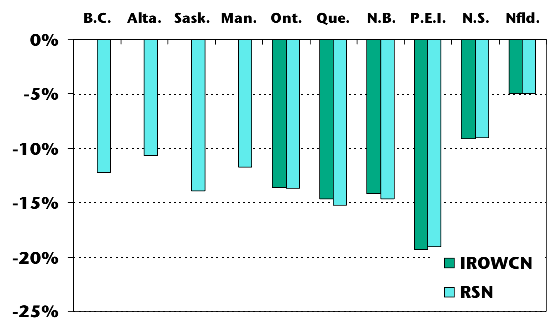
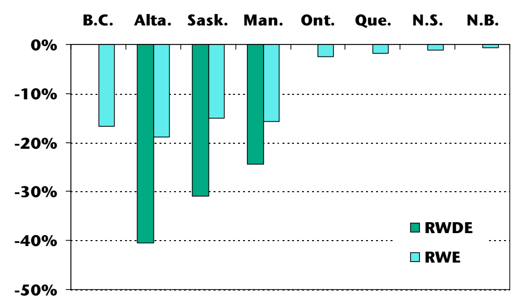


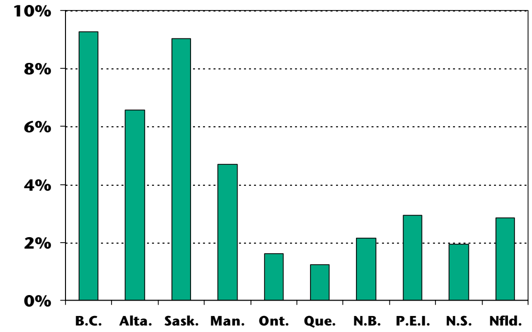
Figure 26: Percentage Change in RWDE and RWE Indicators for the Combined Scenario



5.2.5 Habitat Availability

The HA indicator is applicable for all provinces. The combined scenario results show a positive impact on biodiversity across all provinces (Figure 27) with an overall national increase in the biodiversity index of 6%. Results from the low and high scenarios show an increase range of 3% to 10%. Similar to the GHG and RWE indicators, a larger impact occurs in the West than the East, which is due to a greater shift in land use types (i.e. shifts from cropland and summerfallow to hay and pasture). This is most prominent in the reduced summerfallow, increased permanent cover and increased forage scenarios.

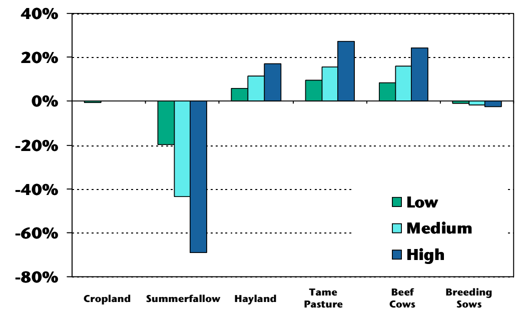
Figure 27: Percentage Change in HA Indicator for the Combined Scenario



5.3 National Summary

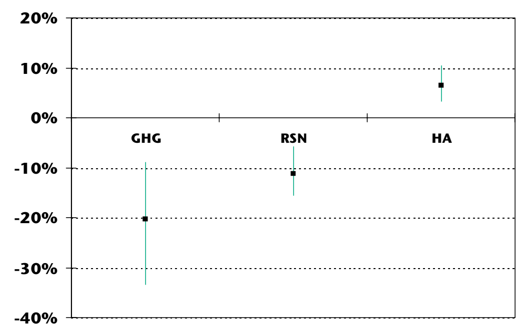
The overall result of the combined suite of environmental management scenarios is a movement of the AEIs in the desired direction at both provincial and national levels. These results are driven by the change in land use and livestock levels, which are determined by the economic optimization model (CRAM). A national summary of land use and livestock changes from the baseline is presented in Figure 28. The figure shows a shift in land use from summerfallow to hayland and tame pasture. The increase in hayland and tame pasture is accompanied by an increase in beef cows.

Figure 28: National Summary of the Percentage Change in Land Use Types and Livestock from 2008 BAU for Low, Medium and High Adoption Rates



The national changes in land use and livestock numbers, as a result of the combined management scenario, are translated into changes in AEIs as represented in Figure 29. The vertical line associated with each indicator represents the range of impact for low and high adoption rates. The black square marker represents results under medium adoption rates.

Figure 29: National Summary of the Percentage Change in AEIs from 2008 BAU for Low, Medium and High Adoption



Indicators for RWDE, RWE and IROWCN are not included in Figure 29 since national totals are not applicable. For the RWDE and RWE indicators, national summaries are not meaningful or relevant. The IROWCN cannot be summed nationally since it is currently applicable for eastern provinces only. The average impact on the RWDE indicator for the Prairie provinces ranges from a 11% to 58% reduction for low and high adoption rates respectively. Average changes in the IROWCN indicator range from a 3% to 22% decrease for low and high adoption rates respectively. The RWE indicator varies substantially across provinces, with the greatest impacts in the west.

It should be understood that the environmental management scenarios are designed to be a package, therefore, these results should not be used to manipulate certain indicators in isolation of others. For example, a scenario may produce a large reduction in GHG emissions, but may have negligible or undesirable impacts on water quality. Likewise, some scenarios may have a desirable impact on water quality, but fail to impact air quality. The suite of environmental management scenarios are intended to work together to produce an overall increase in air, soil and water quality and biodiversity.

Section 6

Summary and Limitations

The results of this analysis reveal that the environmental management scenarios are estimated to have a desirable impact on the AEIs. Air quality is improved through the reduction of GHG emissions by 20% (12 Mt CO_2 equivalent) from baseline levels. An improvement in soil quality is represented by the reduction in RSN, RWDE and RWE indicators. RSN decreases by 11% and the reductions in IROWCN, RWDE and RWE vary according to province. Biodiversity, in terms of wildlife habitat availability, increases by 6% across Canada. Results were also generated for three levels of adoption rates to give an indication of the sensitivity of the AEIs to varying degrees of scenario implementation.

As part of the APF Agreement, ministers must aim to "achieve measurable and meaningful environmental goals in the areas of water, air and soil quality." This analysis demonstrates how we can predict the quantitative impacts of agricultural practices on the environment and is therefore useful for two main reasons. First, it quantifies the impact of various management practices on water, air and soil quality and biodiversity through measurable and meaningful indicators. Second, it assists in identifying appropriate environmental goals by providing an indication of achievable outcomes as a result of environmental management practices.

It is important to note that the environmental management scenarios chosen for this analysis are not necessarily the scenarios that should or will be chosen to meet the APF goals. The intention of this analysis is to demonstrate the type and level of information that can be generated to assist in the process of developing environmental targets. These results should not be translated into stated outcomes.

There are several limitations of this analysis that policy-makers must be aware of when using this information to assist in policy decisions.

First, the GHG indicator is relatively sensitive to the environmental management scenarios since a significant amount of resources have been invested into developing this model for predictive capacity. The other AEIs are grosser in scale and lack the detail that is required for more meaningful measurement and prediction of environmental impacts. Future work will involve further development of agri-environmental indicators to enable a more accurate analysis of the environmental impacts of various management practices.

Second, IROWCN is an annual budget model containing a number of assumptions and generalisations. It is currently used as an "indicator"and provides some broad-level regional comparisons. A number of limitations and areas for improvement have been identified:

- Available weather data lacks the critical evapotranspiration and water holding capacity values for a number of soil landscape polygons. Nitrogen application rates are based on recommended rates adjusted by provincial sales figures and manure application rates are based on the total number of livestock within a polygon and assumed uniform distribution. Since these parameters have a great deal of influence on IROWCN and RSN output values, they should be checked, expanded and improved from the literature, scientific expertise or measured data.

- Currently, IROWCN is calculated for the eastern provinces only, however work is underway to extend the indicator for use in the western provinces.
- The current model does not include practices such as no-till or terracing. Since conservation practices are a fundamental component of scenario generation, this aspect should be incorporated.
- Legume fixation and soil-atmosphere-nitrogen interactions (volatilization, denitrification, mineralization) have a significant influence on the amount of RSN thus on the risk of water contamination. These processes are handled in a rather cursory manner in IROWCN and the coefficients need to be evaluated and improved where new research results apply.

Third, using the current economic model (CRAM) and environmental indicators, it is difficult or sometimes impossible to account for spatial differences that might occur. CRAM is a regional economic model disaggregated by provinces with the exception of the crop component for the Prairies which consists of 22 regions. By contrast, most of the AEIs are based on Soil Landscape of Canada (SLC) polygons that are much smaller than the CRAM regions. Better analytical tools are needed to more realistically apply the production changes generated by CRAM to the SLC (or lower) level for improved estimation of the impacts on AEIs. A Land Use Allocation Model (LUAM) is being developed to help address this issue. Enhancements to the structure of CRAM are required such as division of Ontario, Quebec and British Columbia into multiple regions. An example of other required changes to the model includes extension of the split of zero tillage, moderate tillage and conventional tillage practices to non-Prairie provinces.

Fourth, the choice of scenarios for analysis was limited by the availability of existing models for measurement, which resulted in the exclusion of several important management options. Manure management and riparian zones are two such examples identified by AAFC experts and scientists as important to agriculture in terms of environmental impacts. In future work, it will be necessary to develop indicators for other key management areas.

Finally, explicit cost estimates for the various scenarios are not provided in this report although some estimates of producer surplus were generated by CRAM for this analysis. However, it is recognized that there are problems with the results, which require further investigation. The costs are significantly overestimated for some scenarios involving imposed changes to the land base since the model reflects short-run costs based on upward sloping marginal cost curves. Hence, as the solution moves away from an optimal land use allocation (i.e. the 2008 baseline), costs increase and producer surplus decreases. The model did not account for longer-term adjustments within the sector, which would have impacts on the marginal cost curves in CRAM. Also, some start-up costs were not factored into several of the scenarios (e.g. increasing the cattle herd for the permanent cover scenario). Other studies and analysis provide a basis upon which to provide estimates that better reflect the longer-term financial implications for the sector - these have not yet been factored into the model. For some key mitigation strategies (e.g. greater use of no-till), short-term costs could be replaced by benefits over the longer term indicating that best management practices often provide longer term economic incentives; however, initial cost impediments need to be overcome. Information regarding the costs and benefits of various environmental management practices is critical to policy development and is therefore a necessary part of future work.

Appendix A

Scenario Assumptions

Table A.1: Assumptions for Nitrogen Matching Scenario

	2008 BAU	2008 Alternative
Applicable Region Atlantic (N.B. & P.E.I.) Quebec Ontario Prairies & B.C. (Peace River Region) B.C. (Interior & Lower Mainland)		A1. Cereals after Potatoes A2. Split N applications on Potatoes Q1. Reduce N on Corn (grain & silage) O1. Reduce N on Corn (grain & silage) P1. Reduce Fall N Application BC1. Reduce N on Corn
Adoption Rate	Fertilizer Application on Prairie Crops Spring 70% Fall 30%	Assume 100% adoption in 2008 for the area where reduction is appropriate Fertilizer Application on Prairie Crops **Low** / **Medium** / **High** Spring 80% / 90% / 100% Fall 20% / 10% / 0%
Productivity		No yield impacts from increased management efficiency
Input Use (Kg/ha of N) Atlantic Quebec Ontario Prairies & B.C. (Peace River Region) B.C. (Interior & Lower Mainland)		**Low** A1. Reduce by 10 kg/ha A2. Reduce by 30 kg/ha on 30% of area Q1. Reduce by 15 kg/ha O1. Reduce by 15 kg/ha P1. Reduce fertilizer by attached % BC1. Reduce by 50 kg/ha on30% of area **Medium** A1. Reduce by 20 kg/ha A2. Reduce by 30 kg/ha on 50% of area Q1. Reduce by 30 kg/ha O1. Reduce by 30 kg/ha P1. Reduce fertilizer by attached % BC1. Reduce by 50 kg/ha on 55% of area **High** A1. Reduce by 20 kg/ha A2. Reduce by 30 kg/ha on 70% of area Q1. Reduce by 30 kg/ha O1. Reduce by 30 kg/ha P1. Reduce fertilizer by attached % BC1. Reduce by 50 kg/ha on 70% of area
Cost of Production Atlantic Quebec Ontario Prairies & B.C. (Peace River Region) B.C. (Interior & Lower Mainland)		 A1. Soil testing @$25/ha A2. Soil testing @$25/ha Q1. Soil testing @$25/ha O1. Soil testing @$25/ha P1. N is 12% more costly in spring vs fall. BC1. Soil testing $25/ha

Table A.2: Impacts of Reducing Fall Application on Fertilizer Use and Costs (Nitrogen Matching Scenario)

	Soil Zone Distribution				Fertilizer Applications					
	Black	Dark Brown	Brown	Grey	20% Fall/80% Spring		10% Fall/90% Spring		0% Fall/100% Spring	
Efficiency of Fall vs Spring	73%	86%	97%	63%	Fertilizer Use Adjust-ment	Cost Adjust-ment	Fertilizer Use Adjust-ment	Cost Adjust-ment	Fertilizer Use Adjust-ment	Cost Adjust-ment
BC.1				1.00	0.96	0.97	0.93	0.94	0.89	0.91
AB.1			1.00		1.00	1.01	0.99	1.02	0.99	1.03
AB.2		0.80	0.20		0.99	1.00	0.98	1.00	0.96	1.00
AB.3	0.90	0.10			0.97	0.98	0.95	0.97	0.92	0.95
AB.4		0.50	0.50		0.99	1.00	0.98	1.00	0.97	1.01
AB.5	0.50			0.50	0.97	0.98	0.94	0.95	0.90	0.93
AB.6				1.00	0.96	0.97	0.93	0.94	0.89	0.91
AB.7				1.00	0.96	0.97	0.93	0.94	0.89	0.91
SK.1	0.80	0.10	0.10		0.98	0.99	0.95	0.97	0.93	0.96
SK.2	0.15	0.15	0.70		0.99	1.00	0.98	1.01	0.98	1.01
SK.3			1.00		1.00	1.01	0.99	1.02	0.99	1.03
SK.4		0.10	0.90		1.00	1.01	0.99	1.01	0.99	1.02
SK.5	1.0				0.97	0.98	0.95	0.96	0.92	0.95
SK.6	0.10	0.90			0.98	0.99	0.97	0.99	0.95	0.98
SK.7		0.60	0.40		0.99	1.00	0.98	1.00	0.97	1.00
SK.8	1.00				0.97	0.98	0.95	0.96	0.92	0.95
SK.9	0.90	0.10			0.97	0.98	0.95	0.97	0.92	0.95
MB.1	1.0				0.97	0.98	0.95	0.96	0.92	0.95
MB.2	0.90	0.10			0.97	0.98	0.95	0.97	0.92	0.95
MB.3	1.0				0.97	0.98	0.95	0.96	0.92	0.95
MB.4	1.0				0.97	0.98	0.95	0.96	0.92	0.95
MB.5	0.80	0.20			0.98	0.98	0.95	0.97	0.93	0.95
MB.6	0.80			0.20	0.97	0.98	0.94	0.96	0.91	0.94

Table A.3: Assumptions for Zero Tillage Scenario

	2008 BAU		2008 Alternative			
Applicable Region			All provinces			
Adoption Rate	**Zero till**	**BAU**	**Zero till**	**Low**	**Medium**	**High**
	B.C.	14%	**B.C.**	19%	22%	25%
	Alta.	28%	**Alta.**	38%	53%	67%
	Sask.	39%	**Sask.**	49%	62%	70%
	Man.	13%	**Man.**	23%	37%	61%
	Ont.	27%	**Ont.**	28%	29%	39%
	Que.	5%	**Que.**	12%	18%	29%
	N.B.	3%	**N.B.**	4%	5%	6%
	N.S.	2%	**N.S.**	3%	4%	5%
	P.E.I.	2%	**P.E.I.**	2%	3%	5%
	Nfld.	2%	**Nfld.**	2%	3%	4%
Productivity			No changes in crop yields from increase in soil carbon			
Input Use			CRAM cost structure varies by tillage regime for the Prairies–zero tillage tends to have lower machine expenses but requires more chemical inputs. N fertilizer was increased by 10% over the BAU baseline for new land under zero tillage			
Cost of Production			No change from 2008 BAU baseline.			

Table A.4: Assumptions for Decreased Use of Summerfallow Scenario

	2008 BAU		2008 Alternative						
Applicable Region			Prairies and B.C. (Peace River Region)						
Adoption Rate	**Soil zone**		**Soil zone**	**20008 Scenario**					
				Low		**Medium**		**High**	
		M.ha		*M.ha*	*%*	*M.ha*	*%*	*M.ha.*	*%*
	Black/Gray	1.2	Black/Gray	0.9	-25	0.6	-50	0.3	-75
	Dark Brown	1.1	Dark Brown	0.9	-20	0.7	-40	0.5	-60
	Brown	1.6	Brown	1.5	-10	1.1	-30	0.8	-50
	Prairies	3.9	Prairies	3.2	-17	2.4	-39	1.5	-60
Productivity				No crop yield impacts from increase in soil organic carbon.					
Input Use				In CRAM, the cost structure differs for crops grown on stubble or summerfallow. No change from BAU baseline.					
Cost of Production				No change from BAU baseline.					

Table A.5: Assumptions for Permanent Cover Scenario

<table>
<tr><th></th><th>2008 BAU</th><th>2008 Alternative</th></tr>
<tr><td>Applicable Region</td><td></td><td>All provinces</td></tr>
<tr><td>Adoption Rate</td><td></td><td>Assume adoption of Permanent Cover Program targeted at up to 1,000,000 ha across Canada. Distribution of land converted to improved pasture or hayland varies by region, soil type, actual cultivated marginal lands and the distribution of grazing/hay to support beef animals.

Increase (above BAU) in permanent cover by province (ha)
<table>
<tr><th>Province</th><th>Low</th><th>Medium</th><th>High</th></tr>
<tr><td>B.C.</td><td>16,240</td><td>24,354</td><td>40,590</td></tr>
<tr><td>Alta.</td><td>130,900</td><td>196,350</td><td>327,240</td></tr>
<tr><td>Sask.</td><td>176,480</td><td>264,720</td><td>441,210</td></tr>
<tr><td>Man.</td><td>41,590</td><td>62,380</td><td>103,970</td></tr>
<tr><td>Ont.</td><td>20,950</td><td>31,430</td><td>52,380</td></tr>
<tr><td>Que.</td><td>10,760</td><td>16,130</td><td>26,890</td></tr>
<tr><td>N.B.</td><td>1,050</td><td>1,560</td><td>2,600</td></tr>
<tr><td>P.E.I.</td><td>1,289</td><td>1,930</td><td>3,210</td></tr>
<tr><td>N.S.</td><td>560</td><td>850</td><td>1,410</td></tr>
<tr><td>Nfld.</td><td>140</td><td>210</td><td>360</td></tr>
<tr><td>Canada</td><td>400,000</td><td>600,000</td><td>1,000,000</td></tr>
</table></td></tr>
<tr><td>Productivity</td><td></td><td>No crop or forage yield impacts.

Increase beef cattle herd so that provincial forage inventories and beef cattle increase in similar proportions.</td></tr>
<tr><td>Input Use</td><td></td><td>No change in input use per hectare but total input use will decline due to reduction in amount of cropland.</td></tr>
<tr><td>Cost of Production</td><td></td><td>No change from BAU.</td></tr>
</table>

Note: As requested by Ontario only, beef herd was held constant.

Table A.6: Assumptions for Increased Forage in Crop Rotation Scenario

	2008 BAU	2008 Alternative			
Applicable Region		All regions.			
Adoption Rate		High	1.24 million hectares (3% of current cropland)		
		Medium	0.82 million hectares (2% of current cropland		
		Low	0.41 million hectares (1% of current cropland)		
Productivity Ratio of hayland: Cropland was calculated for each crop district based on 1996 data.		**Yield increase**	**Hayland: cropland (%)**		
			<10%	**10%-25%**	**>25%**
		High			
		Grains & Oilseeds	3.33%	1.67%	0.67%
		Hay	3.33%	1.67%	0.67%
		Medium			
		Grains & Oilseeds	2.22%	1.11%	0.44%
		Hay	2.22%	1.11%	0.44%
		Low			
		Grains & Oilseeds	1.11%	0.56%	0.22%
		Hay	1.11%	0.56%	0.22%
Input Use		**Nitrogen fertilizer use**	**Hayland: cropland (%)**		
			<10%	**10%-25%**	**>25%**
		High			
		Grains & Oilseeds	-6.66%	-2.66%	-1.33%
		Medium			
		Grains & Oilseeds	-4.44%	-1.77%	-0.89%
		Low			
		Grains & Oilseeds	-2.22%	-0.89%	-0.44%
Cost of Production		Costs same as 2008 BAU baseline except for change in fertilizer use on grain and oilseed crops.			

Note: As requested by Manitoba only, adoption rates were decreased by 1/3.

Table A.7: Assumptions for Terracing Scenario

	2008 BAU	2008 Alternative			
Applicable Region		Land in potato rotations in P.E.I. and New Brunswick			
Adoption Rate			**Low**	**Medium**	**High**
	P.E.I. 11%	P.E.I.	16%	26%	36%
	N.B. 18%	N.B.	23%	33%	43%
Productivity		Increased yields due to less water N run-off. Increased yields in the long-run due to less soil erosion.			
Input Use		Less N required due to less nitrogen run-off			
Cost of Production		Initial capital cost of approximately $375/ha in P.E.I. $700/ha in N.B. If properly maintained, a terracing system will last indefinitely. Increase costs by $25/ha to reflect annual maintenance costs. Additional costs may include an estimated 20% reduction in equipment operating efficiency due to crossing grassed waterways ($50/ha.)			

Table A.8: Assumptions for Grazing Scenario: Complementary Grazing

	2008 BAU	2008 Alternative
Applicable Region		B.C., W.Manitoba, N.Saskatchewan, N. and W. Alberta
	BAU 40%	**Low** 45% **Medium** 50% **High** 60% Assume a direct relationship between percent of land affected by improved management and pasture quality. Assume land is moved from hayland to tame pasture.
Productivity		Forage yields on applicable native pastureland will increase by 50% in the newly adopted area. Cattle productivity will increase in terms of higher weaning weights, reflected in lower feed demand (see input use). To further reflect the higher pasture quality, increase calving rate by 4.8% on applicable land base (increased calving rate of 4 more calves/84 cows)
Input Use		In CRAM, adjust downward feed grain and forage demands of feeders to reflect higher weaning weights due to higher forage quality: 500 kg/yr less feed required (0.5 kg/daily gain 25 kg larger weaning weight =50 less days of feed; -50 days*10 kg/day feed diet =-500) Increase in seed and fertilizing requirements.
Cost of Production		Lower feed costs as described above. $10/ha increase in costs for fence upkeep and other related maintenance costs.

Table A.9: Assumptions for Grazing Scenario: Rotational Grazing

	2008 BAU	2008 Alternative
Applicable Region	A. No legumes or N fertilizer used, continuous grazing B. Legumes and N fertilizer used, continuous grazing C. No legumes or fertilizer used, continuous grazing	Applicable regions: A. Western tame pasture (moist) B. Eastern tame pasture C. Eastern native pasture A. Use rotational grazing, with legumes in rotation, no fertilizer, reseed every 5 years). B. Use rotational grazing, continue using legumes, but eliminate use of N fertilizer C. Use rotational grazing, add P, K, lime, no legumes.
Adoption Rate	BAU 50%	**Low** 55%; **Medium** 60%; **High** 70%
Productivity		Improved management of soil fertility by use of rotational grazing and added legumes will improve both the efficiency of the use of the forage and the quality of the forage. This may be reflected via a discretionary increase in yields in the applicable regions. Increase yields by 50% on pasture and unimproved pastures in impacted areas (this is 5%, 2.5%, 5% respectively, in the overall area of the regions covered by A, B, and C above).
Input Use		Higher use of fuel, electricity and fencing inputs. Further to this, in the specified regions there is an additional use of seed, but now no N fertilizer is used. May need more P, K, and lime.
Cost of Production		Initial fixed cost of approx $50/ha ($15,000) for a 300 ha farm for all regions, plus: 1) $10/ha increase in costs (based on $3000 / 300 ha for fuel, fence, upkeep and electricity for maintenance of rotational system). 2) $42/ha net fall in costs (based on $10/ha increase in operating costs, but also $52/ha lower costs due to no fertilizer (-85 kg N fertilizer /ha/yr * $0.619/kg)). 3) $0.50/ha cost increase ($150/300) ha for fuel, repairs, P, K, and lime.

Table A.10: Assumptions for Combined Feeding Scenario

	2008 BAU	2008 Alternative
Applicable Region		All regions of Canada
Adoption Rate	0%	**Low** 20% **Medium** 40% **High** 60%
Productivity		***Hogs*** a. Reducing protein intake has no adverse impacts on animal performance. b. Adding phytase to diet improves feeding efficiency 5 –10%. ***Dairy Cows*** a. Better matching of protein requirements has no impact on yield. b. Reducing protein requirements and adding ruminally protected amino acids has no impact on yield. ***Poultry*** a. Reducing protein intake will not adversely affect growth performance if diets are appropriately supplemented with free amino acids.
Input Use		***Hogs*** a. Reducing protein intake: 15% decrease in protein content. Inclusion of free amino acids to balance protein. b. Adding phytase to diet: no change from BAU baseline. ***Dairy Cows*** a. Protein matching: 10% reduction of N in diet. b. Reducing protein and adding ruminally protected amino acids: 20% reduction of N in diet, and addition of amino acids to diet. ***Poultry*** a. Reducing protein intake:15% reduction of protein in diet.
Cost of Production		***Hogs*** a. Reducing protein intake: 15% increase in cost per unit of feed from BAU. b. Addition of phytase: 5% reduction in cost per unit of feed from BAU. ***Dairy Cows*** a. Protein matching: 10% reduction in use of protein supplement (included in cash costs). Increase feed testing at $10/dairy cow/year. Net cost decrease of $28.12 /dairy cow/year. b. Reducing protein and adding ruminally protected amino acids: 20% reduction in protein supplement (included in cash costs). Increase feed testing at $15/cow/year (additional $5/cow/year to balance rations on an amino acid basis). The cost of ruminally protected amino acids is $0.15/day or about $45.00 /dairy cow/year. Net cost decrease of $16.25/dairy cow/year. ***Poultry*** a. Reducing protein intake: 10% increase in cost/unit of feed from BAU.

Table A.11: Assumptions for Afforestation Scenario

	2008 BAU	2008 Alternative
Applicable Region		All Provinces
Adoption Rate Regional planting shares are based on consultations with the Canadian Forest Service		**Canada** Low = 20,000 ha Medium =50,000 ha High = 100,000 ha **Provinces** B.C. 26% Prairies 43% Ont. 13% Que. 13% Atlantic 5%
Productivity		No effect on yield, remove afforested land from agricultural production.
Input Use		Eliminate agricultural inputs. Increase forestry inputs.
Cost of Production		Hybrid Species = $2150/ha Traditional Species = $1550/ha (Source: Terry Hatton, CFS, 2002).
Additional Assumptions		Tree Species: hybrid poplar / mixture of traditional species in each region. Planting Ramp-up: 5 year planting schedule (yr 1: 10% / yr 2: 10% / yr 3: 20% / yr 4: 30% / yr 5: 30%). CO_2 Results: calculations are for above and below ground biomass. No CO_2 losses from site preparation activities (i.e. assumes no current vegetation on site prior to afforestation). Planted areas do not suffer any losses from natural disturbances (i.e. fire, insects, disease). Harvesting does not occur within the first 25 years.

APPENDIX B
PROVINCIAL CROSSWALK

Table B.1: Crosswalk of Provincial Environmental Targets by Major APF Goal and AAFC Target Analysis

APF Goals	B.C.	Alta.	Sask.	Man.	Ont.	Que.	N.B.	N.S.	P.E.I.	Nfld.
1. Environmental Risk Assessment and Planning Goals										
• Environmental Farm Plans (EFP)/ Conservation Clubs	Yes	T.B.D.	No	No	T.B.D.	Yes	Yes	Yes	T.B.D.	Yes
• Watershed Management Plans	No	No	No	No	Part of NMP	No	No	No	*	*
2. Nutrient Management (Pathogens)										
• Nutrient Management Plans (NMP)	Yes	Yes	No	Yes	T.B.D.	Yes	Yes	Yes	Yes	Yes
• Manure Management (Best Management Practices)	Yes	Yes	No	No	Part of NMP	Yes	Yes	Soil testing	*	*
•keeping field records for manure applications	*	*	No	*	*	*	*	*	*	*
•soil testing (residual nitrogen in NB)	*	*	Yes	*	Part of NMP	*	Yes	Yes	*	Yes
•adjusting mineral fertilizer application rates	*	*	*	*	*	*	*	Yes	*	Yes
• Fertilizer Management (BMP)	Yes	T.B.D.	No	No	*	Yes	Yes	adjust rates	*	*
•appropriate fertilizer application methods	*	*	*	*	*	*	*	*	*	Yes
•leak-proof/adequate manure storage	Yes	*	*	*	*	Yes	Yes	*	*	Yes
•liquid manure storage capacity	Yes	*	*	*	*	*	*	*	*	*
•minimum set-back distances (adequate buffers)	*	*	*	*	Part of NMP	*	*	*	*	Yes
•adequate land available for safe manure spreading	*	*	*	*	*	*	*	*	*	Yes
3. Pest Management										
• Integrated Pest Management (IPM)	No	No	No	No	Yes (sector and region)	Yes (grains/ corn/soy)	No	Yes	*	*
• Pesticide (BMP)	Yes	Yes	No	Yes	No	*	Yes	Certification	*	*
•economic injury or pest monitoring as decision-tool	*	*	*	*	*	*	*	*	*	Yes
•calibrate sprayers annually	*	*	*	*	*	*	*	*	*	Yes
• Total Volume of Pesticide Sold	*	*	No	*	No	*	*	*	Yes	*
• Lower Toxicity Pesticides	*	*	*	*	No	*	*	*	Yes	*
• Non-Chemical Pest Control	*	*	*	*	*	*	*	*	*	Yes
• Certified Applicator/Safety Training	*	*	*	*	Yes	*	*	Yes	*	Yes
• Adequate Setback from Watercourses	*	*	*	*	*	*	*	*	*	Yes
• Organic Farming Practices	*	*	*	*	*	T.B.D.	*	*	Yes	*

Table B.1: Crosswalk of Provincial Environmental Targets by Major APF Goal and AAFC Target Analysis

APF Goals	B.C.	Alta.	Sask.	Man.	Ont.	Que.	N.B.	N.S.	P.E.I.	Nfld.
4. Land and Water Management										
• Bare Soil Days	No	No	No	No	No	No	No	No	*	*
• Conservation Tillage Practices (No-till)	Peace Riv.	Yes	Yes	Yes	No	Yes	No	*	*	Yes
• Reduce Soil Compaction (NS)	*	*	*	*	*	*	*	Yes	*	*
• Reduce Soil Erosion	*	*	*	*	*	*	*	*	Yes	Yes
• Reduced Summerfallow	*	Yes	Yes	*	*	*	*	*	*	*
• Tame Hay Pasture	*	*	Yes	*	*	*	*	*	*	*
• Controlled Livestock Access to Surface Water	No	*	No	*	No	Yes	Yes	Yes	Yes	Yes
• Riparian BMP (buffer zones)	No	Yes	No	Yes	No	Yes	Yes	*	*	Yes
• Irrigation BMP	Yes	T.B.D.	No	No	Low priority	No-N/A	No	Yes	*	*
• Sustainable Grazing Practices	No	Yes	No	Yes	*	No	No	No	*	*
• Wildlife BMP	No	Yes	No	No	Low priority	No	No	No	*	*
• Cropland with Tile Drainage (BC)	No	*	*	*	*	*	*	*	*	*
• Soil Testing (NB)	*	*	Yes	*	*	*	Yes	Yes	*	*
• Residual Nitrogen (NB)	*	*	*	*	*	*	Yes	*	*	*
• Soil Testing (Phosphorous) (NB)	*	*	*	*	*	*	Yes	*	*	*
• Crop Residue Management (Sask.)	*	*	No	*	*	*	*	*	*	*
• Sustainable Soil and Crop Management (MB)	*	*	*	Yes	*	*	*	*	*	*
• Database of inventory of sensitive/vulnerable land use (Ont.)	*	*	*	*	Yes	*	*	*	*	*
• Increase Quality of Forest	*	*	*	*	*	*	*	*	Yes	*
• Maintain Quality of Pastoral Landscape	*	*	*	*	*	*	*	*	T.B.D.	*
5. Nuisance Management										
• Odour Management	*	T.B.D.	No	Yes	If NM Act passes	Yes	Yes	Yes	*	*
• Particulate (dust) Management	*	T.B.D.	No	Yes	No	No	No	No	*	*
• Nuisance Complaints Resolved	Yes	*	*	*	If NM Act passes	*	Yes	*	*	*

Yes - indicates that numerical targets have been set.
No - indicates that no numerical targets have been set.
* - indicates not applicable to region or not specified by province.
T.B.D. indicates “to be developed” at a future date.
[grey box] Scenarios for which APF Target Analysis Conducted.

Appendix C

Model Results

Table C.1: 1996, 2001 and 2008 Baseline Results for CRAM and Agri-Environmental Indicators

	CRAM Results							Environmental Indicators				
Province	Cropland	Summer-fallow	Hayland	Tame Pasture	Native Pasture	Beef Cows	Breed-ing Sows	GHG Emissions	SOC Sink	IROWCN	RSN	RWE
	'000 ha	'000 ha	'000 ha	'000 ha	'000 ha	'000 hd	'000 hd	'000 tonnes CO_2 eqiv.	'000 tonnes Carbon	mg N/l	kg N/ha	t/ha/ year
B.C. a	188	39	348	240	1,173	273	20	2,423	13		26.8	3.2
b	186	35	401	233	1,208	280	18	2,293	45	N/A	24.2	3.2
c	192	30	401	233	1,208	298	21	2,573	40		29.3	3.2
Alta.	7,611	1,437	1,924	1.915	6,615	2,017	174	19,504	-141		23.9	2.6
	7,269	1,236	2,507	2,231	6,679	2,099	200	17,279	831	N/A	29.0	2.4
	7,503	1,029	2,480	2,231	6,679	2,235	227	18,431	948		28.3	2.2
Sask	13,305	4,434	1,089	1,233	5,094	1,135	72	12,771	504		26.3	2.3
	14,304	3,133	1,517	1,406	5,127	1,215	109	9,811	1,849	N/A	30.3	2.1
	14,812	2,610	1,532	1,406	5,127	1,293	123	10,129	2,178		37.4	1.8
Man.	3,944	324	749	356	1,654	510	178	8,521	-89		33.8	2.3
	3,297	256	877	383	1,580	563	288	8,099	112	N/A	40.4	2.2
	3,993	213	857	383	1,580	600	326	8,994	148		58.6	2.2
Ont.	2,414		1,018	348	664	441	296	9,948	105	8.3	41.8	7.8
	2,576		1,013	313	532	376	356	9,469	150	8.5	42.7	8.3
	2,551		1,038	313	532	306	381	10,160	-11	9.0	44.9	7.6
Que.	783		882	197	322	232	318	7,504	-72	3.8	20.6	4.5
	1,000		780	183	186	208	402	7,951	-155	4.2	23.1	5.2
	979		801	183	186	169	429	8,012	-153	4.6	24.9	5.1
N.B.	55		70	20	30	23	7	480	1	1.8	11.2	16.9
	59		79	18	27	20	13	496	6	2.3	14.1	17.8
	59		79	18	27	17	14	492	6	3.0	18.5	16.5
PEI	112		55	12	15	16	12	540	1	3.8	24.5	7.9
	113		58	12	13	13	13	528	3	4.6	29.5	8.0
	112		59	12	13	11	14	523	3	4.1	26.8	8.0
N.S.	20		71	25	37	32	11	575	-1	4.6	40.4	8.3
	21		75	23	33	27	11	554	0	4.9	43.0	9.3
	20		76	23	33	22	11	542	0	2.7	23.5	8.5
Nfld.	0.28		6	2	7	1	0	202	0	9.2	69.9	
	0.52		7	3	7	1	0	209	0	10.1	76.9	N/A
	0.51		7	3	7	1	0	214	0	14.3	107.1	
Canada	28,432	6,234	6,211	4,349	15,612	4,681	1,089	62,468	321		29.9	
	29,456	4,660	7,315	4,805	15,391	4,802	1,411	56,688	2,842	N/A	32.8	N/A
	30,221	3,882	7,330	4,805	15,391	4,951	1,545	60,069	3,159		36.7	

Notes:
[a]1996 Baseline
[b]2001 Baseline
[c]2008 Baseline

Table C.2: Fertilizer Sold: Nitrogen Content for 1996, 2001 and 2008 (tonnes)

Province	1996	2001	2008
		(tonnes)	
B.C.	26,922	16,461	33,652
Alta.	430,783	508,287	538,478
Sask.	517,829	543,998	647,286
Man.	312,350	326,933	390,437
Ont.	173,884	162,513	168,422
Que.	88,207	94,719	92,775
Atlantic	26,237	29,161	27,625

Table C.3: Zero Tillage Baseline Adoption Rates for 1996, 2001 and 2008

Province	1996	2001	2008
		Percent	
B.C.	10	14	14
Alta.	10	27	28
Sask.	22	39	39
Man.	9	13	13
Ont.	18	27	27
Que.	4	5	5
N.B.	2	3	3
P.E.I.	2	2	2
N.S.	3	8	2
Nfld.	4	12	2

Table C.4: 2008 Baseline Results for CRAM and AEIs

	CRAM Results							Environmental Indicators			
Province	Cropland	Summer-fallow	Hayland	Tame Pasture	Native Pasture	Beef Cows	Breeding Sows	GHG Emissions	SOC Sink	IROWCN	RSN
	'000 ha	'000 ha	'000 ha	'000 ha	'000 ha	'000 hd	'000 hd	'000 tonnes CO_2 eqiv.	'000 tonnes Carbon	mg N/l	kg N/ha
B.C.	192	30	401	233	1,208	298	21	2,573	40	N/A	29.3
Alta.	7,503	1,029	2,480	2,231	6,679	2,235	227	18,431	948	N/A	28.3
Sask.	14,812	2,610	1,532	1,406	5,127	1,293	123	10,129	2,178	N/A	37.4
Man.	3,993	213	857	383	1,580	600	326	8,994	148	N/A	58.6
Ont.	2,551		1,038	313	532	306	381	10,160	-11	9.0	44.9
Que.	979		801	183	186	169	429	8,012	-153	4.6	24.9
N.B.	59		79	18	27	17	14	492	6	3.0	18.5
P.E.I.	112		59	12	13	11	14	523	3	4.1	26.8
N.S.	20		76	23	33	22	11	542	0	2.7	23.5
Nfld.	1		7	3	7	1	0	214	0	14.3	107.1
Canada	30,221	3,882	7,330	4,805	15,391	4,951	1,545	60,069	3,159	N/A	36.7

Note: The following tables (C.5 to C.13) provide percentage changes from the 2008 baseline for the CRAM results and the AEIs. While the percentages indicate how things are reacting provincially, they do not take into account the area under production that is affected by the various scenarios. The absolute numbers in Table C.4 should be kept in mind when interpreting the results in the following tables.

Table C.5: Nitrogen Matching: Percentage Change in Land Type, Major Livestock and AEIs for Low, Medium and High Adoption Rates

Province		CRAM Results						Environmental Indicators					
		Cropland	Summerfallow	Hayland	Tame Pasture	Beef Cows	Breeding Sows	GHG	IROWCN	RSN	RWDE	RWE	HA
B.C.	a	-0.4	-0.8	0.2	0.0	-0.1	0.0	-0.6	N/A	-3.0	N/A	N/A	N/A
	b	**0.0**	**-1.5**	**0.1**	**0.0**	**-0.1**	**0.0**	**-0.8**	**N/A**	**-5.3**	**N/A**	**N/A**	**N/A**
	c	0.2	-2.2	0.1	0.0	-0.1	0.0	-1.2	N/A	-8.2	N/A	N/A	N/A
Alta.		0.1	-0.2	-0.1	0.0	0.0	0.1	-0.4	N/A	-2.1	N/A	N/A	N/A
		0.1	**-0.5**	**-0.2**	**0.0**	**0.0**	**0.0**	**-0.7**	**N/A**	**-4.0**	**N/A**	**N/A**	**N/A**
		0.2	-0.8	-0.3	0.0	0.0	0.0	-1.2	N/A	-6.3	N/A	N/A	N/A
Sask.		0.0	-0.1	0.0	0.0	0.0	0.0	-1.0	N/A	-2.0	N/A	N/A	N/A
		0.0	**-0.3**	**0.0**	**0.0**	**0.0**	**0.0**	**-1.8**	**N/A**	**-3.6**	**N/A**	**N/A**	**N/A**
		0.0	-0.4	0.0	0.0	0.0	0.0	-2.8	N/A	-5.4	N/A	N/A	N/A
Man.		0.1	-0.6	-0.2	0.0	0.0	0.0	-1.0	N/A	-3.2	N/A	N/A	N/A
		0.1	**-1.0**	**-0.3**	**0.0**	**0.0**	**0.0**	**-1.8**	**N/A**	**-5.5**	**N/A**	**N/A**	**N/A**
		0.2	-1.4	-0.4	0.0	-0.1	0.0	-2.8	N/A	-8.6	N/A	N/A	N/A
Ont.		-0.4	0.0	0.9	0.0	0.0	-0.7	-1.5	-5.5	-5.4	N/A	N/A	N/A
		-0.1	**0.0**	**0.3**	**0.0**	**0.0**	**-0.3**	**-2.2**	**-11.2**	**--11.2**	**N/A**	**N/A**	**N/A**
		-0.1	0.0	0.3	0.0	0.0	-0.2	-2.2	-11.2	-11.2	N/A	N/A	N/A
Que.		-0.4	0.0	0.5	0.0	0.0	0.0	-0.9	-4.2	-4.3	N/A	N/A	N/A
		-0.2	**0.0**	**0.2**	**0.0**	**0.0**	**0.0**	**-1.4**	**-8.6**	**-8.9**	**N/A**	**N/A**	**N/A**
		-0.2	0.0	0.2	0.0	0.0	0.0	-1.4	-8.6	-8.8	N/A	N/A	N/A
N.B.		-2.9	0.0	2.2	0.0	-0.1	-0.1	-1.5	-4.0	-4.4	N/A	N/A	N/A
		-1.9	**0.0**	**1.4**	**0.0**	**-0.1**	**-0.1**	**-2.0**	**-6.7**	**-7.0**	**N/A**	**N/A**	**N/A**
		-1.9	0.0	1.4	0.0	-0.1	-0.1	-2.2	-7.4	-7.9	N/A	N/A	N/A
P.E.I.		1.3	0.0	2.4	0.0	0.2	-0.2	-1.8	-10.1	-10.0	N/A	N/A	N/A
		-0.6	**0.0**	**1.2**	**0.0**	**0.2**	**-0.3**	**-3.0**	**-15.9**	**-15.8**	**N/A**	**N/A**	**N/A**
		-0.6	0.0	1.1	0.0	0.2	-0.2	-3.3	-17.6	-17.3	N/A	N/A	N/A
N.S.		0.3	0.0	-0.1	0.0	0.0	-0.1	0.0	0.0	0.0	N/A	n/a	N/A
		0.3	**0.0**	**-0.1**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**N/A**	**N/A**	**N/A**
		0.3	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	N/A	N/A	N/A
Nfld.		0.0	0.0	0.0	0.0	1.9	0.0	0.1	0.1	0.0	N/A	N/A	N/A
		0.0	**0.0**	**0.0**	**0.0**	**1.9**	**0.0**	**0.1**	**0.1**	**0.0**	**N/A**	**N/A**	**N/A**
		0.0	0.0	0.0	0.0	1.9	0.0	0.1	0.1	0.0	N/A	N/A	N/A
Canada		0.0	-0.2	0.2	0.0	0.0	-0.2	-0.9	N/A	-2.3	N/A	N/A	N/A
		0.0	**-0.4**	**0.0**	**0.0**	**0.0**	**-0.1**	**-1.4**	**N/A**	**-4.3**	**N/A**	**N/A**	**N/A**
		0.1	-0.5	0.0	0.0	0.0	-0.1	-1.9	N/A	-5.6	N/A	N/A	N/A

Notes:

[a] Results for low adoption rates

[b] Results for medium adoption rates

[c] Results for high adoption rates

Table C.6: Increased Zero Tillage: Percentage Change in Land Type, Major Livestock and AEIs for Low, Medium and High Adoption Rates

		CRAM Results						Environmental Indicators					
Province		Cropland	Summerfallow	Hayland	Tame Pasture	Beef Cows	Breeding Sows	GHG*	IROWCN	RSN	RWDE	RWE	HA
B.C.	a	0.0	0.0	0.0	0.0	0.0	-0.2	0.0	N/A	0.0	N/A	0.0	0.0
	b	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.3**	**-0.4**	**N/A**	**0.0**	**N/A**	**0.0**	**0.0**
	c	0.0	0.0	0.0	0.0	0.0	0.0	-0.6	N/A	0.0	N/A	0.0	0.0
Alta.		0.0	0.0	0.0	0.0	0.0	-0.4	-3.7	N/A	0.2	-9.6	-3.7	0.0
		0.0	**0.0**	**0.0**	**0.0**	**0.0**	**0.1**	**-9.4**	**N/A**	**0.6**	**-23.1**	**-9.5**	**0.0**
		0.1	-0.9	0.0	0.0	0.0	0.1	-15.1	N/A	0.6	-34.6	-15.3	0.1
Sask.		0.0	0.0	0.0	0.0	0.0	0.0	-13.4	N/A	-0.3	-6.3	-3.7	0.0
		0.0	**0.0**	**0.0**	**0.0**	**0.0**	**-0.1**	**-33.7**	**N/A**	**0.2**	**-15.3**	**-8.6**	**0.0**
		0.0	0.0	0.0	0.0	0.0	-0.1	-46.1	N/A	0.8	-19.9	-11.2	0.0
Man.		0.0	0.0	0.0	0.0	0.0	0.0	-5.2	N/A	0.1	-8.0	-4.4	0.0
		0.0	**0.0**	**0.0**	**0.0**	**0.0**	**-0.2**	**-13.2**	**N/A**	**0.7**	**-19.3**	**-10.6**	**0.0**
		0.5	-8.9	0.0	0.0	0.0	0.0	-26.3	N/A	2.0	-38.5	-19.4	0.3
Ont.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.0	0.0
		0.0	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**-0.5**	**0.0**	**0.0**	**N/A**	**0.0**	**0.0**
		0.0	0.0	0.0	0.0	0.0	0.1	-2.8	0.0	0.0	N/A	0.0	0.0
Que.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.0	0.0
		0.0	**0.0**	**0.0**	**0.0**	**0.0**	**0.1**	**-1.5**	**0.0**	**0.0**	**N/A**	**0.0**	**0.0**
		0.0	0.0	0.0	0.0	0.0	0.1	-2.8	0.0	0.0	N/A	0.0	0.0
N.B.		0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	N/A	0.0	0.0
		0.0	**0.0**	**0.0**	**0.0**	**-0.1**	**0.7**	**-0.1**	**0.3**	**0.1**	**N/A**	**0.0**	**0.0**
		0.0	0.0	0.0	0.0	-0.1	0.4	-0.3	0.3	0.1	N/A	0.0	0.0
P.E.I.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.0	0.0
		0.0	**0.0**	**0.0**	**0.0**	**0.0**	**-0.3**	**-0.2**	**0.0**	**0.0**	**N/A**	**0.0**	**0.0**
		0.0	0.0	0.0	0.0	0.0	0.6	-0.6	0.2	0.1	N/A	0.0	0.0
N.S.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.0	0.0
		0.0	**0.0**	**0.0**	**0.0**	**0.0**	**-0.1**	**-0.2**	**0.0**	**0.0**	**N/A**	**0.0**	**0.0**
		0.0	0.0	0.0	0.0	0.0	0.0	-0.2	0.0	0.0	N/A	0.0	0.0
Nfld.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	N/A	0.0
		0.0	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.2**	**0.0**	**0.0**	**N/A**	**N/A**	**0.0**
		0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	N/A	N/A	0.0
Canada		0.0	0.0	0.0	0.0	0.0	-0.1	-4.2	N/A	0.0	N/A	N/A	0.0
		0.0	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**-10.8**	**N/A**	**0.2**	**N/A**	**N/A**	**0.0**
		0.1	-0.7	0.0	0.0	0.0	0.1	-17.2	N/A	0.4	N/A	N/A	0.0

Notes:
[a]Results for low adoption rates
[b]Results for medium adoption rates
[c]Results for high adoption rates

*GHG emission results for the zero-till scenario are based on 2001 census information.

Table C.7: Reduced Summerfallow: Percentage Change in Land Type, Major Livestock and AEIs for Low, Medium and High Adoption Rates

		CRAM Results						Environmental Indicators					
Province		Cropland	Summerfallow	Hayland	Tame Pasture	Beef Cows	Breeding Sows	GHG	IROWCN	RSN	RWDE	RWE	HA
B.C.	a	5.3	-25.0	-0.7	0.0	-1.0	0.0	0.1	N/A	0.4	N/A	-0.6	0.2
	b	**7.7**	**-50.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.7**	**N/A**	**0.6**	**N/A**	**-3.1**	**0.7**
	c	12.4	-77.0	-0.2	0.0	-0.4	0.0	0.9	N/A	1.1	N/A	-4.6	1.0
Alta.		2.3	-18.0	0.6	0.0	0.2	0.0	-1.3	N/A	-0.4	-4.7	-2.2	1.1
		5.1	**-40.0**	**1.1**	**0.0**	**0.0**	**0.1**	**-3.7**	**N/A**	**-0.8**	**-11.3**	**-5.0**	**2.3**
		7.7	-60.0	1.7	0.0	0.2	0.1	-5.7	N/A	-1.2	-16.8	-7.3	3.5
Sask.		2.8	-16.0	0.2	0.0	0.0	0.0	-6.7	N/A	-0.3	-5.0	-1.5	1.8
		6.5	**-37.0**	**0.5**	**0.0**	**0.0**	**0.0**	**-16.0**	**N/A**	**-1.0**	**-11.5**	**-3.3**	**4.1**
		10.4	-59.0	0.4	0.0	0.0	0.2	-26.1	N/A	-1.6	-18.4	-5.1	6.5
Man.		1.4	-25.0	-0.2	0.0	0.0	0.0	-1.0	N/A	0.2	-0.2	-1.1	0.6
		2.6	**-50.0**	**0.3**	**0.0**	**0.1**	**0.0**	**-2.0**	**N/A**	**0.1**	**-1.4**	**-2.4**	**1.4**
		3.9	-75.0	0.3	0.0	0.1	0.1	-3.2	N/A	0.1	-2.4	-3.7	2.0
Ont.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.0	0.0
		0.0	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**N/A**	**0.0**	**0.0**
		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.0	0.0
Que.		0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	N/A	0.0	0.0
		0.0	**0.0**	**0.1**	**0.0**	**0.0**	**0.1**	**0.0**	**0.0**	**0.0**	**N/A**	**0.0**	**0.0**
		-0.1	0.0	0.1	0.0	-0.1	0.3	0.0	0.0	0.0	N/A	0.0	0.0
N.B.		0.1	0.0	0.0	0.0	-0.4	-0.1	-0.1	0.0	0.0	N/A	0.0	0.0
		0.0	**0.0**	**0.0**	**0.0**	**-0.2**	**0.2**	**0.0**	**0.3**	**0.2**	**N/A**	**0.0**	**0.0**
		-0.1	0.0	0.1	0.0	-0.8	0.6	-0.1	0.3	0.2	N/A	0.0	0.0
P.E.I.		0.0	0.0	0.0	0.0	-0.4	-0.1	0.0	0.0	0.0	N/A	0.0	0.0
		0.0	**0.0**	**0.0**	**0.0**	**-0.1**	**0.2**	**0.0**	**0.0**	**0.0**	**N/A**	**0.0**	**0.0**
		0.0	0.0	0.0	0.0	-0.8	0.7	0.0	0.2	0.3	N/A	0.0	0.0
N.S.		0.0	0.0	0.0	0.0	-0.3	0.1	-0.1	0.0	0.0	N/A	0.0	0.0
		0.0	**0.0**	**0.0**	**0.0**	**-0.1**	**0.4**	**0.0**	**0.0**	**0.1**	**N/A**	**0.0**	**0.0**
		0.0	0.0	0.0	0.0	-0.7	0.5	-0.1	0.0	-0.7	N/A	0.0	0.0
Nfld.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	N/A	0.0
		0.0	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**N/A**	**N/A**	**0.0**
		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	N/A	0.0
Canada		2.2	-17.1	0.2	0.0	0.0	0.0	-1.7	N/A	-0.1	N/A	N/A	1.1
		4.8	**-38.6**	**0.5**	**0.0**	**0.0**	**0.0**	**-4.1**	**N/A**	**-0.2**	**N/A**	**N/A**	**2.5**
		7.6	-60.3	0.7	0.0	0.1	0.1	-6.6	N/A	-0.3	N/A	N/A	3.9

Notes:

[a] Results for low adoption rates

[b] Results for medium adoption rates

[c] Results for high adoption rates

Table C.8: Permanent Cover: Percentage Change in Land Type, Major Livestock and AEIs for Low, Medium and High Adoption Rates

Province		CRAM Results						Environmental Indicators					
		Cropland	Summerfallow	Hayland	Tame Pasture	Beef Cows	Breeding Sows	GHG	IROWCN	RSN	RWDE	RWE	HA
B.C.	a	-7.6	-5.6	0.8	5.7	1.7	-0.3	-1.5	N/A	-2.8	N/A	-3.6	1.4
	b	**-11.4**	**-8.4**	**1.1**	**8.5**	**2.5**	**-0.4**	**-2.3**	**N/A**	**-4.2**	**N/A**	**-5.3**	**2.1**
	c	-19.0	-14.0	1.9	14.1	3.8	-0.7	-4.0	N/A	-7.1	N/A	-8.9	3.6
Alta.		-1.3	-3.4	0.5	5.3	1.1	-0.5	-0.3	N/A	-0.7	-2.3	-1.4	1.2
		-1.9	**-5.0**	**0.8**	**8.0**	**1.6**	**-0.8**	**-0.5**	**N/A**	**-1.1**	**-3.4**	**-2.0**	**1.9**
		-3.2	-8.2	1.3	13.3	2.7	-1.3	-0.8	N/A	-1.8	-5.6	-3.4	3.1
Sask.		-1.0	-0.8	1.3	11.1	1.5	-0.2	-1.0	N/A	-0.6	-1.2	-0.9	1.1
		-1.6	**-1.2**	**1.9**	**16.7**	**2.2**	**-0.2**	**-1.6**	**N/A**	**-0.9**	**-1.6**	**-1.3**	**1.7**
		-2.6	-2.0	3.2	27.9	3.7	-0.2	-2.6	N/A	-1.5	-2.6	-2.2	2.8
Man.		-1.0	-0.8	0.7	9.2	2.4	-0.1	-0.7	N/A	-0.5	-1.1	-0.8	0.8
		-1.5	**-1.2**	**1.1**	**13.8**	**3.7**	**-0.1**	**-1.0**	**N/A**	**-0.8**	**-1.6**	**-1.1**	**1.2**
		-2.5	-1.9	1.9	23.0	6.1	-0.1	-1.7	N/A	-1.2	-2.6	-1.9	2.0
Ont.		-0.8	0.0	0.6	4.7	0.0	-0.3	-0.8	-0.9	-0.9	N/A	-0.8	0.5
		-1.2	**0.0**	**0.9**	**7.0**	**0.0**	**-0.4**	**-1.2**	**-1.2**	**-1.3**	**N/A**	**-1.2**	**0.7**
		-2.1	0.0	1.5	11.6	0.0	-0.5	-2.0	-2.1	-2.1	N/A	-2.0	1.1
Que.		-1.1	0.0	0.4	3.9	0.3	-0.1	-0.5	-0.4	-0.4	N/A	-0.8	0.4
		-1.6	**0.0**	**0.7**	**5.9**	**0.4**	**-0.2**	**-0.7**	**-0.7**	**-0.6**	**N/A**	**-1.1**	**0.6**
		-2.7	0.0	1.1	9.8	0.8	-0.1	-1.1	-1.1	-1.1	N/A	-1.9	1.0
N.B.		-1.8	0.0	0.4	3.9	0.6	-0.4	-0.6	-0.3	-0.7	N/A	-0.6	0.4
		-2.7	**0.0**	**0.6**	**5.8**	**0.6**	**-0.4**	**-0.9**	**-0.7**	**-0.9**	**N/A**	**-0.8**	**0.5**
		-4.4	0.0	1.1	9.7	0.7	-0.3	-1.5	-1.4	-1.5	N/A	-1.4	0.9
P.E.I.		-1.2	0.0	0.6	7.8	0.6	-0.4	-0.7	-1.0	-0.9	N/A	-0.4	0.5
		-1.7	**0.0**	**0.9**	**11.7**	**0.6**	**-0.4**	**-1.0**	**-1.5**	**-1.4**	**N/A**	**-0.6**	**0.7**
		-2.9	0.0	1.5	19.5	0.7	-0.7	-1.7	-2.4	-2.4	N/A	-1.0	1.1
N.S.		-2.8	0.0	0.2	1.7	0.6	-0.2	-0.2	-0.4	-0.3	N/A	-0.4	0.2
		-4.2	**0.0**	**0.3**	**2.7**	**0.6**	**-0.2**	**-0.4**	**-0.4**	**-0.4**	**N/A**	**-0.6**	**0.3**
		-7.0	0.0	0.5	4.4	0.6	-0.2	-0.6	-0.4	-0.4	N/A	-0.9	0.6
Nfld.		-3.9	0.0	-1.9	5.5	0.0	0.0	-0.1	-0.8	-0.8	N/A	N/A	-0.1
		-3.9	**0.0**	**-2.8**	**8.3**	**0.0**	**0.0**	**-0.2**	**-1.1**	**-1.2**	**N/A**	**N/A**	**-0.2**
		-5.9	0.0	-4.8	14.2	0.0	0.0	-0.4	-1.9	-2.0	N/A	N/A	-0.4
Canada		-1.1	-1.5	0.7	7.2	1.3	-0.2	-0.7	N/A	-0.9	N/A	N/A	1.0
		-1.7	**-2.3**	**1.1**	**10.8**	**1.9**	**-0.3**	**-1.0**	**N/A**	**-1.3**	**N/A**	**N/A**	**1.5**
		-2.8	-3.7	1.8	18.1	3.2	-0.4	-1.6	N/A	-2.2	N/A	N/A	2.5

Notes:
a Results for low adoption rates
b Results for medium adoption rates
c Results for high adoption rates

Table C.9: Increased Forage Use in Crop Rotations: Percentage Change in Land Type, Major Livestock and AEIs for Low, Medium and High Adoption Rates

		CRAM Results						Environmental Indicators					
Province		Cropland	Summerfallow	Hayland	Tame Pasture	Beef Cows	Breeding Sows	GHG	IROWCN	RSN	RWDE	RWE	HA
B.C.	a	-1.9	-1.1	1.0	0.0	1.6	-0.6	-0.8	N/A	-0.5	N/A	-0.7	0.3
	b	**-1.9**	**-0.9**	**1.0**	**0.0**	**2.1**	**-1.3**	**-1.5**	**N/A**	**-1.0**	**N/A**	**-0.7**	**0.3**
	c	-3.9	-2.0	2.0	0.0	3.7	-1.8	-2.1	N/A	-1.5	N/A	-1.3	0.6
Alta.		-1.2	-2.0	4.6	0.0	4.5	-1.0	1.3	N/A	-0.3	-1.8	-0.8	0.9
		-2.5	**-3.7**	**9.2**	**0.0**	**9.0**	**-2.0**	**2.8**	**N/A**	**-0.7**	**-3.5**	**-1.5**	**1.9**
		-3.7	-5.5	13.6	0.0	13.4	-2.9	4.2	N/A	-1.0	-5.1	-2.2	2.8
Sask.		-1.5	-0.7	15.4	0.0	16.4	-0.2	7.6	N/A	-0.7	-1.1	-0.7	1.4
		-2.9	**-1.4**	**30.6**	**0.0**	**26.9**	**-0.3**	**11.5**	**N/A**	**-1.6**	**-2.3**	**-1.4**	**2.9**
		-4.4	-2.3	46.2	0.0	40.6	-1.6	17.4	N/A	-2.8	-3.7	-2.2	4.3
Man.		-0.7	-0.5	3.6	0.0	3.9	-0.1	0.0	N/A	-1.1	-0.7	-0.4	0.6
		-1.5	**-1.0**	**7.1**	**0.0**	**7.8**	**-0.1**	**0.1**	**N/A**	**-2.1**	**-1.4**	**-0.7**	**1.2**
		-2.2	-2.0	10.6	0.0	11.8	-0.6	0.1	N/A	-3.3	-2.3	-1.2	1.8
Ont.		-0.8	0.0	2.0	0.0	1.0	-0.1	-0.7	-0.2	-0.2	N/A	-0.8	0.6
		-1.6	**0.0**	**4.0**	**0.0**	**2.1**	**-0.3**	**-1.3**	**-0.3**	**-0.3**	**N/A**	**-1.6**	**1.1**
		-2.8	0.0	7.0	0.0	3.5	-0.6	-1.8	-0.4	-0.5	N/A	-2.9	2.0
Que.		-0.8	0.0	1.0	0.0	1.0	-0.1	-0.3	-0.2	-0.2	N/A	-0.5	0.4
		-1.6	**0.0**	**2.0**	**0.0**	**2.0**	**-0.2**	**-0.6**	**-0.4**	**-0.4**	**N/A**	**-0.9**	**0.7**
		-1.6	0.0	2.0	0.0	2.1	-0.9	-0.8	-0.4	-0.4	N/A	-1.0	0.7
N.B.		-1.3	0.0	1.0	0.0	0.9	-0.3	-0.3	-0.3	-0.6	N/A	-0.1	0.4
		-1.3	**0.0**	**1.0**	**0.0**	**1.0**	**-0.5**	**-0.4**	**-0.7**	**-0.9**	**N/A**	**-0.3**	**0.4**
		-2.7	0.0	2.0	0.0	2.0	-2.2	-0.9	-1.4	-1.6	N/A	-0.7	0.8
P.E.I.		-0.5	0.0	1.0	0.0	1.0	-0.3	-0.1	-1.0	-1.0	N/A	0.0	0.3
		-1.6	**0.0**	**3.0**	**0.0**	**3.1**	**-0.6**	**-0.2**	**-2.2**	**-2.2**	**N/A**	**0.1**	**0.9**
		-2.1	0.0	4.0	0.0	4.0	-2.5	-0.5	-3.1	-3.2	N/A	0.0	1.2
N.S.		0.0	0.0	0.0	0.0	0.0	0.0	-0.2	-0.4	-0.3	N/A	0.0	0.0
		-3.8	**0.0**	**1.0**	**0.0**	**1.0**	**-0.4**	**-0.3**	**-0.7**	**-0.8**	**N/A**	**-0.1**	**0.4**
		-3.8	0.0	1.0	0.0	1.0	-1.7	-0.6	-1.5	-1.3	N/A	-0.2	0.4
Nfld.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.2	N/A	N/A	0.0
		0.0	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**-0.3**	**-0.3**	**N/A**	**N/A**	**0.0**
		0.0	0.0	0.0	0.0	0.0	-2.8	0.0	-0.5	-0.5	N/A	N/A	0.0
Canada		-1.2	-1.0	5.7	0.0	7.0	-0.2	1.5	N/A	-0.4	N/A	N/A	1.0
		-2.5	**-2.0**	**11.2**	**0.0**	**12.4**	**-0.5**	**2.4**	**N/A**	**-0.9**	**N/A**	**N/A**	**2.0**
		-3.7	-3.1	16.9	0.0	18.6	-1.1	3.7	N/A	-1.5	N/A	N/A	3.0

Notes:

[a] Results for low adoption rates

[b] Results for medium adoption rates

[c] Results for high adoption rates

Table C.10: Grazing Management: Percentage Change in Land Type, Major Livestock and AEIs for Low, Medium and High Adoption Rates

		CRAM Results						Environmental Indicators					
Province		Cropland	Summerfallow	Hayland	Tame Pasture	Beef Cows	Breeding Sows	GHG	IROWCN	RSN	RWDE	RWE	HA
B.C.	a	-3.8	-2.9	-1.6	6.1	1.1	0.0	-1.7	N/A	-2.3	N/A	-2.3	0.8
	b	**-7.8**	**-6.0**	**-2.8**	**12.0**	**1.9**	**0.0**	**-3.1**	**N/A**	**-4.3**	**N/A**	**-4.7**	**1.6**
	c	-15.1	-11.6	-5.9	24.0	4.1	-0.3	-6.2	N/A	-8.6	N/A	-9.3	3.2
Alta.		-0.3	-0.2	-1.0	2.3	0.2	-0.1	-0.5	N/A	-0.2	-0.2	-0.4	0.2
		-0.9	**-0.6**	**-1.2**	**4.6**	**0.3**	**-0.3**	**-1.3**	**N/A**	**-0.6**	**-0.6**	**-0.9**	**0.5**
		-1.9	-1.6	-1.7	9.2	0.4	-0.6	-2.9	N/A	-1.2	-1.5	-1.7	1.1
Sask.		-0.2	-0.1	0.0	1.7	0.3	0.0	-0.6	N/A	-0.1	-0.1	-0.1	0.1
		-0.3	**-0.1**	**-0.1**	**3.6**	**0.4**	**0.0**	**-1.3**	**N/A**	**-0.2**	**-0.2**	**-0.2**	**0.3**
		-0.6	-0.2	-0.2	7.2	0.7	0.1	-2.7	N/A	-0.5	-0.3	-0.5	0.5
Man.		-0.2	-0.2	-1.7	6.1	0.5	0.0	-0.6	N/A	-0.2	-0.2	-0.3	0.2
		-0.4	**-0.4**	**-3.5**	**12.1**	**0.9**	**0.0**	**-1.2**	**N/A**	**-0.4**	**-0.3**	**-0.6**	**0.3**
		-0.7	-0.7	-7.2	24.2	1.7	0.0	-2.3	N/A	-0.8	-0.5	-1.1	0.5
Ont.		0.0	0.0	0.0	0.0	0.0	0.0	-0.5	0.0	0.0	N/A	0.0	0.0
		0.0	**0.0**	**0.0**	**0.0**	**0.0**	**-0.1**	**-1.0**	**0.0**	**0.0**	**N/A**	**0.0**	**0.0**
		0.0	0.0	0.0	0.0	0.1	0.0	-1.9	0.0	0.0	N/A	0.0	0.0
Que.		0.0	0.0	0.0	0.0	0.0	0.0	-0.2	0.0	0.0	N/A	0.0	0.0
		0.0	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**-0.5**	**0.0**	**0.0**	**N/A**	**0.0**	**0.0**
		0.0	0.0	0.0	0.0	0.1	-0.1	-0.9	0.0	0.0	N/A	0.0	0.0
N.B.		0.0	0.0	0.0	0.0	0.1	-0.2	-0.4	0.0	0.0	N/A	0.0	0.0
		0.0	**0.0**	**0.0**	**0.0**	**0.1**	**-0.1**	**-0.7**	**-0.7**	**-0.9**	**N/A**	**0.0**	**0.0**
		0.0	0.0	0.0	0.0	0.2	-0.3	-1.5	0.0	0.0	N/A	0.0	0.0
P.E.I.		0.0	0.0	0.0	0.0	0.0	-0.4	0.0	0.0	0.0	N/A	0.0	0.0
		0.0	**0.0**	**0.0**	**0.0**	**0.1**	**-0.1**	**0.0**	**0.0**	**0.0**	**N/A**	**0.0**	**0.0**
		0.0	0.0	0.0	0.0	0.2	-0.2	0.0	0.0	0.0	N/A	0.0	0.0
N.S.		0.0	0.0	0.0	0.0	0.0	-0.1	-0.4	0.0	0.0	N/A	0.0	0.0
		0.0	**0.0**	**0.0**	**0.0**	**0.1**	**0.2**	**-0.8**	**0.0**	**0.0**	**N/A**	**0.0**	**0.0**
		0.0	0.0	0.0	0.0	0.2	0.1	-1.6	0.0	0.0	N/A	0.0	0.0
Nfld.		0.0	0.0	0.0	0.0	0.0	0.0	-0.3	0.0	0.0	N/A	N/A	0.0
		0.0	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**-0.6**	**0.0**	**0.0**	**N/A**	**N/A**	**0.0**
		0.0	0.0	0.0	0.0	0.0	0.0	-1.2	0.0	0.0	N/A	N/A	0.0
Canada		-0.2	-0.1	-0.6	2.4	0.3	0.0	-0.5	N/A	-0.3	N/A	N/A	0.1
		-0.5	**-0.3**	**-1.0**	**4.7**	**0.4**	**-0.1**	**-1.2**	**N/A**	**-0.6**	**N/A**	**N/A**	**0.3**
		-1.0	-0.7	-1.8	9.5	0.8	-0.1	-2.4	N/A	-1.2	N/A	N/A	0.6

Notes:

[a] Results for low adoption rates

[b] Results for medium adoption rates

[c] Results for high adoption rates

Table C.11: Combined Feeding Strategies: Percentage Change in Land Type, Major Livestock and AEIs for Low, Medium and High Adoption Rates

		CRAM Results						Environmental Indicators					
Province		Cropland	Summerfallow	Hayland	Tame Pasture	Beef Cows	Breeding Sows	GHG	IROWCN	RSN	RWDE	RWE	HA
B.C.	a	0.0	0.0	0.0	0.0	0.0	-0.6	-0.4	N/A	-1.3	N/A	0.0	0.0
	b	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**-1.2**	**-0.8**	**N/A**	**-2.4**	**N/A**	**0.0**	**0.0**
	c	0.0	0.0	0.0	0.0	0.0	-1.8	-1.2	N/A	-3.7	N/A	0.0	0.0
Alta.		0.0	0.0	0.0	0.0	0.0	-0.9	-0.3	N/A	-0.4	N/A	0.0	0.0
		0.0	**0.0**	**0.0**	**0.0**	**0.0**	**-1.8**	**-0.5**	**N/A**	**-0.7**	**N/A**	**0.0**	**0.0**
		0.0	0.0	0.0	0.0	0.0	-2.7	-0.8	N/A	-1.0	N/A	0.0	0.0
Sask.		0.0	0.0	0.0	0.0	0.0	-1.0	-0.3	N/A	-0.1	N/A	0.0	0.0
		0.0	**0.0**	**0.0**	**0.0**	**0.0**	**-2.1**	**-0.5**	**N/A**	**-0.2**	**N/A**	**0.0**	**0.0**
		0.0	0.0	0.0	0.0	0.0	-3.3	-0.7	N/A	-0.3	N/A	0.0	0.0
Man.		0.0	0.0	0.0	0.0	0.0	-0.4	-0.9	N/A	-0.7	N/A	0.0	0.0
		0.0	**0.0**	**0.0**	**0.0**	**0.0**	**-0.8**	**-1.7**	**N/A**	**-1.4**	**N/A**	**0.0**	**0.0**
		0.0	0.0	0.0	0.0	0.0	-1.2	-2.4	N/A	-2.1	N/A	0.0	0.0
Ont.		0.0	0.0	0.0	0.0	0.0	-0.6	-1.0	-0.8	-0.9	N/A	0.0	0.0
		0.0	**0.0**	**0.1**	**0.0**	**0.0**	**-1.2**	**-1.9**	**-1.6**	**-1.7**	**N/A**	**0.0**	**0.0**
		-0.1	0.0	0.2	0.0	0.1	-1.8	-2.8	-2.5	-2.6	N/A	-0.1	0.0
Que.		0.0	0.0	0.0	0.0	0.0	-0.6	-1.6	-3.1	-3.2	N/A	0.0	0.0
		0.0	**0.0**	**0.0**	**0.0**	**0.0**	**-1.2**	**-2.9**	**-5.9**	**-6.2**	**N/A**	**0.0**	**0.0**
		0.0	0.0	0.0	0.0	0.0	-1.7	-4.3	-8.8	-9.3	N/A	0.0	0.0
N.B.		0.0	0.0	0.0	0.0	-0.1	-1.7	-1.1	-3.7	-3.9	N/A	0.0	0.0
		0.0	**0.0**	**0.0**	**0.0**	**-0.1**	**-3.2**	**-2.0**	**-7.4**	**-7.7**	**N/A**	**0.0**	**0.0**
		0.0	0.0	0.0	0.0	-0.1	-4.7	-2.9	-11.5	-11.9	N/A	0.0	0.0
P.E.I..		0.0	0.0	0.0	0.0	0.0	-1.9	-0.8	-1.7	-1.6	N/A	0.0	0.0
		0.0	**0.0**	**0.0**	**0.0**	**0.0**	**-3.8**	**-1.6**	**-3.1**	**-3.2**	**N/A**	**0.0**	**0.0**
		0.0	0.0	0.0	0.0	-0.1	-5.6	-2.2	-4.8	-4.8	N/A	0.0	0.0
N.S.		0.0	0.0	0.0	0.0	0.0	-1.2	-1.0	-4.4	-4.3	N/A	0.0	0.0
		0.0	**0.0**	**0.0**	**0.0**	**0.0**	**-2.6**	**-1.8**	**-8.8**	**-8.5**	**N/A**	**0.0**	**0.0**
		0.0	0.0	0.0	0.0	-0.1	-3.8	-2.7	-12.8	-12.5	N/A	0.0	0.0
Nfld.		0.0	0.0	0.0	0.0	0.0	0.0	-0.2	-2.3	-2.4	N/A	N/A	0.0
		0.0	**0.0**	**0.0**	**0.0**	**1.9**	**-2.8**	**-0.5**	**-4.7**	**-4.7**	**N/A**	**N/A**	**0.0**
		0.0	0.0	0.0	0.0	3.8	-5.6	-0.7	-7.0	-7.1	N/A	N/A	0.0
Canada		0.0	0.0	0.0	0.0	0.0	-0.7	-0.7	N/A	-1.5	N/A	N/A	0.0
		0.0	**0.0**	**0.0**	**0.0**	**0.0**	**-1.3**	**-1.3**	**N/A**	**-3.1**	**N/A**	**N/A**	**0.0**
		0.0	0.0	0.0	0.0	0.0	-2.0	-1.9	N/A	-4.6	N/A	N/A	0.0

Notes:

[a]Results for low adoption rates

[b]Results for medium adoption rates

[c]Results for high adoption rates

Table C.12: Agro-Forestry: Percentage Change in Land Type, Major Livestock and AEI's for Low, Medium and High Adoption Rates

		CRAM Results						Environmental Indicators					
Province		Cropland	Summerfallow	Hayland	Tame Pasture	Beef Cows	Breeding Sows	GHG	IROWCN	RSN	RWDE	RWE	HA
B.C.	a	-0.6	-0.6	-0.6	-0.6	-0.8	0.1	-4.2	N/A	-0.9	N/A	-0.3	1.3
	b	**-1.4**	**-1.5**	**-1.6**	**-1.5**	**-2.1**	**0.0**	**-10.6**	**N/A**	**-2.3**	**N/A**	**-0.7**	**3.2**
	c	-2.9	-3.0	-3.1	-3.0	-4.2	0.0	-21.3	N/A	-4.5	N/A	-1.4	6.6
Alta.		0.0	0.0	0.0	0.0	0.0	0.0	-0.3	N/A	0.0	0.0	0.0	0.1
		0.0	**0.0**	**-0.1**	**-0.1**	**0.0**	**0.0**	**-0.7**	**N/A**	**-0.1**	**0.0**	**0.0**	**0.1**
		-0.1	-0.1	-0.1	-0.1	-0.1	0.0	-1.3	N/A	-0.1	0.0	0.0	0.3
Sask.		0.0	0.0	0.0	0.0	0.0	-0.1	-0.9	N/A	-0.1	0.0	0.0	0.1
		-0.1	**0.0**	**-0.1**	**-0.1**	**0.0**	**-0.2**	**-2.2**	**N/A**	**-0.1**	**0.0**	**0.0**	**0.3**
		-0.1	-0.1	-0.1	-0.1	0.0	0.0	-4.5	N/A	-0.2	0.0	0.0	0.5
Man.		0.0	0.0	0.0	0.0	0.0	0.0	-0.4	N/A	-0.1	0.0	0.0	0.1
		-0.1	**-0.1**	**-0.1**	**-0.1**	**0.0**	**0.0**	**-0.9**	**N/A**	**-0.1**	**0.0**	**0.0**	**0.3**
		-0.2	-0.1	-0.2	-0.1	-0.1	0.0	-1.9	N/A	-0.3	0.0	0.0	0.5
Ont.		-0.1	0.0	-0.1	-0.1	0.0	-0.1	-0.5	-0.1	-0.1	N/A	0.0	0.0
		-0.2	**0.0**	**-0.2**	**-0.2**	**-0.1**	**-0.2**	**-1.3**	**-0.2**	**-0.2**	**N/A**	**0.0**	**0.0**
		-0.3	0.0	-0.3	-0.3	-0.1	-0.2	-2.6	-0.5	-0.5	N/A	0.0	0.0
Que.		-0.1	0.0	-0.1	-0.1	-0.1	-0.1	-0.7	-0.2	-0.2	N/A	0.0	0.0
		-0.3	**0.0**	**-0.3**	**-0.3**	**-0.1**	**-0.1**	**-1.6**	**-0.3**	**-0.3**	**N/A**	**0.0**	**0.0**
		-0.7	0.0	-0.7	-0.7	-0.3	0.0	-3.2	-0.6	-0.6	N/A	0.0	0.0
N.B.		-0.2	0.0	-0.2	-0.2	-0.2	-0.4	-1.4	0.0	-0.1	N/A	0.0	0.5
		-0.5	**0.0**	**-0.5**	**-0.5**	**-0.4**	**0.0**	**-3.4**	**-0.2**	**-0.2**	**N/A**	**0.0**	**1.2**
		-1.1	0.0	-1.1	-1.0	-0.7	-0.1	-6.7	-0.3	-0.3	N/A	0.1	2.5
P.E.I.		-0.2	0.0	-0.2	-0.3	-0.1	-0.7	-1.6	-0.5	-0.5	N/A	0.0	0.6
		-0.5	**0.0**	**-0.5**	**-0.5**	**-0.3**	**0.0**	**-3.8**	**-1.1**	**-1.0**	**N/A**	**0.1**	**1.5**
		-1.1	0.0	-1.1	-1.1	-0.6	0.0	-7.7	-2.1	-2.1	N/A	0.2	3.0
N.S.		-0.2	0.0	-0.2	-0.2	-0.1	-0.3	-1.0	-0.4	-0.3	N/A	0.0	0.4
		-0.5	**0.0**	**-0.5**	**-0.5**	**-0.4**	**0.0**	**-2.3**	**-0.4**	**-0.4**	**N/A**	**0.1**	**1.1**
		-1.0	0.0	-1.1	-1.0	-0.7	0.0	-4.7	-0.8	-0.8	N/A	0.1	2.2
Nfld.		0.0	0.0	-0.1	-0.4	-1.9	0.0	-0.3	-0.1	-0.1	N/A	N/A	0.3
		0.0	**0.0**	**-0.6**	**-0.4**	**-5.7**	**0.0**	**-0.7**	**-0.4**	**-0.4**	**N/A**	**N/A**	**0.7**
		-2.0	0.0	-1.0	-1.2	-9.4	0.0	-1.3	-0.7	-0.8	N/A	N/A	1.7
Canada		0.0	0.0	-0.1	-0.1	-0.1	-0.1	-0.7	N/A	-0.2	N/A	N/A	0.1
		-0.1	**0.0**	**-0.2**	**-0.1**	**-0.2**	**-0.1**	**-1.7**	**N/A**	**-0.4**	**N/A**	**N/A**	**0.2**
		-0.2	-0.1	-0.4	-0.3	-0.3	0.0	-3.4	N/A	-0.9	N/A	N/A	0.5

Notes:

[a] Results for low adoption rates

[b] Results for medium adoption rates

[c] Results for high adoption rates

Table C.13: Combined Scenario: Percentage Change in Land Type, Major Livestock and AEIs for Low, Medium and High Adoption Rates

		CRAM Results						Environmental Indicators					
Province		Cropland	Summerfallow	Hayland	Tame Pasture	Beef Cows	Breeding Sows	GHG	IROWCN	RSN	RWDE	RWE	HA
B.C.	a	-14.3	-36.0	1.8	11.1	3.8	-0.7	-8.4	N/A	-6.9	N/A	-9.8	4.8
	b	**-24.3**	**-62.0**	**2.1**	**18.6**	**7.1**	**-1.2**	**-17.1**	**N/A**	**-12.2**	**N/A**	**-16.7**	**9.3**
	c	-47.3	-90.0	3.1	33.9	12.9	-1.8	-31.9	N/A	-18.0	N/A	-29.1	17.3
Alta.		-0.6	-23.7	4.8	7.6	6.7	-1.1	-6.2	N/A	-5.0	-18.2	-8.7	3.5
		0.0	**-50.0**	**9.4**	**12.5**	**10.6**	**-1.9**	**-15.9**	**N/A**	**-10.7**	**-40.4**	**-18.9**	**6.6**
		-0.7	-77.0	13.4	22.3	18.2	-2.8	-26.3	N/A	-15.6	-57.7	-29.7	10.5
Sask.		0.2	-17.7	15.7	12.8	16.3	-1.3	-21.3	N/A	-7.3	-13.8	-7.1	4.5
		1.8	**-40.0**	**31.2**	**20.2**	**32.8**	**-2.4**	**-50.4**	**N/A**	**-13.9**	**-31.0**	**-15.1**	**9.0**
		2.9	-64.0	46.9	34.9	45.9	-3.5	-77.8	N/A	-20.8	-44.0	-21.1	14.4
Man.		-0.9	-27.0	4.0	15.3	8.2	-0.5	-9.8	N/A	-6.9	-10.5	-7.1	2.5
		-1.3	**-54.0**	**7.7**	**25.7**	**15.3**	**-0.9**	**-21.9**	**N/A**	**-11.7**	**-24.4**	**-15.7**	**4.7**
		-2.3	-90.0	11.1	46.6	25.3	-1.3	-41.2	N/A	-16.9	-47.2	-29.0	7.9
Ont.		-1.5	0.0	2.0	4.6	0.3	-1.2	-4.8	-6.8	-6.8	N/A	-1.4	0.9
		-2.7	**0.0**	**4.0**	**6.8**	**1.6**	**-1.8**	**-8.8**	**-13.6**	**-13.7**	**N/A**	**-2.5**	**1.6**
		-4.7	0.0	7.0	11.3	2.9	-2.8	-14.8	-14.7	-14.8	N/A	-4.3	2.8
Que.		-1.8	0.0	1.0	3.8	0.6	-0.7	-4.7	-7.5	-7.8	N/A	-1.0	0.7
		-3.3	**0.0**	**2.0**	**5.5**	**1.8**	**-1.4**	**-9.0**	**-14.7**	**-15.3**	**N/A**	**-1.9**	**1.2**
		-4.7	0.0	2.0	9.1	1.8	-2.0	-14.2	-17.8	-18.4	N/A	-2.6	1.6
N.B.		-3.3	0.0	1.2	3.7	0.1	-1.9	-4.8	-8.1	-8.3	N/A	-0.6	1.2
		-4.4	**0.0**	**1.0**	**5.3**	**5.6**	**-3.7**	**-8.3**	**-14.1**	**-14.7**	**N/A**	**-1.2**	**2.1**
		-8.2	0.0	2.0	8.6	10.0	-5.2	-13.8	-19.5	-20.0	N/A	-2.2	4.2
P.E.I.		-1.8	0.0	1.2	7.5	0.6	-2.5	-4.7	-12.1	-11.9	N/A	-0.2	1.3
		-3.6	**0.0**	**3.0**	**11.2**	**4.8**	**-4.1**	**-9.3**	**-19.3**	**-19.0**	**N/A**	**-0.4**	**2.9**
		-5.8	0.0	4.0	18.4	6.1	-6.1	-15.1	-21.7	-21.5	N/A	-0.7	5.2
N.S		-3.0	0.0	0.0	1.5	0.1	-1.6	-2.8	-4.7	-4.7	N/A	-0.4	0.7
		-9.3	**0.0**	**1.0**	**2.1**	**3.2**	**-2.9**	**-5.3**	**-9.1**	**-9.0**	**N/A**	**-0.7**	**1.9**
		-13.8	0.0	1.0	3.4	4.4	-4.2	-9.5	-13.5	-13.3	N/A	-1.2	3.4
Nfld.		-31.4	0.0	0.0	5.1	0.0	-2.8	-1.0	-2.5	-2.5	N/A	N/A	1.6
		-51.0	**0.0**	**0.0**	**7.9**	**0.0**	**-2.8**	**-2.0**	**-5.0**	**-5.0**	**N/A**	**N/A**	**2.9**
		-86.3	0.0	0.0	13.0	0.0	-5.6	-3.6	-7.4	-7.4	N/A	N/A	5.0
Canada		-0.5	-20.0	5.9	9.5	8.5	-0.9	-8.9	N/A	-5.9	N/A	N/A	3.3
		0.2	**-43.6**	**11.6**	**15.4**	**15.9**	**-1.6**	**-20.3**	**N/A**	**-11.2**	**N/A**	**N/A**	**6.5**
		0.1	-69.1	17.1	27.1	24.4	-2.3	-33.4	N/A	-15.6	N/A	N/A	10.5

Notes:

[a] Results for low adoption rates

[b] Results for medium adoption rates

[c] Results for high adoption rates

APPENDIX D

PROVINCIAL SUMMARIES

British Columbia

Results of the current analysis show that the suite of environmental management scenarios has a desirable impact on all AEIs in British Columbia. These results are driven by changes in land use and livestock and are summarized in Figure D.1. In British Columbia, land use shifts from cropland and summerfallow to hayland and tame pasture. Under medium adoption rates, cropland decreases by 47,000 ha and summerfallow by 18,000 ha. The area in hayland and tame pasture increase by 9,000 ha and 43,000 ha respectively. The remaining 13,000 ha are converted to afforestation.

Figure D.1: Summary of Percentage Change in Land Use Type and Livestock for British Columbia Under Low, Medium and High Adoption Rates

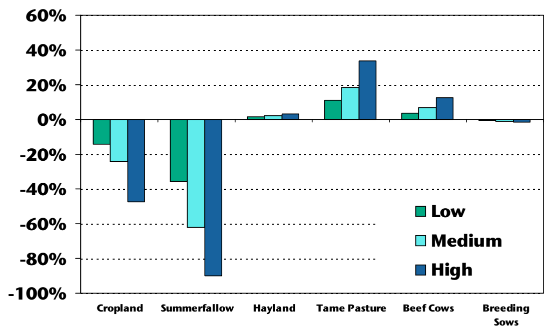
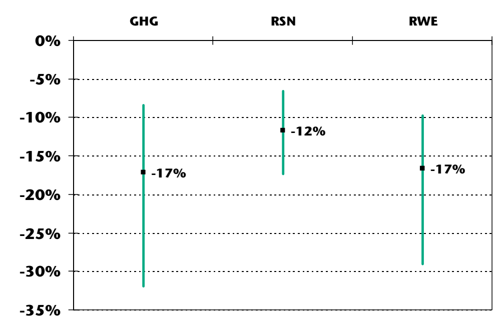


Figure D.2 provides a summary of the percentage change in AEIs for British Columbia. The vertical line associated with each indicator represents the range of impact for low to high adoption rates (see Appendix A). The black marker represents the impact under medium adoption rates. The HA indicator is not included in the figure below since it is represented by a positive change from the base, a 9% change under medium adoption rates and a range of 5% to 17% under low and high adoption rates.

Figure D.2: Summary of Percentage Change in AEIs for British Columbia under Low, Medium and High Adoption Rates



The largest percentage change in AEIs is reflected in the GHG and RWE indicators, which show a 17% improvement under medium adoption rates. The main drivers of these results are the afforestation, grazing management and permanent cover scenarios. The wide range of impact suggests that these indicators are sensitive to the level of adoption. It is important to note that the reduction in the RWE indicator is likely understated since the current models do not account for differences in tillage types for non-Prairie provinces. Future work will involve alteration of the necessary models to account for tillage differences.

Alberta

Results of the analysis show that the environmental management scenarios have a desirable impact on all AEIs for Alberta. These results are driven by the changes in land use and livestock levels. Figure D.3 summarizes the percentage change in land use types and livestock for Alberta. A substantial amount of land shifts from cropland and summerfallow to hayland and tame pasture. Under medium adoption rates, cropland decreases by 3,000 ha and summerfallow by 514,000 ha. The area in hayland and tame pasture increase by 232,000 ha and 278,000 ha respectively - the remaining hectares are converted to afforestation. The increase in hay and tame pasture area is accompanied by an increase in beef cows.

Figure D.4 summarizes the magnitude of impact of the combined scenarios on the AEIs. The vertical line associated with each indicator represents the range of impact for low to high adoption rates (see Appendix A). The black marker represents the impact under medium adoption rates. The HA indicator is not included in the figure since it is represented by a positive change from the base. The HA indicator increased by 7% for medium adoption rates, and 3% to 11% for low and high adoption rates respectively.

In Alberta, the largest impact occurs in the RWDE indicator. The summerfallow and zero tillage scenarios are the main drivers of this result. Overall, scenarios with the largest impact in Alberta are better nitrogen matching, increased zero tillage and reduced summerfallow.

Figure D.3: Summary of Percentage Change in Land Use Type and Livestock for Alberta under Low, Medium and High Adoption Rates

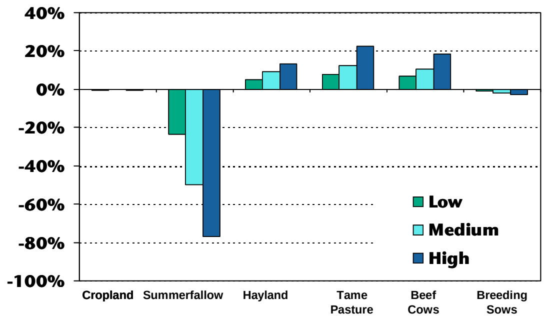


Figure D.4: Summary of Percentage Change in AEIs for Alberta under Low, Medium and High Adoption Rates

Saskatchewan

The suite of management scenarios results in a desirable impact on all AEIs. These results are driven by the changes in land use and livestock levels. In Saskatchewan, the overall impact of the scenarios on land use is a shift from cropland and summerfallow to hayland and tame pasture (Figure D.5). Under medium adoption rates, cropland increases by 267,000 ha and summerfallow decreases by 1 million ha. The area in hayland and tame pasture increases by 479,000 ha and 285,000 ha respectively - the remaining hectares are converted to afforestation. The rise in hay and tame pasture is accompanied by an increase in beef cows. The increase in cropland is due to the fact that the amount of land converted to cropland in the reduced summerfallow scenario is greater than the total cropland conversion to forage and afforestation in all the other scenarios.

Figure D.5: Summary of Percentage Change in Land Use Type and Livestock for Saskatchewan under Low, Medium and High Adoption Rates

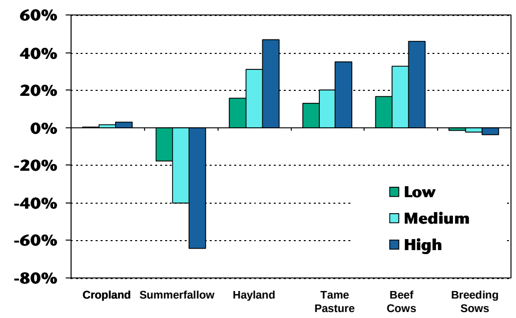
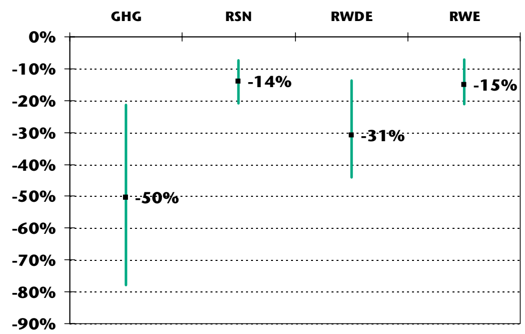


Figure D.6: Summary of Percentage Change in AEIs for Saskatchewan under Low, Medium and High Adoption Rates



The impact of the scenarios on the AEIs is summarized in Figure D.6. The vertical line associated with each indicator represents the range of impact for low to high adoption rates (see Appendix A). The black marker represents the impact under medium adoption rates. The HA indicator is not included in the figure since it is represented by a positive change from the base. The HA indicator increases by 9% under medium adoption rates, and 4% and 14% for low and high adoption rates respectively.

Scenarios with the greatest impact in Saskatchewan are nitrogen matching, zero tillage and reduced summerfallow. These scenarios are the major drivers of the change for the GHG and RWDE indicators. Increased use of forage in crop rotations results in a relatively large increase in GHG emissions (12%) due to the increase in the number of livestock. However, the overall combined effect of the scenarios is a reduction in emissions.

In Saskatchewan, the suite of management scenarios has the largest impact on the GHG indicator. GHG emissions are reduced by 50% (5.1 Mt CO_2 equivalent), which is 42% of total national emission reductions.

Manitoba

The results indicate that all the management scenarios have a desirable impact on all AEIs. These results are driven by the changes in land use and livestock levels. In Manitoba, land use shifts from cropland and summerfallow to hayland and tame pasture (Figure D.7). Cropland and summerfallow decrease by 54,000 ha and 115,000 ha respectively. Hayland increases by 66,000 ha and tame pasture by 98,000 ha. Beef cow numbers increase while breeding sow numbers decline slightly.

Among the AEIs, the largest percentage changes occur for RWDE and GHG indicators. Figure D.8 summarizes the overall impact of the scenarios on each indicator. The vertical line associated with each indicator represents the range of impact for low to high adoption (see Appendix A). The black marker represents the impact under medium adoption rates. The HA indicator is not included in the figure below since it is represented by a positive change from the base. Under medium adoption rates, the HA indicator increases by 5%. Results for low and high adoption rates are 3% and 8% respectively.

Scenarios with the greatest impact on AEIs for Manitoba are nitrogen matching, zero tillage and reduced summerfallow.

It should be noted that the 2008 BAU estimate for RSN is much higher in Manitoba than in other provinces. This is due to the fact that the nitrogen fertilizer sales (per ha basis), one of the main drivers of the model, are highest in Manitoba.

Figure D.7: Summary of Percentage Change in Land Use Type and Livestock for Manitoba under Low, Medium and High Adoption Rates

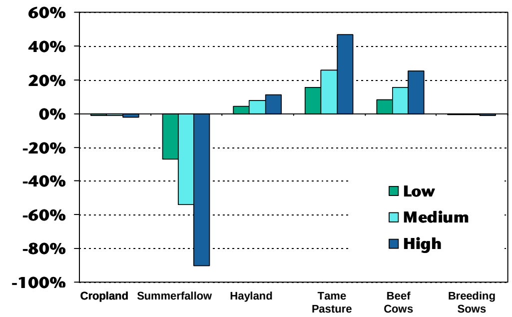
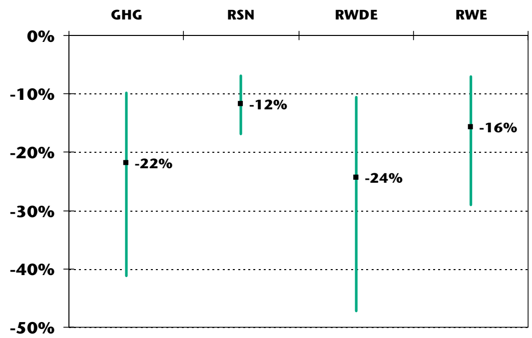


Figure D.8: Summary of Percentage Change in AEIs for Manitoba under Low, Medium and High Adoption Rates



Ontario

The environmental management scenarios result in a change in the AEIs, which suggests an improvement in air, soil and water quality and biodiversity in Ontario. These results are mainly driven by the changes in land use and livestock numbers (Figure D.9). Under medium adoption rates, cropland decreases by 69,000 ha while the area in hayland and tame pasture increase by 42,000 ha and 21,000 ha respectively - the remaining hectares are converted to afforestation. The increase in forage is accompanied by an increase in beef cows and a decline in breeding sows.

Figure D.9: Summary of Percentage Change in Land Use Type and Livestock for Ontario under Low, Medium and High Adoption Rates

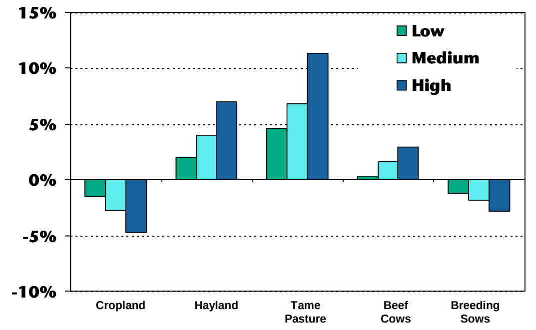
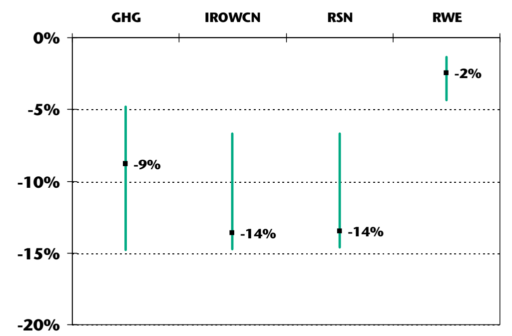


Figure D.10 summarizes the overall impact of the scenarios on each indicator for Ontario. The vertical line associated with each indicator represents the range of impact for low to high adoption rates (see Appendix A). The black marker represents the impact under medium adoption rates. The HA indicator is not included in the figure since it is represented by a positive change from the base. Under medium adoption rates, the HA indicator increases by 2%. Results for low and high adoption are 1% and 3% respectively.

Figure D.10: Summary of Percentage Change in AEIs for Ontario under Low, Medium and High Adoption Rates



A relatively large percentage reduction (14%) occurs in IROWCN and RSN indicators. This reduction is driven by the nitrogen matching scenario, which assumes a reduction in excess nitrogen on corn crops in Ontario. It is important to note that the reduction in the RWE indicator is likely understated since the current models do not account for differences in tillage types for non-Prairie provinces. Future work will involve alteration of the necessary models to account for tillage differences.

Quebec

Combined scenario results for Quebec show that all indicators are moving in the desired direction. These results are mainly driven by the changes in land use and livestock numbers. A summary of the changes in land use type and livestock numbers for Quebec is presented in Figure D.11. The suite of management scenarios result in a shift from cropland (33,000 ha) to hayland (16,000 ha) and tame pasture (10,000 ha), with the remainder of the land shifting to afforestation. The number of beef cows increases slightly due to increased forage, while breeding sows decline marginally.

Figure D.11: Summary of Percentage Change in Land Use Type and Livestock for Quebec under Low, Medium and High Adoption Rates

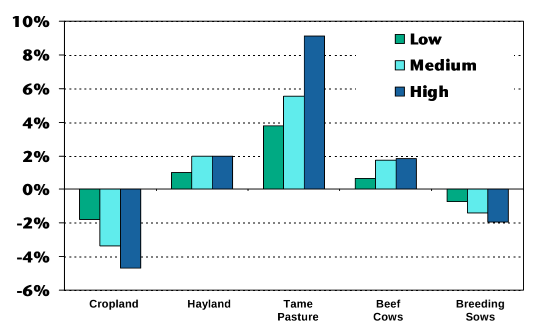


Figure D.12 is a summary of the overall impact on each indicator. The vertical line associated with each indicator represents the range of impact for low to high adoption rates (see Appendix A). The black marker represents the impact under medium adoption rates. The HA indicator is not included in the figure below since it is represented by a positive change from the base. The HA indicator increases by 1% under medium adoption rates, and 1% and 2% under low and high adoption rates respectively.

The suite of scenarios has the greatest impact on the IROWCN and RSN indicators. A reduction of 15% in nitrogen indicators suggests an improvement in water and soil quality. Scenarios with the greatest impact in Quebec are: 1) nitrogen matching - impacts IROWCN and RSN and 2) combined feeding - impacts IROWCN, RSN and GHG. It is important to note that the overall reduction in the RWE indicator is likely understated since the current models do not account for differences in tillage types for non-Prairie provinces. Future work will involve alteration of the necessary models to account for tillage differences.

Figure D.12: Summary of Percentage Change in AEIs for Quebec under Low, Medium and High Adoption Rates

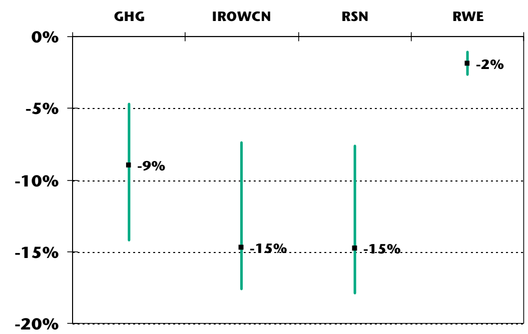


Figure D.13: Summary of Percentage Change in Land Use Type and Livestock for New Brunswick under Low, Medium and High Adoption Rates

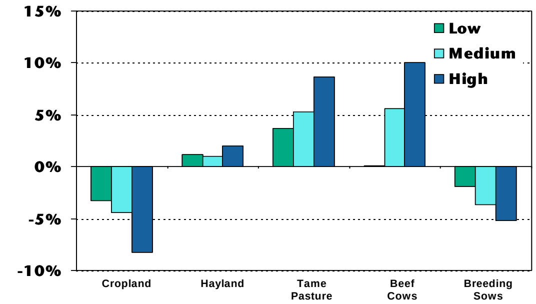
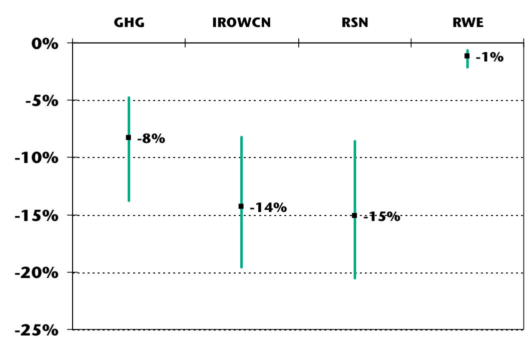


Figure D.14: Summary of Percentage Change in AEIs for New Brunswick under Low, Medium and High Adoption Rates



New Brunswick

In New Brunswick, the environmental management scenarios have an overall desirable impact on the AEIs. These results are mainly driven by the changes in land use and livestock numbers. Changes in land use are small - approximately 1,800 ha (medium adoption) of cropland are shifted to hayland and tame pasture (Figure D.13) and 800 ha to afforestation. Breeding sow numbers fall by approximately 4% (medium adoption) and beef cow numbers increase by 6%.

Figure D.14 is a summary of the impact on the AEIs. The vertical line associated with each indicator represents the range of impact for low to high adoption rates (see Appendix A). The black marker represents the impact under medium adoption rates. The HA indicator is not included in the figure below since it is represented by a positive change from the base. The HA indicator increases by 2% under medium adoption rates and 1% and 4% under low and high rates respectively.

The largest percentage change from the baseline occurs for the IROWCN and RSN indicators. The changes in IROWCN and RSN are mainly a result of the nitrogen matching scenario (reduced nitrogen fertilizer application on potatoes) and the combined feeding scenario.

Prince Edward Island

The environmental management scenarios have a desirable impact on all indicators in Prince Edward Island. AEI impacts are driven by changes in land use and livestock numbers. Figure D.15 summarizes the percentage change in land use type and livestock numbers. Cropland is reduced by 4,100 ha, hayland and tame pasture increase by 1,800 ha and 1,300 ha respectively - the remaining hectares are converted to afforestation.

The percentage changes in AEIs from the baseline are shown in Figure D.16. The vertical line associated with each indicator represents the range of impact for low to high adoption rates (see Appendix A). The black marker represents the impact under medium adoption rates. The HA indicator is not included in the figure below since it is represented by a positive change from the base. The HA indicator increases by 3% under medium adoption rates and 1% and 5% under low and high rates respectively.

The large reduction in IROWCN and RSN is mainly driven by the nitrogen matching scenario due to reduced nitrogen fertilizer application on potatoes, with a lesser impact from the combined feeding scenario.

Nova Scotia

Results of the analysis show that the combined environmental management scenarios have a desirable impact on all indicators in Nova Scotia. AEI impacts are driven by changes in land use and livestock numbers. Figure D.17 summarizes the percentage change in land use type and livestock numbers for Nova Scotia. Cropland is reduced by 1,900 ha and hayland and tame pasture increase by 760 ha and 490 ha respectively - the remaining hectares are converted to afforestation.

Figure D.15: Summary of Percentage Change in Land Use Type and Livestock for Prince Edward Island under Low, Medium and High Adoption Rates

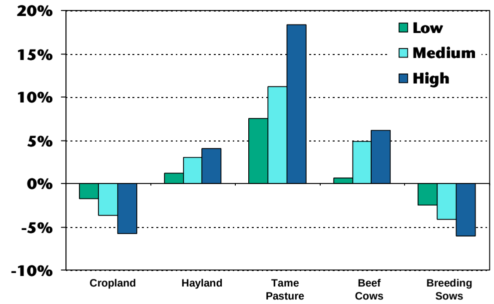


Figure D.16: Summary of Percentage Change in AEIs for Prince Edward Island under Low, Medium and High Adoption Rates

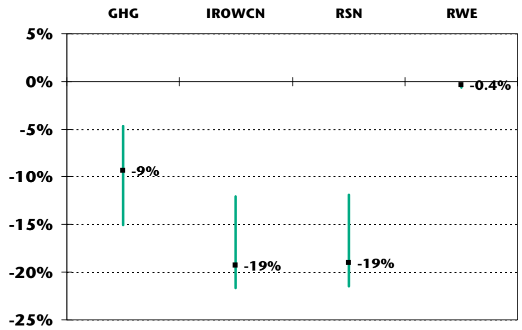
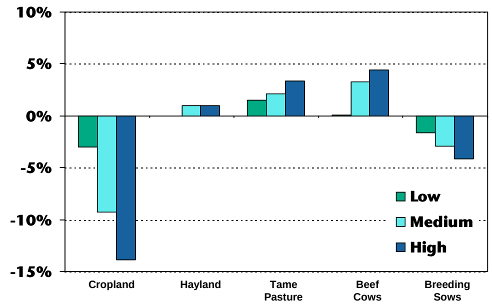


Figure D.17: Summary of Percentage Change in Land Use Type and Livestock for Nova Scotia under Low, Medium and High Adoption Rates



The percentage changes in AEIs from the baseline are shown in Figure D.18. The vertical line associated with each indicator represents the range of impact for low to high adoption rates (see Appendix A). The black marker represents the impact under medium adoption rates. The HA indicator is not included in the figure below since it is the only indicator with a positive change from the base. The HA indicator increases by 2% under medium adoption rates, and 1% and 3% under low and high rates respectively.

Reductions in the GHG indicator are mainly due to the combined feeding and afforestation scenarios. The decreases in the IROWCN and RSN indicators are driven by the combined feeding scenario.

Newfoundland

In Newfoundland, the environmental management scenarios have an overall desirable impact on the AEIs. These results are mainly driven by the changes in land use and livestock numbers. Changes in land use are extremely small due to the limited amount of agricultural land in the province. Some cropland (260 ha) is shifted to tame pasture and afforestation in the combined scenario (Figure D.19). Breeding sow numbers fall by approximately 3% (medium adoption) due to increased domestic feed grain prices as the result of reduced production in other provinces. Beef cow numbers are unchanged.

Figure D.20 is a summary of the impact on the AEIs. The vertical line associated with each indicator represents the range of impact for low to high adoption rates (see Appendix A). The black marker represents the impact under medium adoption rates. The HA indicator is not included in the figure below since it is represented by a positive change from the base. The HA indicator increases by 3% under medium adoption rates, and 2% and 5% under low and high rates respectively.

The scenario with the greatest impact on the environmental indicators in Newfoundland is the combined feeding strategy, impacting GHG, IROWCN and RSN. Due to the relatively small land base for agricultural production combined with the large scale of the models used in this analysis, the results for Newfoundland are somewhat limited in their usefulness for developing targets.

Figure D.18: Summary of Percentage Change in AEIs for Nova Scotia under Low, Medium and High Adoption Rates

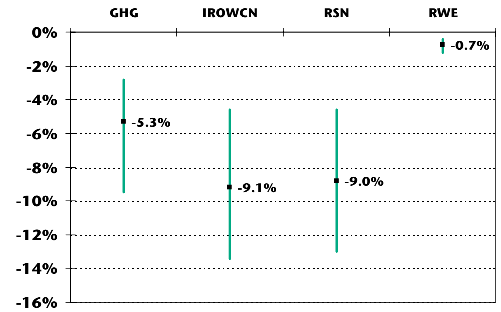


Figure D.19: Summary of Percentage Change in Land Use Type and Livestock for Newfoundland under Low, Medium and High Adoption Rates

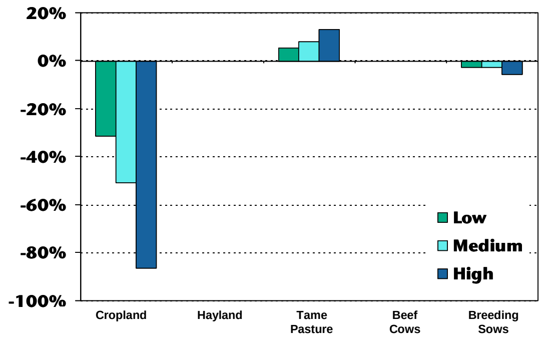
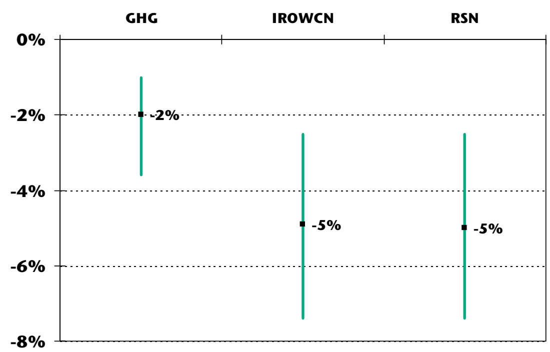


Figure D.20: Summary of Percentage Change in AEIs for Newfoundland under Low, Medium and High Adoption Rates



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