Environmental and Economic Evaluation of Conventional and Organic Production Systems in the Canadian Prairie Provinces

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Fulfillment of the Requirements

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In the Department of Agricultural Economics

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by

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Abstract

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Supervisor: Dr. Suren Kulshreshtha

Greenhouse gas emissions have been a growing concern throughout the world, particularly in the Western society. Agriculture has been identified as both a major source of greenhouse gas emissions and a potential solution in mitigating emissions through carbon sequestration. Changing agriculture current production practices (called conventional production system) to an organic production system can reduce the need for synthetically produced agricultural inputs, and thereby reduce these emissions. However, this may generate other co-benefits (or costs) to the society. The focus of this study was to evaluate the implications of converting conventional agriculture production system to an organic one for greenhouse gas emissions, level of agricultural production, farmer net income, regional and national level changes (in terms of gross domestic product, household income, and employment levels). The scope of the study was limited to the Prairie Provinces in Canada. This area was selected because it contained a majority of area under organic production system in Canada. Since there are several types of changes resulting from the conversion, a trade-off analysis was used to evaluate the overall desirability of the two options – conventional production system and the organic production system.

Multiple models were used to estimate various criteria. These included: the Canadian Regional Agriculture Model (CRAM), the Greenhouse Gas Emissions Model (GHGEM), and the Canadian Agriculture Regional Development Input-Output Model (CARDIOM).

The study concluded that converting land under conventional production system to an organic production system reduces greenhouse gas emissions and improves regional gross domestic product, household income, and employment. However, it results in a reduction in quantity of agricultural production, national gross domestic product, national household income, and national employment.

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Chapter 1

Introduction

1.1 Introduction

Impact of agriculture on the environment, commonly referred to an example of externality created by agriculture, has come increasingly under the microscope (Hanley, 1991). An externality is an unpriced interdependence between two of more economic agents (firms or households). Climate change is one of the externality created by economic activities.

Over the past century, the climate on earth has become increasingly warm. The Intergovernmental Panel on Climate Change (IPPC) has reported that the surface temperature of the earth has increased between 0.4°C and 0.8°C (IPCC, 1996b). Temperature increases have varied significantly on a regional scale; however the global surface temperature increase is the matter of great concern. Although a temperature change of between 0.4°C and 0.8°C may appear insignificant or minute, recall that the last ice age was as a result of a change in temperature of only approximately 5°C (IPCC, 1996b).

Greenhouse gas (GHG) emissions are commonly believed to be the root cause of climate change. These emissions occur both naturally and as a result of human activity (IPCC, 1996a). Climate change, according to the IPCC, refers to “any change in climate over time, whether due to natural variability or as a result of human activity” (IPCC, 2002). United Nations Framework Convention on Climate Change (UNFCCC) describes climate change as “a change to climate that is attributable directly or indirectly to human activity that alters the composition of the global atmosphere and that is, in addition to natural climate variability, observed over a comparable time periods” (IPCC, 2002).

Human activities cause changes in the natural cycles of the earth's atmosphere. According to Environment Canada (2005), the burning of fossil fuels and the generation of hydrocarbons is greatly disrupting the carbon cycle[1]. The human consumption of oil and coal, as well as the elimination of forests in both the developed and developing worlds has both increased carbon in the atmosphere and reduced the planet's ability to sequester carbon.

The greenhouse effect is the build-up in the concentration of trace gases in the atmosphere, as referred to as the increase of Radiatively Important Gases (RIGs) (Ayres and Walter, 1991). Ayres and Walter describe RIGs as carbon dioxide (CO_2), nitrous oxide (N_20), methane (CH_4), ozone (O_3), and chlorofluorocarbons (CFCs). RIGs are harmful to the earth's atmosphere because they absorb and reradiate long-wave thermal radiation. This creates changes to the balance of radiation within the earth and traps more energy in the global atmosphere (Ayres and Walter, 1991).

Carbon dioxide is primarily released into the atmosphere through the burning of fossil fuels in combustible engines (Environmental Protection Agency, 2006). Methane emissions are released through the production and transportation of raw materials such as coal, oil, and natural gas. In addition, methane emissions are a by-product of the decomposition of organic waste from municipal solid waste landfills and municipal lagoons, as well as the production of all types of livestock (Environmental Protection Agency, 2006). Nitrous oxide emissions are emitted primarily from synthetic inputs. The most notable of these synthetic inputs being nitrogen fertilizer in agriculture, general industrial activities, and the by-product of combustion of solid waste and fossil fuels (Environmental Protection Agency, 2006).

[1] The carbon cycle is the movement and storage of carbon. Carbon is found and stored in vegetation, the ocean, within rock sediment, and within the atmosphere. Carbon is stored in carbon sinks, such as forests or oil reserves and coal. A sink is anything that traps carbon, taking it out of the atmosphere.

Scientists and politicians around the world have identified agriculture as one of the major contributors to the world's GHG emissions (Rosenberg et al., 1998; Cole et al., 1997). Within Canada, the Federal Government has identified that "primary agriculture contributes approximately 10 per cent of Canada's GHG emissions, not including transportation, input costs, or agri-food processing" (Government of Canada, 2000). Other sources peg agriculture emissions at 10 to 12 per cent of the total estimated GHG emissions (Smith et al., 2007 and Bellarby, et al., 2008). According to one study, over 65 per cent of total methane emissions and 80 per cent of nitrous oxide emissions are emitted from agricultural activities (Desjardins et al., 2001).

Agriculture is a major producer of methane and nitrous oxide. The breakdown of agricultural GHG emissions in Canada, per Desjardins et al. (2001), is shown in Figure 1.1. Nitrous oxide accounts for approximately 53 per cent of Canada's total GHGs from agriculture. Methane and carbon dioxide account for approximately 36 per cent and 11 per cent, respectively.

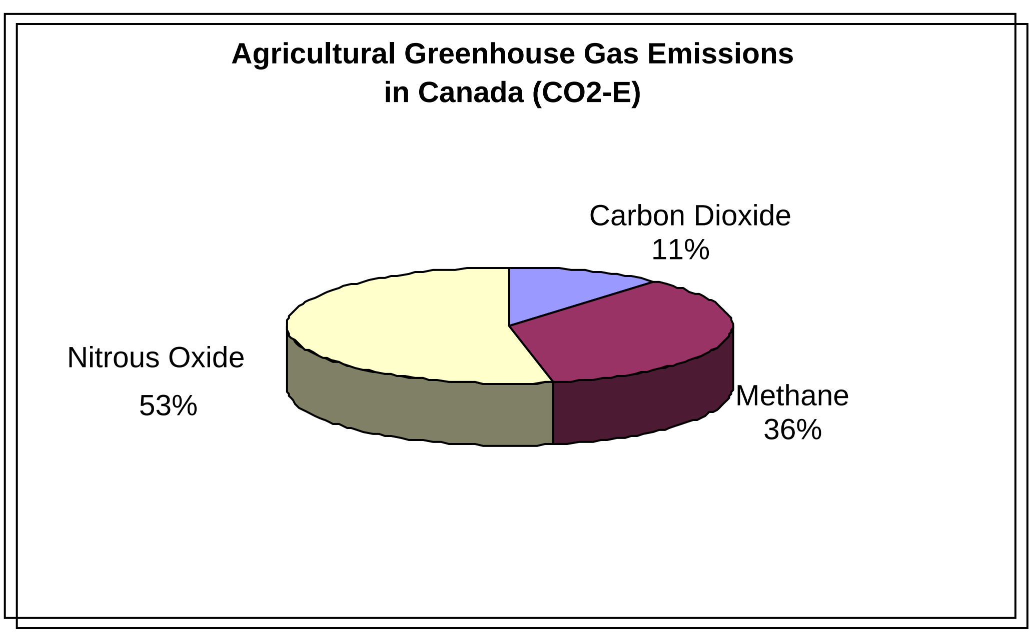

Figure 1.1 Greenhouse gas emissions in Canada

Source: Desjardins et al. (2001)

Lemmen et al. (2008) indicate that all regions of Canada are showing impacts of climate change. The authors explain that "climate change will exacerbate many current climate risks, and present new risks and opportunities with significant implications for communities, infrastructure, and ecosystems." In addition, Lemmen et al. (2008) note that resource-dependent industries, such as agriculture, are particularly vulnerable to the effects of climate change. Due to the importance of agriculture across the Prairie Provinces[2], impacts of climate change are extremely significant. Sauchyn and Kulshreshtha (2008) have made the following statements on the impacts of climate change which could be experienced across the Prairie Provinces:

- Increases in the water scarcity represent the most serious climate risk in the Prairie Provinces;
- Ecosystems will be impacted by shifts in bioclimate, changes in fire and insect disturbances, stressed aquatic habitats, and the introduction of non-native species, with implications for livelihoods and economies dependent on ecological services;
- The Prairies are losing some advantage of a cold winter. Cold winters limit pests and diseases, facilitate winter operations in the forestry and energy sectors, and provide access to remote communities through the use of winter roads;
- Communities dependent on agriculture and forestry are highly sensitive to climate variability and extremes. Droughts, which can have associated economic impacts of billions of dollars, wildfires and severe floods, are projected to occur more frequently in future.

Many of these impacts could have a significant effect on producers, and result in significant changes for society.

1.2 Need for Study

As mentioned above, Canada's agriculture sector contributes approximately 10 per cent of Canada's GHG emissions. Due to the high level of emissions the industry produces under

[2] Prairie Provinces refer to Alberta, Saskatchewan, and Manitoba.

current management, it is imperative that alternative production practices are investigated to identify methods of reducing total emissions.

Organic farming eliminates the use of synthetic fertilizers and synthetic pest control mechanisms, potentially reducing total GHG emissions from agriculture. In addition, organic agriculture utilizes beneficial management practices which incorporate mitigation strategies for reducing GHG emissions (Scialabba, 2000). A recent report by the Food and Agriculture Organization (see Niggli, 2009) indicates that "organic agriculture reduces energy requirements for production systems by 25 to 50 per cent compared to conventional chemical-based agriculture". The report reveals that an additional 20 per cent of agricultural GHG emissions could be eliminated from agriculture by abandoning the use of industrially-produced nitrogen fertilizer (Niggli et al., 2009). The combination of reduced emissions from the employment of organic agriculture and elimination of nitrogen fertilizer production could possibly make farming a carbon neutral industry (Niggli et al., 2009).

The adoption of organic agriculture may potentially benefit many parties, including producers, federal and/or provincial governments, and the environment. European farmers have converted from conventional agriculture to organic agriculture at a much more rapid pace than North America farmers. One reason that European farmers have been able to convert to organic agriculture more quickly is because some European governments subsidize producers during the transition period from conventional to organic farming (Häring, 2001). Some of the benefits observed from this conversion are increases in net farming income, perceived improvements in food quality and a minimization of negative environmental impacts from agricultural production (Häring, 2001).

Although the role of organic agriculture in mitigation of GHG emissions is recognized, there may be other impacts on the economy. As demand for farm inputs contributing to GHG emissions decreases (fertilizer and pesticides), some of the industries producing these inputs would be affected adversely. Eventually some of these impacts could result in lower regional economic development. In other words, conversion from conventional to organic agriculture, in addition to GHG mitigation, may result in lower economic activity. Thus, a situation of trade-off between environmental protection and economic development may result from such a conversion.

In Canada, there has been minimal research done on organic agriculture's role in GHG mitigation. Most studies are primarily based upon the effect of tillage practices on GHG emissions. Some studies, such as the Alternative Cropping System (ACS) by Agriculture and Agri-Food Canada, and the Glenlea Study at the University of Manitoba[3] have examined some of these questions. Nonetheless, there is a need for a study involving an integrated economic – environmental evaluation of organic agriculture against farms and society at large in terms of GHG emissions and economic desirability from producer and regional economic point of view.

Beyond the impacts that the conversion of productions systems will have on agriculture, such as changes to levels of production and net farm returns, and on the environment, there may be externalities that are generated for communities, regions and Canada as a whole. There has been very little research done in Canada that evaluates these externalities.

This study evaluates external benefits and costs that could influence the Prairie Provinces and other parts of Canada. These externalities could include impacts in terms of GHG emissions,

[3] These are examples where the organic production system is a topic of investigation.

gross domestic product (GDP) and employment levels within the Prairie provinces and in other regions of Canada.

1.3 Problem Statement

In the study of organic agriculture in the Prairie Provinces, a number of questions require further investigation. Among these numerous questions, the following are particularly noteworthy:

1. How effective is converting agriculture systems from conventional to organic practices in reducing GHG emissions?
2. What are the societal costs and benefits as a result of a transition from conventional to organic agriculture?

One could hypothesize that further expansion of organic agriculture in the prairie region of Canada will reduce environmental damage and possibly create economic gains. In 2006, the European Union and its member countries reached the conclusion that this hypothesis is true (Walls, 2006). Organic agriculture may increase gross domestic product (GDP) of a region through increase economic activity. Organic agriculture is more labour intensive than conventional agriculture. Increased employment opportunities may result in increased spin-off employment and increased GDP, with a greater number of business transactions in those communities where organic agriculture is employed. All of these may result in more economic growth in rural communities.

One could hypothesize that conversion of areas currently under conventional production system to organic production system may create some trade-offs. This conversion will likely have trade-off effects on the following:

1. Total production levels of products generated from conventional versus organic agriculture;
2. Difference in GHG emissions generated by conventional versus organic agriculture;
3. Change in the farm income;
4. Changes in employment levels in an area created by conventional versus organic agriculture; and,
5. Total GDP produced in a region as a result of conventional versus organic agriculture.

In order to further promote such conversions in Canada, one must evaluate these trade-offs. The overall reduction in GHG emissions must be balanced against economic costs (or benefits) from such a conversion. This study was undertaken to fill this void in Canada, particularly with respect to the Prairie Provinces.

1.4 Objectives of the Study

The study was designed to meet the following objectives:

1. Review the current state of organic agriculture industry in the Prairie Provinces;
2. Evaluate the environmental implications (as measured through GHG emissions) of conversion of land under conventional production system into organic production system;
3. Determine the economic effect of conversion from conventional to organic production system on Prairies producers;
4. Estimate changes to employment levels within individual Prairie Provinces and other parts of Canada as a result of a shift towards increased organically managed land;

5. Estimate regional economic consequences (measured as gross domestic product) of the conversion to organic production system for the three Prairie Provinces and for other parts of Canada; and,
6. Evaluate the trade-offs between economic returns (producer, regional and national levels) and total GHG emission reduction.

1.5 Scope of the Study

This study is limited to the three Canadian Prairie Provinces – Alberta, Saskatchewan, and Manitoba. These provinces represent the majority of dryland organic agriculture production in Canada. The study will evaluate changes to yield, levels of GHG emissions, and economic consequences that are caused by a conversion of agricultural land from a conventional production system to an organic productions system. Although food processing is an important component of the agriculture and agri-food system, it was excluded because most organic crops are exported for further processing abroad. Furthermore, at the retail level, data on sales of these products is very poor. Although a part of the crop mix includes forages, which have a strong relationship with livestock production, in this study organic livestock production was excluded.

1.6 Hypothesis

This study hypothesizes that conversion of agricultural land from conventional to organic production system is a win-win situation. The positive effects would be realized through reduction in GHG emissions because of the reduced use of the synthetic fertilizers and pest control products, which contribute significantly to emissions. At the producer level, higher prices for organic products will offset the lower production levels, resulting in higher income for the primary producers. Regional employment may increase because of higher labour requirements for organic agriculture. Regional gross domestic product may increase as a result of increased labour requirements and spin-off. Other parts of Canada may not benefit as much on account of economic linkages with the Prairie agriculture. National employment and GDP, however, may decline due to lower demand for the synthetic farm inputs. Thus, conversion of agricultural land to organic production system may result in lower GHG emissions, higher producer returns, increased regional employment and gross domestic product, and lower national employment and gross domestic product.

1.7 Organization of Thesis

The remainder of this thesis is organized into five chapters. Chapter 2 is a literature review of relevant studies and reports. Chapter 3 constructs the conceptual framework for this study, focusing on theoretical discussion of the analysis. Chapter 4 describes the analytical model and data sources used in this study. Chapter 5 discusses the results of the study, and trade-offs that may exist between farm, regional, and environmental systems. Chapter 6 summarizes the study and the conclusions reached.

Chapter 2

Literature Review

2.1 Organic Agriculture

Organic agriculture is defined as a "system of managing agricultural holdings that implies major restrictions on fertilizers and pesticides" (Stolze et al., 2000). According to these authors, organic agriculture[4] is based on different crop farming practices, protection of the environment and seeking to promote sustainable agricultural development. Organic agriculture "pursues a number of aims, such as the production of products which contain no chemical residues, the development of environmentally sensitive production methods, which avoid the use of artificial chemical pesticides and fertilizers, and the application of production techniques that restore and maintain soil fertility" (Stolze et al., 2000).

According to the International Federation of Organic Agriculture Movements (IFOAM, 2005), organic agriculture consists of and / or aims for the following:

1. Protecting the long-term fertility of soils by maintaining organic matter levels, fostering soil biological activity and careful mechanical interventions;

2. Providing crop nutrients indirectly by using relatively insoluble nutrient sources which are made available to the plant by the action of soil micro organisms;

3. Nitrogen self sufficiency through the use of legumes and biological nitrogen fixation, as well as effective recycling of organic materials including crop residues and livestock wastes;

4. Weed, disease and pest control relying primarily on crop rotations, natural predators, diversity, organic manuring, resistant varieties and limited thermal, biological and chemical intervention;

[4] In this discussion, the term 'organic' agriculture is used to denote 'organic production system' as used earlier.

5. Extensive management of livestock, paying full regard to their evolutionary adaptation, behaviour needs and animal welfare issues with respect to nutrition, housing, health, breeding and rearing;

6. Careful attention to the impact of the farming system on the wider environment so as to conserve wildlife populations and natural habitat;

7. Maintain the genetic diversity of the agricultural system and its surroundings; and,

8. To allow everyone involved in organic production and processing a quality of life conforming to the UN human rights charter.

Organic agriculture aims to progress toward an entire production, processing and distribution chain which is both socially just and ecologically responsible.

2.1.1 Role in reducing greenhouse gas emissions

Statistics Canada commissioned a study reporting major benefits of an organic farming system[5]. It suggested that organic farming "protects the environment, minimizes soil degradation and erosion, decreases pollution, replenishes and maintains long-term soil diversity, and provides care that promotes the health and behavioural needs of animals" (Parsons, 2002). Lotter et al. (2003) explains that agriculture is a tool that is effective in carbon sequestration. In addition, Pimentel et al. (2005) report that organic system eliminate agrochemicals and reduce other external inputs to improve the environment and farm economics.

Around the world, there have been a number of studies conducted to estimate the environmental benefits of organic farming measured in GHG reduction. In a study commissioned by the Food and Agriculture Organization of the United Nations, it was found that "conversion to organic farming would mitigate 40 per cent of the world's agriculture GHG emissions" (Niggli et al., 2009). In addition, the study noted that approximately 20 per cent of

[5] In this study, organic farming system is interpreted to mean organic production system.

the agricultural GHG could be reduced by abandoning industrially produced nitrogen fertilizers used on conventional farms. In this regard, Niggli et al. (2009) has argued that:

> "organic agriculture has a huge potential, both in terms of the recommendations of the IPCC Fourth Assessment Report and for future food security. This positive potential, as listed below, should be considered in further climate change mitigation strategies in agricultural production.
>
> - Organic agriculture reduces erosion caused by wind and water as well as by overgrazing at a rate of 10 million ha annually, a crucial precondition for future food security.
> - Organic agriculture is a good way to rehabilitate poor soils, restore organic matter content and bring such soils back into productivity.
> - Organic agriculture is inherently based on lower livestock densities and can compensate for lower yields by a more effective vegetable production. Organic agriculture has a land use ratio of 1:7 for vegetable and animal production.
> - The potential productivity of organic farms and organically managed landscapes can be improved considerably by scientific agro-ecological research.
> - Organic agriculture offers many added benefits such as conserving agricultural biodiversity, reducing environmental degradation impacts and integrates farmers into high value food chains."

Niggli et al. (2009) maintains that organic agriculture offers multiple opportunities to reducing GHG emissions. The authors note that "organic agriculture reduces energy requirements for production system by 25 to 50 per cent compared to conventional chemical-based agriculture." They explain that GHGs can be reduced further because there is ability for sequestration in soil resulting in a greater potential to mitigate climate change.

In a recent study done at the Rodale Institute, it was estimated that organic farming "can reduce the output of carbon dioxide by 37 to 50 per cent, reduce costs for the farmer, and increase our planet's ability to positively absorb and utilize GHGs" (Lotter, 2003). The Rodale Institute completed a 23 year research project designed to compare organic and conventional farming methods and production systems. Not only did the Institute conclude that carbon dioxide output would be significantly reduced but organic system would facilitate an increase in soil carbon of between 15 and 28 per cent. Lotter (2003) indicated that organic agriculture makes economic sense because it returns similar levels of profitability to conventional farming, even without organic price premiums. "Real world organic price premiums allow farmers to take advantage of certified organic production system to achieve economically viable returns without massive governmental subsidies" (Lotter, 2003). The conclusions of the study indicate that organic farming maximizes benefits for both the individual farmer and society as a whole. Organic agriculture "mitigates current environmental damages and promotes a cleaner and safer world for future generations" (Lotter, 2003).

A separate study in the Federal Republic of Germany tested GHG emissions on 90 farms with the aim to improve the field of research and the management of commercial farms (Küstermann et al., 2007). The results indicate that GHG emissions from conventional and organic agriculture are relatively equivalent for fuel consumption and machinery use (Küstermann et al., 2007). The study revealed that the major defining difference is conventional farming produces an additional 637 kg CO_2-eq ha^{-1} yr^{-1} of GHG emissions, which is primarily caused by the manufacturing of nitrogen fertilizer and pesticides (Küstermann et al., 2007). According to this analysis, possibilities for the optimization of management and the mitigation of GHG emission are present, further suggesting that organic farming has a high potential for carbon sequestration and the reduction of GHG emissions.

Although organic agriculture is effective in GHG emission reduction, it does come at the expense of total production. Stockdale et al. (2001), based on a study in Europe, found that "yields of arable crops are 60 to 80 per cent of those in comparable conventional systems". "In developing countries, organic farming practices increase crop yields with minimum external inputs. Lower variable costs and premium prices mean that organic farming systems are profitable" (Stockdale et al., 2001). Based on a review of other studies, Niggli et al. (2009) found that the yield reductions for organic agriculture in intensively managed farmed regions under the best geo-climate conditions could be between 30 to 40 per cent and that in less favourable regions' yield losses tended to be negligible.

2.1.2 Willingness to pay for organic products

Demand for organic products is increasing around the world as scientists have linked organic agriculture to a reduction in GHG emissions, along with providing perceived health benefits to consumers. This is because organically produced products are not exposed to perceived harmful agents (Stolze, 2005). Consequently consumers have increased demand for organic products and have indicated a higher willingness-to-pay for them.

In a recent study, Bonti-Ankomah and Yiridoe (2006) determined that because yields from organic farming are lower than yields from conventional farming, consumer's willingness-to-pay a premium price for organically produced products is an important factor for overall profitability and long-term financial sustainability in the organic agriculture sector. "The magnitude of the price mark-up is also important because it helps in assessing the value consumers place on particular product attributes" (Bonti-Ankomah and Yiridoe, 2006). Because yields from organic production are generally lower than under conventional production, willingness-to-pay from consumers is of utmost importance for financial sustainability of the sector. Bonti-Ankomah and Yiridoe (2006) noted that although there is a limited amount of long-term time-series on organic market prices studies in North America, consumers are willing to pay price premiums for organic products, with similar results for the EU, and other regions of the world. The authors explain that "consumer willingness-to-pay for organic versus conventionally-grown foods reflects not only an observation that individuals make trade-offs between attributes associated with consuming alternative products, but also an observation that individual consumer preferences are unique". There is no clear pattern about the levels of price premiums individual consumers and consumer groups are willing to pay, and there is limited information about which organic products attract higher mark-ups. “Own-price elasticity of demand is relatively higher for organic products partly because organic products tend to have a wider range in appearance, and limited availability during particular seasons” (Bonti-Ankomah and Yiridoe, 2006).

Batte et al. (2004) concluded that consumers’ willingness to pay higher prices for processed foods with organic content varied based upon income levels and demographic characteristics of the households. “Specialty grocery shoppers were more likely to purchase organic foods than their traditional grocery counterparts, and had a greater willingness to pay for these products” (Batte et al., 2004). They indicated that “consumers are willing to pay premium prices for organic foods, even those with less than 100 per cent organic ingredients.”

Based on the review of these studies it can be concluded that consumers are willing to pay premium prices for organically produced and manufactured products; however due to limited price market time series, no firm conclusions have been made that reveal the willingness-to-pay for individual organic products and overall magnitude of consumers’ willingness-to-pay.

2.1.3 Organic agriculture market

It is estimated that organic farming is practiced in 120 countries around the world (Willer and Yussefi, 2004). It has been further estimated that between less than one per cent and seven per cent of total gross farm production is from organic products (Baccus, 2001); however, organic products are becoming increasingly attractive to both producers and consumers. Baccus (2001) explains the reason for these changes as follows: producers are facing rising input costs and consumers’ continue to seek safer food sources feeling that organic products answer some of the current food scares. In 2006, it was estimated that there were 30.7 million hectares of organically managed farm land (Research Institute of Organic Agriculture, see FiBL, 2008), representing less than one per cent of total global agricultural land. Willer and Yussefi (2004) estimate that the countries with the greatest number of organically managed areas are: Australia (12.1 million hectares), China (3.5 million hectares) and Argentina (2.8 million hectares). Oceanic countries represent 39 per cent of the total organic area, while Europe and Latin America represent 21 and 20 per cent of the total area respectively (Willer and Yussefi, 2004).

It has been estimated that international sales of organic products reached USD$38.6 billion in 2006 (Organic Trade Association, 2008), with the largest importers of organic products being the European Union and the United States. The majority of growth in the organic food industry has occurred in North America followed by Western European countries (Willer and Yussefi, 2004).

Organic agriculture production is distributed throughout Canada. In 2002 there were 478,700 hectares (1.2 million acres) under organic production, representing 1.3 per cent of the Canada's agricultural land base (Willer and Yussefi, 2004). In 2006, organic farming was practiced by 3,555 farms -- 1.55 per cent of the all Canadian farms (Statistics Canada, 2009). Value of output of organic farms in 2005 was approximately CAD $1 billion, with a 10 to 20 per cent per annum growth rate (Nutrition Business Journal, 2004).

Of the 1.12 million total certified acres, 85 per cent are in the Prairie Provinces. Saskatchewan is the largest single province of certified organic land with 730,164 acres. The majority of the organic land base throughout the Prairie Provinces is used in grain production, followed by livestock, and vegetables (Nutrition Business Journal, 2004).

In Canada, there are no direct production subsidies for producers wanting to convert to an organic production system. Therefore, they are faced with bearing the entire risk of conversion, but have the ability to purchase insurance for their production system (Schmitz et al., 2002). As a result, the only incentive for an operation to switch from a conventional to an organic system is the economic potential for a premium marketable product. The Canadian government is beginning to develop measures to support organic producers in terms of providing agronomic advice. In addition, in 1999 further steps were taken in Canada to revise organic standards to match those in the European Union, the United States, and Japan. These changes have facilitated and enhanced trade of organic products (Forge, 2004). Alongside these types of support, evaluation of implications and positive aspects of organic agriculture for Canada has also begun.

Canadians and the Canadian government have recognized the benefits of organic production through the increases of organic food and beverage consumption, as retail sales have increased 15 to 20 per cent per year and reached approximately USD $2.4 billion in 2005 (Willer and Yussefi, 2004).

2.2 Review of Analytical Tools

Analysis of the social desirability of an organic production system requires an integrated approach involving various types of models. Included here are studies that have used models for economic optimization, GHG emissions, and trade-off analysis (TOA). A review of these studies is provided below.

2.2.1 *Economic Optimization Model -- Canadian Regional Agriculture Model*

Canadian Regional Agriculture Model (CRAM) has a long history as an analytical policy tool at Agriculture and Agri-Food Canada (AAFC). One of the first applications of CRAM was to look at the implications of the introduction of medium quality wheat on the Prairies (Webber, 1986). Since then it has been used to examine the impact of the 1985 U.S. Food Security Act on the Canadian Grains sector (MacGregor and Graham, 1988) and the impact of direct government assistance programs on the beef and hogs sectors (Webber et al., 1989). CRAM has also been employed within AAFC to examine the implications of the Canada-U.S. Trade Agreement (CUSTA), the Multilateral Trade Negotiations (MTN) (Graham et al., 1990), and changing the Western Grain Transportation Act (WGTA) (Klein et al., 1991; MacGregor et al., 1994). CRAM has also been used for the environmental assessment of the crop insurance program (Coyle, 2009, and Giraldez et al., 1998) and research on return on investment studies for wheat (Klein and Freeze, 1995; and Klein et al., 1995), potatoes (Oxley et al., 1996), hogs (Fox et al., 1998), and forages (Thomsen et al., 2000).

2.2.2 *Greenhouse Gas Emissions Model*

The Greenhouse Gas Emissions Model (GHGEM) model is a component of the Canadian Economic Emission Model for Agriculture (CEEMA). CEEMA contains two separate but integrated modules -- an economic optimization model, CRAM, and a greenhouse gas emissions model, GHGEM. It has been used to estimate GHG emissions and the impacts that mitigation measures would have on GHG emissions from Canadian agriculture. According to Kulshreshtha et al. (1999), in the GHGEM, Canada is divided into 55 regions and the model evaluates various human activities that are related to GHG emissions. Boehm et al. (2000) used the GHGEM model to study different scenarios and strategies and the net effects to overall GHG emissions in primary agriculture in Canada. The author noted that the design of the model allows for the effects to be studied at a regional level and spill-over effects on the economy associated with choosing the appropriate mitigation strategy. The GHGEM model has been used to study emissions of GHG from irrigation expansions in both Alberta and Saskatchewan (Kulshreshtha and Junkins, 2001), the effects of agriculture processing expansion in Canada (Bussler et al., 2001), implications on GHG emissions due to the expansion of the biofuels industry (Seecharan et al., 2002) and the ability of Canadian soils to sequester carbon emissions (Boehm et al., 2002, Sobool and Kulshreshtha, 2006b). The GHGEM is a widely used model in Canada to evaluate the net effects of GHG emissions in Canada as a result of shifts, changes or expansion of an agricultural practice.

2.2.3 Trade-off Analysis

The trade-off analysis (TOA) system is developed to simulate the complex interactions between economic and environmental factors of agricultural systems (Stoorvogel et al., 2004a). The TOA is an effective tool to evaluate differing scenarios based on a given set of criteria. It is often used to evaluate land use, economic and environmental impacts (Stoorvogel et al., 2004b). Brown et al. (2002) describe that the objective of TOA is to allow decision makers to consider trade-offs between different criteria to evaluate alternative management options. They defined it as "utilizing a number of methodological tools. Trade-offs are generally presented when the decision-makers have multiple objectives. In such situations, a multi-criteria approach is applied. This technique allows one to examine information on different criteria and impacts and explore the outcomes and impacts of decisions made as a result of different priorities, through applying different weights to economic, social and ecological criteria

(Brown et al., 2002). Therefore, trade-offs allow for decisions to be made based upon consensus as opposed to conflict (Martinez-Alier et al., 1998; Brown et al., 2002).

TOA is as an effective tool that has been used for analysing policy and describing the relationship between different criteria. "TOA between environmental and economic indicators is a useful way to represent dynamic properties of agriculture systems" (Stoorvogel et al., 2004a). TOA can be used to evaluate the sources of non-linearities of bio-physical processes and farmer decision making and how impacts changes such as agriculture policy or major environmental event (earthquake) impact these decisions and land use (Stoorvogel et al., 2004b). TOA allowed for a scenario based approach to determine agriculture impacts on a particular environment (Morardet and Koukou-Tchamba, 2004). TOA can also be used to measure the minimization of impacts. Miller (2010) used TOA to determine energy crops that minimize both nitrogen use and land uses. In combination with the use of a linear programming tool, Lu and Ittersum (2004) used TOA to evaluate the integration of biophysical, agro-technical and social-economic information to determine land use. They describe that the TOA reveals the solution space for each of the objectives and an analysis of the trade-off relationships between pairs of objectives.

TOA is also effective in evaluating policy changes and environmental settings. Outside of determining land use, the TOA is an effective tool for characterizing both the performance and production of individual species (Martin and van Noordwijk, 2009).

Although TOA only allows for two dimensional representation, multiple scenarios facilitates the evaluation of more that two criteria. Brown et al. (2001) used TOA to measure social, economic, and ecological criteria to determine the impacts of Marine protected areas and management options including tourism. To measure the relationships between macro-economic goals and environmental goals, Karunaratne (2005) used TOA to measure trade-offs between output expansion, income growth, and employment against pollution. The TOA is often used in ecological economics to determine solutions for land use, evaluating production and measuring the environmental impacts.

Chapter 3

Conceptual Model

This chapter presents the conceptual framework used in this study to identify the most socially desired outcomes between the conventional and organic production system. This framework involves a tool introduced in Chapter 2, the "trade-off analysis". Since organic production could affect producers as well as other residents of the region through linkages with economic development activities, and through generation of ecological goods and services, trade-offs could exist.

The chapter is divided into five sections: Section 3.1 provides a basic description of TOA. This is followed in Section 3.2 by criteria for assessing a trade-off situation. Section 3.3 provides a description of trade-off criteria selected for this study. Finally assessment of a socially desirable production system is presented in Section 3.4. The last section summarizes the discussion in this chapter.

3.1 Trade-off Analysis

Often decisions made by people have far reaching implications both in the short and long-run. This is due to the multifunctional nature of some production processes, and in part due to spill-over effects on other sectors. The multi-functional role of agriculture has been recognized by OECD (2001); it is defined to consist of two key elements: (*i)* the existence of multiple commodity and non-commodity outputs that are jointly produced by agriculture; and (*ii)* the fact that some of the non-commodity outputs exhibit the characteristics of externalities or public goods, with the result that markets for these goods do not exist or function poorly. Given agricultural decisions affect multiple products, it is conceivable that some of these choices may result in benefits to some members of society and a cost to others. Costs can be financial (change in the level of production and its value) or environmental (such as increases in GHG emissions) or in terms of change in the pace of regional economic development (such as changes in the employment opportunities). When evaluating the impacts of a conversion from a conventional to an organic production system, one must use an approach which addresses implications of these changes. This is the essence of a TOA, as suggested by Silveira (2003):

> "Traditional trade-off paradigm indicates that rising one aspect of performance imply reductions in some other aspect. Therefore, [stakeholders] must prioritize their competitive objectives and devote resources to improve performance in the main objectives" (Silveira, 2003).

The TOA concept makes use of production possibility frontiers (PPF) allowing for an illustrated approach of solving problems of multiple desirable outcomes for multiple stakeholders.

The major advantage in using a TOA is that it integrates both public policy and the interests of other stakeholders using scientific and quantitative information to support policy decision making (Stoorvogel et al., 2001). The TOA analysis is often criticized for its oversimplification of a problem, providing multiple outcomes in a two dimensional space, when the problem incorporates more spatial stakeholders. This issue can however, be addressed through running of multiple scenarios.

3.2 Criteria for Trade-off Analysis

The use of TOA analysis allows for the evaluation of both the positive and negative impacts resulting from adoption of different management practices in agriculture. As noted above, two trade-offs are pertinent in the conversion of conventional to organic production system. These are: (1) Trade-off between level of production and environment, described in

Section 3.2.1; and (2) Trade-off between micro and macro level economic impact, which is described in Section 3.2.2.

3.2.1 Trade-off between Economic-Environment

Economic - Environmental performance of a cultural practice is a major determinant of it's socially desirability. The environmental attribute of interest in this study is the emissions of GHGs. The economic attribute in this study is gross domestic product, household income, and employment. Each of these two systems of production may have different levels of economic attributes, and levels of GHGs. Some of these changes may be socially desirable (such as a reduction in GHG emissions).

Let us compare the organic and conventional production systems. Under the organic production system, one could hypothesize that the producer would expect lower production (yield per unit of land). However, organic agriculture producers could be compensated with a higher value per unit of product, therefore, generating higher returns relative to other agricultural products, particularly those produced under conventional production system. If price of these products is not high enough, adoption of organic production system would be slower.

The environmental benefits may be perceived in terms of GHG emissions. GHG emissions affect air quality, but also have more serious consequences in terms of climate change. This aspect of the TOA can be measured in terms of level of GHG emissions produced. Since various GHGs have a different global warming potential, a standard measure is to convert these emissions into carbon dioxide equivalent (CO_{2E}). This makes comparison of environmental friendliness (in terms of GHG emission intensity) of various production systems easier.

In evaluating the change in net returns to producers, regions, or the nation and the change in GHG emissions, a trade-off production frontier can be developed and an analysis can be conducted to determine the more socially desirable option.

Figure 3.1 illustrates the trade-off between economic benefits and environmental benefits. Assume point A represents the current situation where a certain amount of land is under conventional production system. Although producers could have higher income but the environmental benefits are lower. If this land is converted to organic agriculture, it may result in a reduction of national economic benefit and an increase in environmental benefits. This is represented by point B in Figure 3.1. If conversion to organic agriculture produces both economic and environmental benefits, there would be no trade-off because it would result in a win-win.

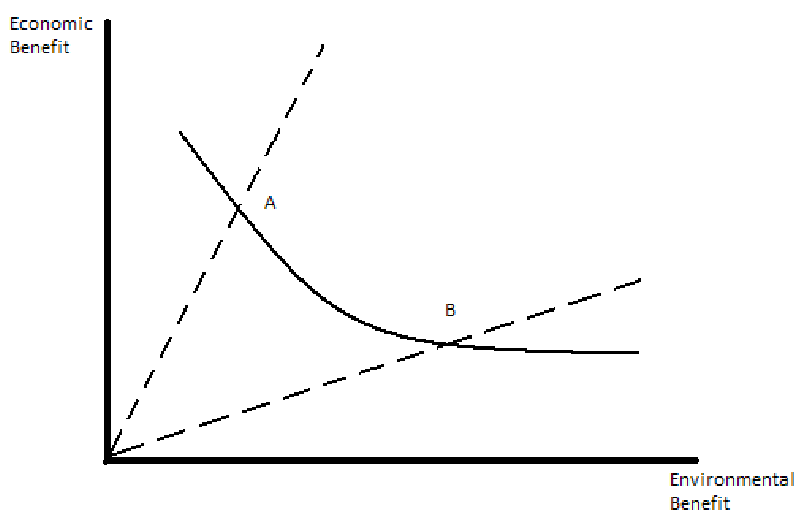

Figure 3.1 Trade-off analysis economic benefit versus environmental benefit

3.2.2 Trade-off between Micro and Macro Level Economic Impacts

Evaluating the economic impacts leads to possible conflicts between agricultural producers and other business activities at the regional and/or national level. Although the latter is measured as gross domestic product (GDP), a more socially sensitive measure of economic growth is employment opportunities. These opportunities may exist at the farm or in the non-agricultural industries in the region or in other parts of Canada. A positive change in regional and/or national GDP indicates an economic improvement. Since a producer's decision to convert would have an impact on farm level economics, various spin-offs (forward and backward linkages) would result in regional (or national) level changes in GDP. Figure 3.2 illustrates the trade-off between farm level and regional and/or national GDP benefits. Assume point A represents the current situation where, say all land is under conventional production system. If the conversion to organic agriculture results in an increase in regional/national GDP and a decrease in farm level GDP, there would be a shift towards point B in Figure 3.2.

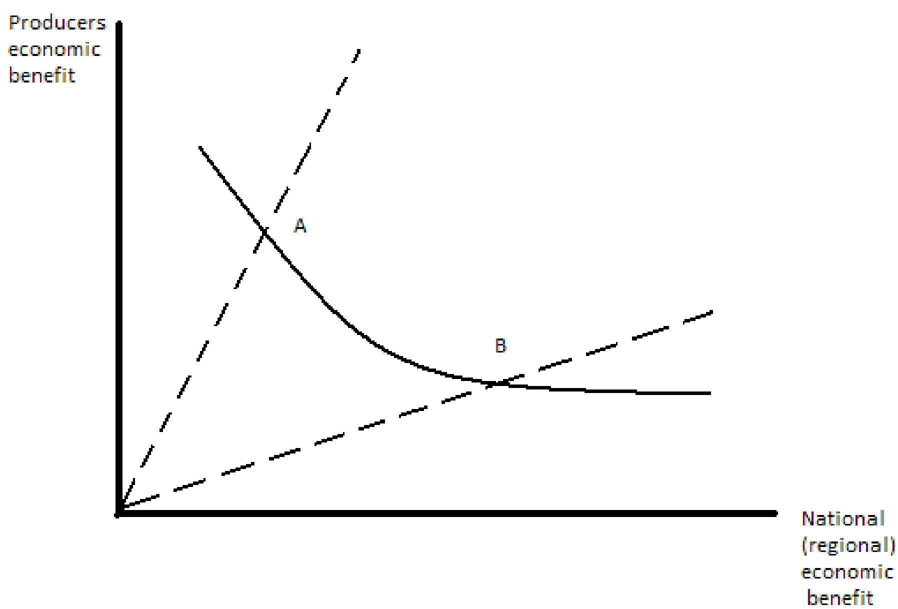

Figure 3.2 Trade-off analysis, the producer's economic benefit versus national or regional economic benefit

3.3 Measurement of Trade-off Criteria

To evaluate the trade-offs between agriculture production level, GHG emissions and economic growth (regional and/or national), each of these criteria must be measured. The simplest of these is agriculture production level under each production system. This can be measured in terms of value per hectare. The convention for measurement of GHG emissions is estimates in CO_{2E}. Economic growth can be measured in terms of GDP or employment generation. Each of these is described in detail in the following sub-sections.

3.3.1 Farm Level Economics

The farm level returns were measured as the difference between gross revenue and cost of production of various crops. All crops are aggregated to produce an aggregate farm level economic measure – profit under a given production system. Let the i^{th} production system be organic production or conventional production system. The farm level profitability is estimated by using equation 3.1.

$$\Pi_i = \sum_{j=1}^{j=n} x_{ij} - y_{ij} \qquad (3.1)$$

Where:

$i = 1$ – organic production system

$i = 2$ – conventional production system

Π_i = net returns from the i^{th} production system.

x_{ij} = gross revenue from the sale of j^{th} crop under the i^{th} production system; and,

y_{ij} = total cost of j^{th} crop under i^{th} production system.

By comparing the net returns under the two production systems, (Π_1 -Π_2), one is able to estimate level of change from the aforesaid conversion.

3.3.2 Regional Economic Development

Regional economic impact of a given production system is created by changes in the farm level economics resulting from a conversion from a conventional to an organic production system. Conceptually, two types of changes are relevant for this type of assessment: One, although individual producers are price takers, their combined actions may lead to a change in the market level parameters, particularly the price of a commodity. However, for this option to be effective, change in the production would have to be large enough to affect the price received by producers. Furthermore, if the farmers trade their product in an open economic system, where prices are determined in the international market, production change will have to be even larger to have any effect on world price levels, and thus on the price received by Canadian producers. Two, the conversion would invariably imply change in the cultural practices, and thus use of different farm inputs, which are produced by the non-agricultural sector. The linkages between these input-producing sectors in the regional (or national) economy would be affected by this conversion, resulting in a change in non-farm industries GDP level.

One of the major factors of production in any economy is labour. As expenditure patterns of producers change, so does their respective demand for goods and services. This would result in a change in the level of output of various non-agricultural sectors. These changes would invariably affect the total number of workers employed by the sector. Thus, the changes that originate with the nature of farm inputs required under various systems, would translate into macro-level changes in GDP and employment levels. For example, many industries, such as chemical, fertilizer, and other synthetic input companies, may experience losses in sales if producers adopt an organic production system. On the other hand, organic agriculture is more labour intensive, which may result in an increase in local employment and an increase in economic activities in rural communities.

3.3.3 Greenhouse Gas Emissions

GHG emissions are commonly measured as carbon dioxide equivalents. Primary agriculture produces carbon dioxide, methane, and nitrous oxide emissions. Equation 3.2 illustrates the carbon dioxide equivalent GHG emissions calculation.

$$CO_{2E} = CO_2 + 21*(CH_4) + 310*(N_2O) \quad (3.2)$$

Where:

CO_{2E} – Carbon Dioxide Equivalent
CO_2 - Carbon Dioxide
CH_4 - Methane
N_2O - Nitrous Oxide

Each of the gases in Equation 3.2 is released from various farm activities. Therefore, accounting for these emissions requires a system of relationship between level of farm activity and the resulting GHG emissions of individual gas. These activities are related to, among other things, fertilizers, chemicals and the burning of fossil fuels. In addition to direct contribution of these practices to GHG emissions, other emissions are also produced indirectly. For example, fertilizer is the largest contributor of nitrous oxide (N_2O) emissions through atmospheric deposition and leaching. Organic agriculture and conventional agriculture are fundamentally different in the way that they address pest control and increase yields. Organic agriculture uses cultural and mechanical practices (cultivation of land and mowing) to control pests and uses natural (organic) form of nitrogen. Conventional agriculture is very much a high input system, using chemicals and synthetic fertilizers. As a result, one may hypothesize that emissions from fuel consumption will increase in organic agriculture but these emission increases may be offset by the reduction in chemical and fertilizer production and application.

In addition to the direct GHG emissions from application of fertilizers under conventional production system, GHG emissions are also produced as a result of the production of fertilizer, storage and transportation of synthetic inputs. As an example, manufacturing of fertilizer uses a large quantity of natural gas. Furthermore, the burning of fossil fuels during transportation of the fertilizer from the production site to the farm adds further to the total GHG emissions.

Production, distribution and application of agriculture pest control products (such as agriculture chemicals) are another source of GHG emissions. The production of these products also requires a large quantity of energy. The use of chemicals in a conventional production system allows farmers to minimize crop production losses caused by pests. However, when chemicals are not used (under organic production system), increased fuel use is required for controlling pests.

Emissions from burning of fossil fuel are also a major part of the total GHG emissions from agriculture. Fossil fuel is required for the majority of all farming operations, whether it is the application of a product or the energy to power the control mechanism. Under an organically managed operation, fuel consumption increases as compared to fuel consumption in a conventional production system. This is the primary source of carbon dioxide emissions.

3.4 Assessment of Socially Desirable Option

If all three types of changes – micro-economic (farm level), macro-economic, and environmental changes, could be measured in a common currency, determination of socially desirable option would be relatively simple. If all changes were to be measured as net of other changes (i.e., no double-counting) the social welfare function would be a sum of these three changes. The production system that results in a higher value for the social welfare function could be labelled as the socially desirable.

As shown above, GHG emissions are measured in physical quantities, while the other two changes are in monetary units. Although change in GHG emissions can be converted into social benefits, some of which are monetizable, the process is still in its infancy (Smith and Hitz, 2003). Benefits of lower GHG emissions are postulated in terms of ecosystem damages, adverse impacts from poor air and water quality, morbidity and mortalities, and higher health risks (typically translated into higher insurance costs) (Smith et al., 2003).

Given the nature of these indicators, one approach to show these trade-offs is a 'radar diagram'. A radar diagram allows for a visual display of multiple variables to be displayed. This diagram is shown in Figure 3.3. Each of the four sides in this figure pertains to an indicator.

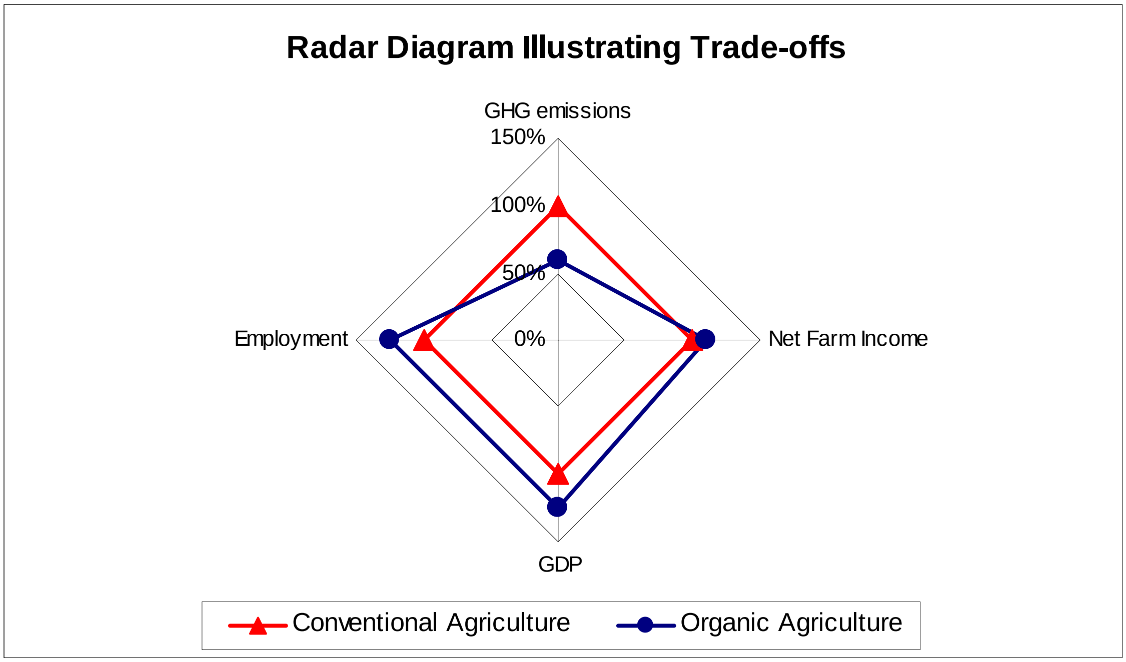

Figure 3.3 Radar diagram showing trade-offs for a four dimensional case

The relative change in any of them suggests either a benefit or a cost of adopting a different production system. For example, in Figure 3.3, organic agriculture show improvement in net farm income, GDP and employment as illustrated by an increase or a shift out, which could be economic improvement. GHG emissions indicator shows a reduction in total emissions.

If the socially desirable scenario and the economic situation both result in improvements, it is a win-win situation (there is a gain in the value of all three criterion). If one criterion is lower while the other two are higher, a situation of trade-off is indicated.

3.5 Conclusion

To assess the implications of a conversion from a conventional production system to an organic production system, TOA is a useful tool. There are multiple criteria that need to be evaluated to determine the most socially desirable scenario. The TOA facilitates these comparisons resulting from a change in multiple goals of decision makers. The radar diagram allows for an illustration of the different trade-off scenarios and the impacts of the change.

Chapter 4

Analytical Model

4.1 Introduction

This chapter outlines the empirical methodology adopted to determine economic and environmental implications of converting a conventional production system to an organic production system. As mentioned in Chapter 3, this involved using three separate, but linked, models for estimating various criteria used for the TOA. These models are explained in this chapter. In addition, links between these models are also described.

4.2 Overview of Model for Trade-off Analysis

As noted in Chapter 3, the TOA in this study was based on three criteria: a microeconomic criterion of farm level profitability, a macroeconomic criterion of regional economic growth, and an environmental quality criterion of GHG emission levels. An overview of the study methodology is shown in Figure 4.1. It involves use of three – CRAM, GHGEM and CARDIOM models. Using these models allows numerical estimation of these criteria for identification of possible trade-offs from the said conversion. TOA provides a basis for an evaluation of overall social desirability of the organic production system relative to the conventional production system. Level of GHG emissions from organic and conventional production systems are compared against the economic impacts that result from such a conversion. This then becomes the basis for a decision to be made by society on the more socially desirable option to adopt.

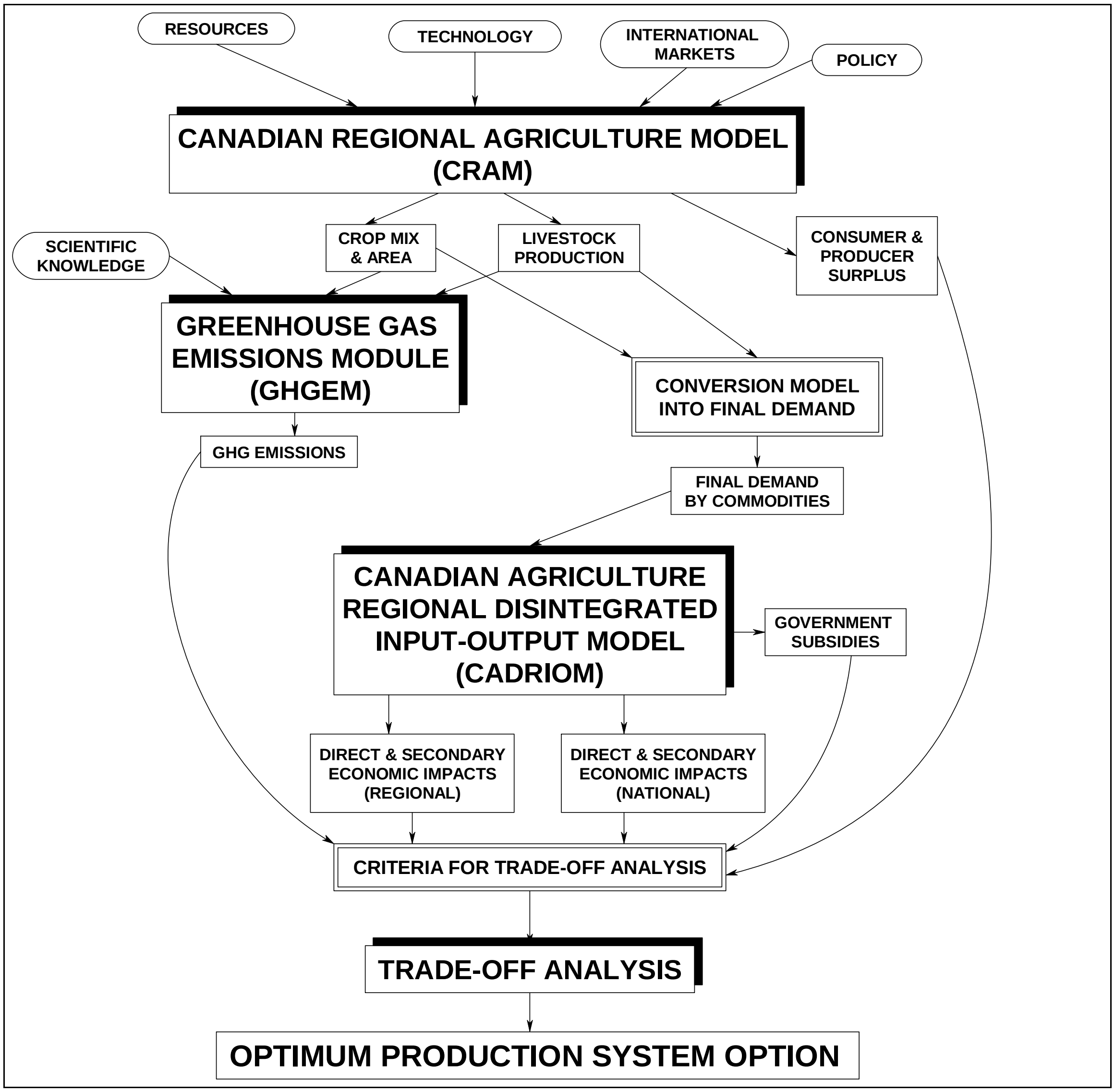

Figure 4.1 Overview of study methodology to determine optimal production system

4.3 Description of Model

The three models – CRAM, GHGEM and CARDIOM, were used for estimating the criteria for the TOA. These three models are described below.

4.3.1 Farm Level Economic Model -- CRAM

The CRAM is an optimization model that estimates the type of land use pattern in various regions of Canada given a set of demand and supply conditions. Canadian agricultural regions are divided into 55 crop regions, which allows for accurate estimation of farm level changes by soil type and individual characteristics of the regions across Canada. It includes both crop and livestock production activities. With the given supply elasticity, resource availability, and demand functions, it determines the optimal enterprise mix for Canada (Wiborg, 2000). The objective function in the model is maximization of the sum of producer and consumer surplus.

Evaluation of change in the farm level economics of a conversion of area under conventional to organic production system was done by 22 CRAM regions (Seven in Alberta, Nine in Saskatchewan, and six in Manitoba) located in the Prairie Provinces. The CRAM system of equations first solved for the conventional production system. The data required were obtained from Agriculture and Agri-food Canada. The same was repeated for the organic production system.

To evaluate using CRAM on the Canadian Prairies, a number of assumptions were required.

1. It was assumed that livestock, whether conventionally or organically managed, will produce the same level of emissions. This assumption implies that a producer, both conventional and organic, will feed the same quantity and quality of feed to their livestock. Therefore, it was assumed that the livestock rations would be equivalent under both conventional and organic production systems. Under these conditions, one would expect that livestock enterprises level of GHG emissions would be similar.
2. Demand for organically produced products is high enough that an increase equivalent to ten per cent of the agriculture land on the prairies will not significantly affect prices in the organic markets. As noted in Chapter 2, organic

products are priced in the international market. A small increase in the Canadian organic production, therefore, is not expected to significantly affect international organic commodity prices. Similarly a reduction of area under conventional production system would result in no change in conventional commodity prices.

Crop rotations in conventional agriculture are extremely diverse and vary from region to region and soil type to soil type. In addition, crops such as canola cannot be grown under organic management due to cross pollination. Dow AgroSciences (2009) explains a recent court case regarding the cross pollination of canola traits from one field to another:

> "In 1998, out-crossing between canola varieties was documented in a producer's chem-fallow field in northern Alberta. Pollen flow from an adjacent field in 1997 conferred herbicide tolerance to volunteers. Tolerance was not anticipated by the producer, so the same herbicide was applied to control the volunteers, and it was ineffective."

Inconsideration of the above observations, in this study the crop rotation followed by organic producers excluded canola. Although canola is an important crop in conventional agriculture and has traditionally produced strong financial returns for producers, organic producers are unable to grown canola due to the risk of cross pollination with genetically modified varieties and unapproved non-organic varieties. This may have created a bias toward organic agriculture. This bias may be a result of the removal of a crop for conventional farmers that has historically produced strong economic incentives.

In consideration of the above crop rotation used in this study, one commonly used by organic producers was selected. This consists of a six year rotation, each crop given once, as shown in Equation 4.1.

Alfalfa – Wheat – Barley – Flax – Oats – Peas (4.1)

To determine the area to be converted (in this study) from conventional to organic production system, ten per cent of the total cropped area was selected. This magnitude of change was chosen because this production that could be produced from this area of land would help meet the growing demand of organic products in the future and at the same time be small enough as not to significantly influence the market price of organic products.

The area of each of the six crops was divided equally among the selected crop rotation in the 22 CRAM regions. All changes were based on 2005 levels, obtained from Statistics Canada (2007b).

4.3.2 Greenhouse Gas Emission Model

The Greenhouse Gas Emissions Model (GHGEM) estimates total GHG emissions generated from various activities directly or indirectly related to agricultural production. Since much of organic products are shipped unprocessed, total emissions were limited to those from agricultural production and farm input sectors. As noted above, livestock production and processing activities were excluded from the study. Since most organic products are shipped in unprocessed form, food processing activities were also excluded from this study.

The model consists of a number of activity modules associated with GHG emissions. These include: Crop Production Module (Module A1), Farm Level Fuel and Fertilizer Use Module (Module A2), On-farm Energy Use Module (Module C), Off-farm Energy Use Module (Module E), and Manufacturing and Transportation of Farm Inputs Module (Module D). Each of these modules will now be described in some detail.

Crop Production Module (A1): The crop production module, as outlined by Sobool and Kulshreshtha (2005), evaluates the potential sources of GHG emissions from production of crops. A list of included activities is shown in Table 4.1. These activities are discussed in this section, while the fertilizer and farm fuel component being discussed in the next subsection.

Table 4.1: Crop production activities and related greenhouse gas emissions

Activity	CO_2 Emissions	CH_4 Emissions	N_2O Emissions
Crop Residues			**X**
Fertilizer Application			**X**
Production of N-Fixing Crops			**X**
Soil Organic Matter (Source/Sink)	**X**		
Fuel for Farm Equipment	**X**	**X**	**X**

Crop residues refer to the left over straw in the field after the crop has been harvested. N_2O emissions are released back into the atmosphere as a result of the break-down and decomposition of the crop residues. Sobool and Kulshreshtha (2005) discuss that "the amount of nitrogen fixed by a crop is not known for certain." However they report that 45 per cent of crops' total biomass is harvested, while the remaining 55 per cent of biomass remains on the surface as crop residue. The amount of residues is directly related to management practices and the nitrogen content of the various crop types, as shown in Table 4.2, which was used to calculate total N_20 emissions.

The methodology followed for estimating total N_2O can be described as follows: Total N_2O emissions were related to the total area of a crop type in a region and the emission coefficient for the crop type in the given region. The following equations were used to determine total N_20 emissions:

Table 4.2 Proportion of crop biomass containing nitrogen

Crop	Proportion
Canola	0.860
Durum	0.860
Flax	0.860
Oats	0.860
Wheat	0.860
Barley	0.860
Field Peas	0.860
Lentils	0.860
Soybeans	0.860
Corn (grain)	0.860
Corn (silage)	0.860
Hay	0.300
Pasture	0.860
Summerfallow	0.000
Unimproved	0.000
Other	0.000
Potato	0.250

Source: Sobool and Kulshreshtha (2005).

$$N_2O\_TEM(c.r)_{CR} = AREA\ (c.r) * N_2O\_EC(c.r)_{CR} \tag{4.2}$$

Where: Area (c.r) = Area of crop type (c) in region (r), in ha, (obtained from CRAM output), and

$N_2O\_EC(c.r)_{CR}$ = Emission coefficient for nitrous oxide from crop residue of crop type (c) in region (r) , in tonnes ha $^{-1}$, using Equation (4.3)

Estimation of the crop residue emission coefficient for each crop in a given CRAM region was done as follows:

$$N_2O\_EC(c.r)_{CR} = N\_CONT(c) * YIELD(c.r) * N_2O\_EF * {}^{44}/_{28} \tag{4.4}$$

Where: *N_CONT(c)* = Nitrogen content of crop type (c), in tonnes ha^{-1}, as shown in Equation (4.4)

YIELD(c.r) = Yield for crop type © in region ®, in tonnes ha^{-1},

(obtained from CRAM output), and

N_2O_EF = Nitrous oxide emissions factor (using a default value of 0.125 kg N_2O-N kg N^{-1})

Nitrogen content (*N_CONT(c)*) of crop type (c) was estimated using equation (4.5), as shown below:

N_CONT(c) = *PROP_BIOMSS(c) * CROP_FACTOR(c)* (4.5)

Where: *PROP_BIOMSS(c)* = Proportion of crop type (c) that contains nitrogen as Shown in Table 4.2, and

CROP_FACTOR(c) = Quantity of nitrogen released from each specific crop type (c)

There are two types of crops that need to be investigated with regards to the crop nitrogen quantity released (*CROP_FACTOR(c)*). They are: nitrogen-fixing (F_F) crops and non-nitrogen-fixing (F_N) crops. Nitrogen-fixing crops include field peas and alfalfa. These crops need to be researched separately because they naturally release nitrogen into the atmosphere. Non-nitrogen-fixing crops include: wheat, oats, barley, and flax; these do not naturally release nitrogen into the atmosphere. The respective *CROP_FACTOR* is shown in Equations 4.6 and 4.7 for nitrogen fixing and non-nitrogen-fixing crop, respectively.

F_N = $2(FRAC_{NCRO}) * (1 – FRA_{CR})$ (4.6)

F_F = $2(FRAC_{NCRFB}) * (1 – FRA_{CR})$ (4.7)

Where: $FRAC_{NCRO}$ = Fraction of nitrogen in non-N-fixing crops (using a value of 0.015 kg N per kg of dry biomass),

$FRAC_{NCRFB}$ = Fraction of nitrogen in N-fixing crops (using a value of 0.03 kg N per kg of dry biomass), and

FRA_{CR} = Fraction of crop residue removed from the field (assumed to be 0.45 kg N kg crop-N^{-1})

The same general principle and equations were used to determine the N_2O emissions being released into the soil as a result of nitrogen-fixing crops (legumes) as were used for the other crop residues. In other words,

$$N_2O\_TEM(c.r)_{CR} = AREA\ (c.r) * N_2O\_EC(c.r)_{BNF} \quad (4.8)$$

Where: Area (c.r) = Area of crop type (c) in region (r), in ha, (obtained from CRAM output), and

$N_2O\_EC(c.r)_{BNF}$ = Emission coefficient for nitrous oxide from nitrogen-fixing crop type (c) in region (r) , in tonnes ha $^{-1}$.

Estimation of the nitrogen-fixing emission coefficient, $N_2O\_EC(c.r)_{CR}$, depended on the level of nitrogen-fixing components in the crop, as estimated by equation (4.9):

$$N_2O\_EC(c.r)_{BNF} = N\_CONT(c) * N_2O\_EF * {}^{44}/_{28} \quad (4.9)$$

Where: $N\_CONT(c)$ = Nitrogen content of nitrogen-fixing crop type (c), in tonnes ha^{-1}, and,

N_2O_EF = Nitrous oxide emissions factor.

Nitrogen content (*N_CONT(c)*) of nitrogen-fixing crop type (c), in region (r), was estimated using equation (4.10):

$$N\_CONT(c.r) = [TOT\_PROP\_BIOMSS(c)*CROP\_FACTOR(c)]/\mathrm{AREA}(c.r) \quad (4.10)$$

Where: TOT_*PROP_BIOMSS(c)* = Total production N-fixing crop type (c) in region (r) in tonnes, estimated as Crop Yield in tonnes ha^{-1} x Area Planted for N-fixing crop type (c) in region (r), in ha, *CROP_FACTOR(c)* = Quantity of nitrogen released from each specific N-fixing crop type (c), and

AREA(c.r) = Area of N-fixing crop type (c) in region (r),in ha.

The nitrogen content for alfalfa and peas as used ion this study are shown in Table 4.3.

Table 4.3 Nitrogen content for nitrogen-fixing crops

Variable	Factor
Alfalfa	0.02580
Peas	0.05160

Source: Sobool and Kulshreshtha (2005).

The crop factor (*CROP_FACTOR(c)*) for peas (c) was estimated as follows:

$$CROP\_FACTOR(c) = 2*FRAC_{NCRBF}*DMF(c)_{NCRBF} \quad (4.11)$$

Where: $FRAC_{NCRBF}$ = Fraction of nitrogen content from dry mass of nitrogen-fixing crops type (c) (default value of 0.03 kg N kg dry biomass^{-1}), and

$DMF(c)_{NCRBF}$ = Dry matter fraction of N in nitrogen-fixing crops (c).

Soil organic matter contributes to total crop production and related GHG emissions. Total emissions are a reflection of soil structure and farming practices. Minimal or zero tillage farming practices allow for the sequestration of carbon back into the soil. Table 4.4 below illustrates the total emissions generated from soil organic matter in 2000. Due to management practices Alberta and Saskatchewan have been estimated to be a carbon sink.

Table 4.4 CO_2 emissions from soil organic matter in 2000, kilo tonnes

Region	Soil Organic Matter
Alberta	(930.23)
Saskatchewan	(3,659.96)
Manitoba	174.35

Source: Sobool and Kulshreshtha (2005).

Farm-Level Fuel and Fertilizer Use Module (A2): Farm fuel and fertilizer (energy) use contributes to GHG emissions in a number of modules throughout the GHGEM. To calculate the usage of energy both on and off farm, a breakdown of farm types was evaluated. Whereas the Sobool and Kulshreshtha (2005) study used eight farm types, only those for the grains and oilseed farm type were used in the present study. Total energy use based GHG emissions were a total of the following six fuel types: Gasoline; Diesel; Liquid Petroleum Gases (LPGs); Natural Gas; Electricity; Furnace Oil. Data for estimation of these coefficients were obtained from the Farm Energy Use Survey (FEUS) compiled by Agri-Food Canada (AAFC, 1997). The FEUS identified the following primary fuel uses: Farm Machinery; Trucks and Automobiles; Heat and Light; Other Uses; and Non-Farm related uses.

The GHGEM used quantity of fuel, which is determined by the fuel expenditures included in the cost of production budgets in CRAM, for various crops. Dividing total expenditure in the province by the average fuel price for the province yielded the total quantity of fuel use.

GHG Emissions estimation for farm machinery fuel use was estimated using the following equation:

$$TEM(g.c.r)_{FU} = Area\ (c.r) * EC(g.c.r)_{FU} \tag{4.12}$$

Where: *Area (c.r)* = Area for crop type (c) in region (r), in ha, (CRAM output),

$EC(g.c.r)_{FU}$ = Emission factor for farm machinery fuel use for GHG (g), crop type (c) in region (r), in tonnes ha^{-1}.

Emissions factors for farm machinery use were estimated as:

$$EC(g.c.r)_{FU} = TOTAL\_FUEL(c.r) * EF(p)_{FM} \tag{4.13}$$

Where: *TOTAL_FUEL(c.r)* = Total fuel used for farm machinery for each crop type (c) in region (r), in litres per ha (CRAM output), and

$EF(p)_{FM}$ = Provincial emissions factor for farm machinery fuel use, in tonnes per acre.

Provincial emissions level was calculated using the average GHG emissions for gasoline, diesel, and LPGs under each farm type. The values were estimated as:

$$EF(p)_{FM} = TEM(g.p)_{FM} / FUEL\ CONS(p)_{FM} \qquad (4.14)$$

Where: $TEM(g.p)_{FM}$ = Total emissions for GHG (g) from farm machinery (FM) In province (p) in tones,

$FUEL\ CONS(p)_{FM}$ = Total fuel consumed in province (p) for farm machinery in litres, obtained from CRAM output.

The emission factors for the Prairie Provinces are illustrated in Table 4.5. These factors indicate the level of carbon dioxide, methane, and nitrous oxide emissions that are generated in the Prairie Provinces from the operation of farm equipment.

Table 4.5 Farm machinery fuel use emission factors, in tonnes per litre, 2000

Region	CO_2	CH_4	N_2O
Alberta	0.002698	0.002860	0.003678
Saskatchewan	0.002704	0.002814	0.003735
Manitoba	0.002694	0.002892	0.003638

Source: Sobool and Kulshreshtha (2005).

GHG emissions generated from the application of fertilizers are especially important in the total GHG emissions of agriculture. According to Sobool and Kulshreshtha (2005) to calculate these emissions, fertilizer use had to be broken down into fertilizer types. This is shown in Table 4.6.

The N_2O emission from each province was then calculated based upon the amount of fertilizer used in that province. The following equation was used to calculate total N_2O emissions from fertilizer use ($N_2O\_TEM(c.r)_{FRTU}$):

Table 4.6 Nitrogen evolved as N_2O, by type of fertilizer

Fertilizer	Fraction N Evolved as N2O
Urea	0.0030
Ammonium sulphate	0.0010
Ammonium nitrate	0.0030
Anhydrous ammonia	0.0160
Nitrogen solutions	0.0030
Other nitrogen	0.0010
Calcium nitrate	0.0020
Phosphate	0.0012
Potash/other fertilizer	0.0012

Source: Sobool and Kulshreshtha (2005).

$$N_2O\_TEM(c.r)_{FRTU} = AREA(c.r) * N_2O\_EC(c.r)_{FRTU} \quad (4.15)$$

Where: $AREA(c.r)$ = Area of crop type (c) in region (r), in ha, (CRAM output)

$N_2O\_EC(c.r)_{FRTU}$ = N_2O emission coefficient from fertilizer use for crop type (c) in region (r), in tonne per ha.

The N_2O coefficient was based upon the levels of fertilizer applied to a crop and the proportion which contributes to N_2O emissions.

$$N_2O\_EC(c.r)_{FRTU} = QNTY(c.r) * N\_CONT(p)_{FRT} * 44/28 \quad (4.16)$$

Where: $QNTY(c.r)$ = Quantity of fertilizer applied to crop (c) in region (r), in tonnes per ha, (estimated from CRAM output Table 4.7),

$N\_CONT(p)_{FRT}$ = Nitrogen content of fertilizer in province (p), in tonnes per tonne of fertilizer.

Table 4.7 below indicates the amount of nitrous oxide emissions that are released in a gaseous form from the consumption of nitrogen fertilizer in each province.

Table 4.7: Fertilizer consumption and nitrogen evolved as N_2O, 2000

Region	Nitrogen Fertilizer Consumption (tonnes)	N Evolved as N_2O (tonnes)	Nitrogen Content (t per t of fertilizer)
Alberta	508286.00	3247.89	6.39E-03
Saskatchewan	543996.00	3431.40	6.38E-03
Manitoba	326933.00	2572.42	7.87E-03

Source: Sobool and Kulshreshtha, 2005

On-Farm Energy Use Module (Module C): The On-Farm Energy Use Module estimates the GHG emissions as a result of the transportation inputs -- the transportation of grain from the field to storage, and the transportation of the grain to the primary collection point, i.e., primary elevator or processor. On-Farm Transportation of Crops was calculated as follows:

$$TEM(g.c.r)_{OFCT} = AREA(c.r) * EC(g.c.r)_{OFCT} \qquad (4.17)$$

Where: $AREA(c.r)$ = Area of crop type (c) in region (r), in ha, (CRAM output), and

$EC(g.c.r)_{OFCT}$ = Emission coefficient for GHG (g) for crop type (c) in region (r), in tonnes per ha.

Off-Farm Energy Use Module (Module E): Off-farm activities as described by Sobool and Kulshreshtha (2005) included activities related to hauling of commodities from the primary elevator to the final Canadian destination. Emissions generated from use of energy in transporting products beyond Canadian boundary were not a part of the calculation. Estimation of the total emission was a sum of those from rail and truck transportation activities. Estimation was done as follows:

For Rail:

$$TEM(g.c.r)_{OFF\text{-}RAIL} = AREA(c.r) * EC(g.c.r)_{OFF\text{-}RAIL} \qquad (4.18)$$

Where: $AREA(c.r)$ = Area of crop type (c) in region (r) in ha (CRAM output), and

$EC(g.c.r)_{OFF\text{-}RAIL}$ = Emission coefficient for GHG (g) crop type (c) in region (r) from off-farm transportation of crop products via railways, in tonnes per ha.

For Truck:

$$TEM(g.c.r)_{OFF\text{-}TRUCK} = AREA(c.r) * EC(g.c.r)_{OFF\text{-}TRUCK} \quad (4.19)$$

Where: $AREA(c.r)$ = Area of crop type (c) in region (r) in ha (CRAM output), and

$EC(g.c.r)_{OFF\text{-}TRUCK}$ = Emission coefficient for GHG (g) crop type (c) In region (r) from off-farm transportation of crop products via trucks, in tonnes per ha.

Transportation accounts for the majority of the GHG emissions generated from off-farm emissions. However the storage of crops also accounts for GHG emissions. Off-farm storage emissions are calculated as follows:

$$TEM(g.c.r)_{OFF\text{-}STOR} = AREA(c.r) * EC(g.c.r)_{OFF\text{-}STOR} \quad (4.20)$$

Where: $AREA(c.r)$ = Area of crop type (c) in region (r) in ha (CRAM output)

$EC(g.c.r)_{OFF\text{-}STOR}$ = Emission coefficient for GHG (g), crop type (c) in region (r), resulting from crop storage, in tonnes per ha.

Manufacturing and Transportation of Farm Inputs Module (Module D): The Manufacturing and Transportation of Farm Inputs Module calculate GHG emissions from the manufacturing and transportation of fertilizers, chemicals, and machinery. The following equations illustrate these calculations:

For Fertilizer Production:

$$TEM(g.c.r)_{FRT} = AREA(c.r) * EC(g.c.r)_{FRT} \quad (4.21)$$

Where: $AREA(c.r)$ = Area of crop type (c) in region (r) in ha (CRAM output), and

$EC(g.c.r)_{FRT}$ = Emission coefficient for GHG (g), crop (c) in region (r) from fertilizer production in tonnes per ha.

For Fertilizer Transportation:

$$TEM(g.p.m)_{FERT\_TRANS} = T\text{-}KM(p.m)_{FERT} * FUEL\_FACTOR(m) * EF(g) \quad (4.22)$$

Where: $T\text{-}KM(p.m)_{FERT}$ = Total t-km for transport of fertilizers in province (p) by mode (m),

$FUEL\_FACTOR(m)$ = Fuel factor for mode of transport, and

$EF(g)$ = Diesel emissions factors in tonnes per litre.

For Chemical Production:

$$TEM(g.c.r)_{PEST} = AREA(c.r) * EC(g.c.r)_{PEST} \quad (4.23)$$

Where: $AREA(c.r)$ = Area of crop type (c) in region (r) in ha (CRAM output), and

$EC(g.c.r)_{PEST}$ = Emission coefficient for GHG (g), crop (c) in region (r) from chemical production in tonnes per ha.

For Chemical Transportation:

$$TEM(g.p.m)_{PEST\_TRANS} = T\text{-}KM(p.m)_{PEST} * FUEL\_FACTOR(m) * EF(g) \quad (4.24)$$

Where: $T\text{-}KM(p.m)_{PEST}$ = Total t-km for transport of chemicals in province (p) by mode (m),

$FUEL\_FACTOR(m)$ = Fuel factor for mode of transport, and

$EF(g)$ = Diesel emissions factors in tonnes per litre.

For Machinery Production:

$$TEM(g.c.r)_{MACH} = AREA(c.r) * EC(g.c.r)_{MACH} \quad (4.25)$$

Where: $AREA(c.r)$ = Area of crop type (c) in region (r) in ha (CRAM output), and

$EC(g.c.r)_{MACH}$ = Emission coefficient for GHG (g), crop (c) in region (r) from machinery production in tonnes per ha.

For Machinery Transportation:

$$TEM(g.p.m)_{MACH\_TRANS} = T\text{-}KM(p.m)_{MACH} * FUEL\_FACTOR(m) * EF(g) \quad (4.26)$$

Where: $T\text{-}KM(p.m)_{MACH}$ = Total t-km for transport of machinery in province (p) by mode (m),

$FUEL\_FACTOR(m)$ = Fuel factor for mode of transport, and

$EF(g)$ = Diesel emissions factors in tonnes per litre.

Indirect Agroecosystem Emissions Module (Module H): The Indirect Agroecosystem Emissions Module calculates the levels of emissions from atmospheric deposition of nitrogen, nitrogen leaching, cultivation of organic soils, and human sewage. Module H is the summation of these indirect sources. Estimation is done as follows:

Atmospheric Deposition:

$$N_20\_TEM(c.r)_{ADF} = AREA(c.r) * N_20\_EC\ (c.r)_{ADF} \quad (4.27)$$

Where: $AREA(c.r)$ = Area of crop type (c) in region (r) in ha (CRAM output), and

$N_20\_EC(c.r)_{ADF}$ = Emission coefficient for atmospheric deposition for crop (c) in region (r), in tonnes per ha.

Nitrogen Leaching:

$$N_20\_TEM(c.r)_{LRF} = AREA(c.r) * N_20\_EC\ (c.r)_{LRF} \quad (4.28)$$

Where: $AREA(c.r)$ = Area of crop type (c) in region (r) in ha (CRAM output), and

$N_20\_EC(c.r)_{LRF}$ = N_20 emission coefficient for crop (c) in region (r), in tonnes per ha.

Cultivation of Organic Soils:

$$CO_2\_TEM(p)_{HS} = AREA(p) * CO_2\_EC_{HS} \quad (4.29)$$

Where: $AREA(p)$ = Area of histosols in province (p) in ha, and

$CO_2\_EC_{HS}$ = Emission coefficient for CO_2 from cultivation of histosols, in tonnes per ha. (IPCC default value of 10 tonnes ha^{-1} yr^{-1} was used.

Human Sewage:

$$N_20\_TEM(p)_{HS} = AREA(p) * N_20\_EC_{HS} \quad (4.30)$$

Where: $AREA(p)$ = Population in province (p), and

$N_20\_EC_{HS}$ = N_20 emission coefficient from human sewage in kg $capita^{-1}$.

Agroecosystem Module (Module I.1.): The Agroecosystem module estimates total emissions from wetlands areas and cultivated land. These provide opportunities for carbon sinks. Module I.1. is estimated as follows:

Cultivated Land:

$$CH_4\_TEM(l.r)_{CL} = AREA(l.r) * CH_4\_EC\ (l.r)_{CL} \quad (4.31)$$

Where: $AREA(l.r)$ = Area of land type (l) in region (r) in ha (CRAM output), and

$CH_4\_EC(c.r)_{ADF}$ = Methane emission coefficient for cultivation of land type (l), in tonnes per ha.

Wetlands:

$$CH_4\_TEM(r)_{WTLD} = AREA(r)_{WTLD} * CH_4\_EC_{WTLD} \quad (4.32)$$

Where: $AREA(r)_{WTLD}$ = Area of wetland in region (r) in ha (CRAM output), and

$CH_4\_EC_{WTLD}$ = Methane emission coefficient for wetlands (IPCC average default value of 0.235 tonnes CH_4 ha^{-1} yr^{-1}.

In summary, the GHGEM allows for a comprehensive evaluation of the GHG emissions that are produced as a consequence of both on-farm and off-farm activities. The Crop Production Module computes all GHG emissions that are produced from the production of crops. These include both emissions that are produced naturally and as a result of human activity. Natural emissions are generated from nitrogen-fixing crops, such as alfalfa and field peas, as they are able to convert nitrogen in the soil into usable nitrogen source for the crop, however in turn releasing some of that nitrogen into the atmosphere. Other natural sources of emissions occur from environmental cycles, such as the breaking down of soil organic matter. The Farm Level Fuel and Fertilizer Use Module determines the amount of emissions produced from use of farm inputs (excluding fuel)) for production. The On-farm Energy Use Module calculates the GHG emissions from the transportation of products and farm inputs on the farm. The Off-farm Energy Use Module determines GHG emissions as a result of transportation of products off the farm to primary collection points. The Manufacturing and Transportation of Farm Inputs Module calculates the GHG emissions as a result of the production and transportation of machinery, chemicals, and fertilizer. The GHGEM allows for a comprehensive evaluation of the GHG emissions which are produced as a consequence of producing agricultural commodities in Canada by taking both direct and indirect linkages.

4.3.3 Regional Economic Development Model

The CARDIOM allows for the evaluation of the economic impacts as a result of converting agricultural land to organic production for various regions of Canada. Canada is divided into 10 provinces. In addition, results are also generated for aggregate Canada. The CARDIOM has the following characteristics, as reported by Kulshreshtha and Sobool (2006):

1. The CARDIOM was designed as a multi-regional I-O model, as feedback effects in the model among provinces were excluded;
2. Since the focus of GHG mitigation measure is on agriculture sector, this sector was represented in a disaggregated manner;

3. Since much of the agricultural production leads to processing of these products in various provinces, the manufacturing sector was disaggregated into food processing and other manufacturing;

4. The model was developed in such a manner that both indirect and induced impact scenarios can be estimated; and

5. The model was appended with an employment module. This enabled the model to estimate not only the impact on economic measures but also on employment in various sectors in a given region.

The CARDIOM was based on the data provided by Statistics Canada with further adjustments made to enable the above listed features (Sobool and Kulshreshtha, 2006a). Figure 4.2 illustrates the methodology of the CARDIOM. Initial data supplied by Statistics Canada pertained to S-Level aggregation of sectors and commodities. Agriculture production and manufacturing activities were further subdivided into additional sub-sectors.

The model estimates Type I and Type II impacts for each of the ten provinces and Canada. Type I is the where the household income and expenditures were not endogenized, and Type II is the where the household income and expenditures were endogenized. For both Type I and Type II impacts, the CARDIOM generates impacts using a propensity to consume for each province. Employment generated by the model includes workers (both paid and self-employed) and managers.

Results from the CARDIOM are expressed in terms of the following four economic criteria:

1. Total sales by sector;
2. Gross domestic product at market prices;
3. Household incomes; and
4. Imports.

The provincial and national multipliers in this model were based on year 2000 levels of transactions and trade patterns of the region with other Canadian regions as well as with regions outside Canada. These are summarized in two key matrices: the Use Matrix and the Make Matrix. The multiplier is summarized below from Sobool and Kulshreshtha (2006a).

1. The U-Matrix (use) values are converted into per unit requirements for various sectors;
2. The Y_f matrix is primary input use for production of commodities by a sector. These transactions are converted into coefficient matrix and appended to the B-matrix described below;
3. A matrix of input coefficient is created by taking per unit requirements of intermmediate goods (step one) and appended by coefficients for primary inputs (step two). This matrix is called B-Matrix and is of (number of commodities X number of sectors) dimension;
4. The V-matrix (make) is also converted into coefficients on per unit of commodity output. This matrix is called D-matrix and is of (number of sectors X number of commodities) dimension;
5. The multiplier system in matrix form was estimated as follows:

$$g = (I-DB)^{-1} (DE) \qquad (4.27)$$

Where:

g is a column vector of sectoral output;

D is the market share coefficient matrix;

B is the use coefficient matrix;

I is an identity matrix; and

E is a vector of final demand.

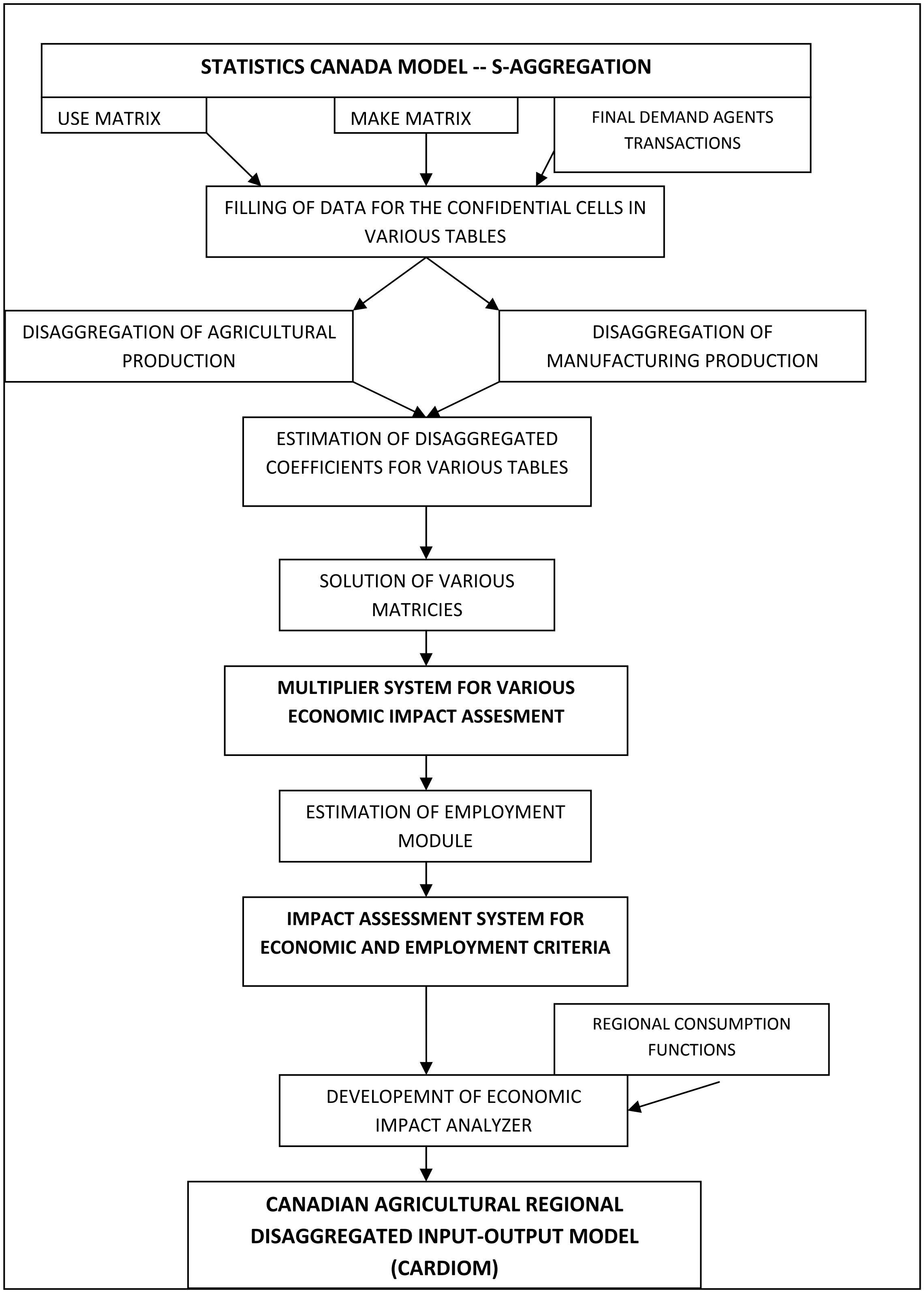

Figure 4.2 Overview of methodology followed for the development of the model

Source: Sobool and Kulshreshtha (2006a).

6. The resulting sectoral output is then related to primary input use and results in estimation of impact on various economic indicators listed above;
7. With the appended employment module, the solution in Step Five above is also linked to changes in employment levels in the region by various sectors.

In order to link results from CRAM with CARDIOM, a CRAM – CARDIOM interface module was developed. This interface module adjusted the outputs from the CRAM to meet the input requirements for the CARDIOM.

4.4 Source of Data

For the purposes of this study a variety of data were required. The CRAM model required farm level data to estimate the use of machinery, chemicals, fertilizers, and fuel in primary production. Since the cropping rotation (Alfalfa – Wheat – Barley – Flax – Oats – Peas) to be evaluated has already been selected, levels of inputs and production costs for the individual crops were determined from provincial and federal governments and university cost estimates, as described in this section.

4.4.1 Farm Level Data

The CRAM output for 2000 was used to develop a starting platform from which both conventional and organic cost of productions could be estimated. To estimate the cost of production for conventional agriculture the Saskatchewan Crop Production Guides (Government of Saskatchewan, 2000, and Government of Saskatchewan 2005) for the years 2000 and 2005 were used. Detailed data sets are presented in Appendix A. Alberta and Manitoba do not have this same information for conventional agriculture. As a result, information from Saskatchewan was used for similar soil zones.

The crop production guides produced by Saskatchewan Agriculture and Food (2005) “provide information that can help estimate the income and cost of production for different crops on summerfallow and stubble in various soil zones in the province”. In these guides average fuel, fertilizer, chemical, repair, and other costs for various cropping zones are reported. In this study, brown, dark brown and black soil zone areas of Alberta, Saskatchewan, and Manitoba were included. The provincial guides were used to estimate cost of conventional agricultural practices in these soil zones. Since no cost data were available for the grey soil zone, the areas of Peace River Alberta, northern parts of Alberta, Saskatchewan, and Manitoba, and the far eastern part of Manitoba, were excluded from this analysis.

Organic production information was gathered from the University of Saskatchewan (2005) and Alberta Agriculture, Food, and Rural Development (2001). Details on these data are presented in Appendix B. The University of Saskatchewan (2005) Organic Crop Production Guide uses the same format as the Crop Production Guide of the Saskatchewan Government.

Production estimates were obtained from provincial crop production guides, as described earlier. Where production guides were not available, yield estimates were used from a production area with similar soil and weather characteristics from a neighbouring province. To calculate producer returns, price data from the above sources were used in combination with yield production from the provincial yield estimates.

Price indices are a normalized average of prices for a given class of goods or services in a given region, during a given interval of time (Lipsey et al., 1997). Since some of the costs data were for different years, they were updated using price indices. Data for 2000 collected from Alberta Agriculture, Food, and Rural Development was updated to year 2005 to make them comparable to data from Government of Saskatchewan and the University of Saskatchewan. Data on price indices were obtained from Statistics Canada (2007a).

4.4.2 Greenhouse Gases

Using the CRAM output for 2000, the GHGEM was used to calculate total emissions generated as a result of inputs used. This is accomplished through multiplying various GHG emission coefficients by level of crop production from the modified CRAM. All data in this model were obtained from Sobool and Kulshreshtha (2005).

4.4.3 Regional Model

Data for the Canadian Agriculture Regional Disaggregated Input-Output Model (CARDIOM) and for the CRAM – CARDIOM interface were obtained from Kulshreshtha and Sobool (2006). The CRAM – CARDIOM interface converts the output from CRAM into a usable format for the inputs for the CARDIOM.

4.5 Price Data and Producer Returns

Price data for farm level economics were obtained from two sources. Statistics Canada (2007c) database was used to obtain prices for conventionally produced products. Organic agricultural product prices were obtained from the University of Saskatchewan (2005). There is very little to no market for organic hay, therefore the price used for organic hay was equated to given the same price as conventionally produced hay.

4.6 Assessment of Trade-offs

The TOA was undertaken at the regional and national level. At each level four criteria were used. These are: (1) total GHG emissions in Carbon dioxide equivalent units (CO_{2E}); (2) farm level economic impact, as measured by net returns (gross revenue minus total costs) from the two production systems; (3) regional impacts, as measured through change in gross domestic product at market prices; and (4) employment, as measured in full time equivalents.

4.7 Study Hypothesis

It is hypothesized that conversion of agricultural land to organic agriculture will result in a win-win situation. GHG emissions from organic production system will be significantly lower because less synthetic fertilizers and chemical pest control mechanisms will be applied, thereby reducing N_2O emissions in various regions. Higher returns for organic products and lower production costs will improve farmer net returns. This would likely result in an increase the producer net returns and total GDP of the region as well as that of Canada. Higher economic activity in the region will likely improve due to an increase direct and indirect effects.

4.8 Model Simulation

The study considered a conversion of ten per cent of the total cultivated land in the three Prairie Provinces from conventional to organic production system. Total area converted was 5,216 ha divided further as: 1304 ha under alfalfa, 968 ha under wheat, 368 ha under barley, 212 ha under oats, 964 ha under flax, and 1,400 ha under field peas. This level was selected on an estimated growth in production of organic products from 2000 to 2005.

4.9 Summary

To evaluate impact of converting some agricultural land under conventional production to an organic production system, a number of models were required. Three models that were used were: CRAM, GHGEM and CARDIOM. The CRAM allowed for an evaluation of farm level effects as a result of the conversion from a conventional production system to an organic production system. Assumptions were required regarding farming practices and management to allow for a comprehensive study to be completed. These assumptions included: conventional and organic livestock will produce the same levels of emissions; an increase of organic production by ten per cent will not impact organic prices due to consumers' willingness-to-pay, and finally, demand for organic products will increase. Data for this model were collected from provincial government cost estimation based upon soil type.

The GHGEM used the cost of production estimates used in the CRAM under the two production systems. Conventional and organic management requires the use of differing inputs. To calculate the difference in emissions levels, the GHGEM was separated into a number of modules allowing for a more comprehensive evaluation of GHG emissions, both direct and indirect which are generated from agriculture activities.

Finally the CARDIOM model evaluated the regional and national economic impacts, determining impacts to output, GDP, household income and employment for various regions of Canada. The results of the three models and an evaluation of the trade-offs resulting from this conversion.

Chapter 5

Results

This chapter reports the estimation results that were generated using the CRAM, GHGEM, and CARDIOM models described in the previous chapters for the two production systems – conventional and organic. As noted earlier, results from these models were used for the TOA. The CRAM used agriculture cost of production data to determine the use of inputs for crop production. Production information generated from CRAM and market prices were used to determine producer returns. The CRAM output was also used as an input for the GHGEM to calculate GHG emissions produced from each of the production system. CRAM outputs were also required to estimate the regional and national economic development implications of conversion from conventional to organic production system. Since the output of GHGEM and the CARDIOM are large (they include all activities associated with agriculture and processing), only the factors that are directly applicable to primary organic and conventional production systems are discussed. Further details on these results are presented in Appendices[6].

This chapter is divided into six sections. In Section 5.1 a comparison of farm level economic and production impacts is made, followed by in Section 5.2 by a comparison of GHG emission levels for the two systems. This discussion includes emissions of all three individual gases reviewed -- carbon dioxide, methane, and nitrous oxide, as well as emissions in carbon dioxide equivalent. The third section contains analysis of regional and national economic benefits. The fourth section provides the impact of a carbon market on the desirability of organic production system. Section 5.5 contains a description and result of the TOA, primarily in

[6] Appendix C contains emissions of carbon dioxide from the conventional and organic production systems. Methane, nitrous oxide and carbon dioxide equivalent emissions are presented in Appendix D to E, respectively.

terms of the cost to society associated with reducing GHG emissions. Finally, the last section of the chapter presents a summary of results.

5.1 Comparison of Farm Level Economic and Production Impacts

From the standpoint of a producer undertaking the conversion from conventional to organic crop production, three important characteristics need to be evaluated:

1. Production;
2. Prices; and
3. Net Returns to producers.

Total production comparisons are presented in Table 5.1 showing a provincial breakdown of the changes in physical production levels resulting from the conversion of land under conventional to organic production system. As noted here, there is a decrease in the total amount (physical weight) of production between conventional production and organic production.

Table 5.1 reveals that there is no consistency in the level of reduction in production between conventional and organic production of the same crop in the three Prairie Provinces. There are a number of reasons that organic production is not identical to conventional production in oats, alfalfa, and barley but significantly different for other crops. Weather patterns greatly influence total production. If rain or heat units are limiting factors for a crop under conventional production system, then an organic crop will have a comparable yield. Another factor may be the natural nutrients of the soil. Crops such as alfalfa are nitrogen fixing and require different nutrients which might be more available in one crop region over another.

Table 5.1 also indicates that the level at which yield of each commodity (resulting in total level of output for that crop) decreases is inconsistent. Crops such as alfalfa and oats require very few inputs to control pest and keep weed populations down. However, high maintenance crops, such as flax and peas, with a weak ability to compete against weeds and other pests, put organic producers at a major disadvantage. A crop's ability to compete refers to the crops ability to grow faster and larger than voluntary plants in a plant population. Competition in this context refers to competing for soil nutrients, moisture both in the soil and precipitation, and for sunlight.

Table 5.1 Net effect of total crop output from a conversion of conventional to organic production system in the Prairie Provinces in 2000

	Conventional Production			Organic Production			Convnetional - Organic
	AREA ('000 HA)	YIELD (TONNES HA^{-1})	PRODUCTION ('000 TONNES)	AREA ('000 HA)	YIELD (TONNES HA^{-1})	PRODUCTION ('000 TONNES)	PRODUCTION ('000 TONNES)
				Alberta			
Alfalfa	448.00	1.95	871.68	448.00	1.66	743.68	128.00
Wheat	392.00	2.06	806.40	392.00	1.48	580.61	225.79
Barley	98.00	2.21	217.00	98.00	1.66	162.75	54.25
Flax	392.00	1.40	548.80	392.00	0.76	296.35	252.45
Field Peas	644.00	2.20	1416.80	644.00	1.19	765.07	651.73
				Saskatchewan			
Alfalfa	648.00	17.66	1271.52	648.00	17.21	1239.26	32.26
Wheat	432.00	14.10	676.80	432.00	13.43	644.50	32.30
Barley	198.00	18.90	415.80	198.00	16.81	369.75	46.05
Oats	108.00	14.65	175.80	108.00	14.07	168.80	7.00
Flax	468.00	8.10	421.20	468.00	5.01	260.68	160.52
Field Peas	684.00	14.20	1079.20	684.00	7.46	566.66	512.54
				Manitoba			
Alfalfa	208.00	20.65	1073.80	208.00	20.65	1073.80	0.00
Wheat	144.00	7.10	255.60	144.00	7.24	260.50	-4.90
Barley	72.00	10.40	187.20	72.00	9.25	166.54	20.66
Oats	104.00	8.45	219.70	104.00	7.80	202.90	16.80
Flax	104.00	3.40	88.40	104.00	2.64	68.54	19.86
Field Peas	72.00	9.60	172.80	72.00	4.09	73.58	99.22
				Prairie Provinces			
Alfalfa	1304.00	40.26	3217.00	1304.00	39.52	3056.74	160.26
Wheat	968.00	23.26	1738.80	968.00	22.14	1485.60	253.20
Barley	368.00	31.51	820.00	368.00	27.72	699.04	120.96
Oats	212.00	23.10	395.50	212.00	21.87	371.71	23.79
Flax	964.00	12.90	1058.40	964.00	8.41	625.56	432.84
Field Peas	1400.00	26.00	2668.80	1400.00	12.73	1405.31	1263.49

Evaluating the yields of different crops indicates that for crops, such as wheat and barley, yields are significantly higher due to the supplementation of synthetic produced nutrients. Crops that are less competitive, such as flax and field peas, show significantly lower yields under organic production system than under conventional production system. Same level of alfalfa production was estimated for both conventional and organic production systems in Manitoba. Lack of data for Manitoba resulted in this assumption based on Saskatchewan data.

The lower yields under organic production system are a result of no herbicides being used to control weed populations, increasing the crop competition. Conversely, lower input crops, such as alfalfa and oats, show less difference in yields between conventional and organic production systems. The conventional production system is superior in total crop production as compared to the organic one, due to its ability to use all available practices, technology and inputs to reduce crop competition and increase nutrient availability.

Although organic production system yield lower levels of production, organic producers are compensated through higher prices for their products. This premium is a reflection of lower availability of organic product due to lower production levels and higher willingness-to-pay by consumers for these products. Average price for crops included in the study are shown in Table 5.2 for the three provinces. With the exception of hay, there are significant premiums received by organic producers. No premiums are received for organic hay because there is minimal demand for it over conventionally-produced hay. However, hay and cover crop are essential for organic crop rotation.

Evaluating economic implications at the farm level requires analysis of three major concepts: cost of production, crop mix, and gross revenue.

1. Cost of production refers to the cost associated with producing a product. Provincial data were input into CRAM to estimate the cost of production for both farming systems.

Table 5.2 Producer prices received for the sale of agricultural products in the Prairie Provinces, 2000

Crops	Conventional Average Price (Tonne)	Organic Average Price (Tonne)
Alberta		
Alfalfa Hay	66.00	66.00
Feed Barley	110.34	188.01
Wheat	98.99	255.51
Oats	92.86	171.84
Flax	226.27	767.22
Feed Peas	136.00	197.89
Saskatchewan		
Alfalfa Hay	66.00	66.00
Feed Barley	91.01	216.38
Wheat	100.74	287.49
Oats	91.09	212.33
Flax	225.36	810.73
Feed Peas	135.00	196.43
Manitoba		
Alfalfa Hay	66.00	66.00
Feed Barley	91.38	124.58
Wheat	99.48	259.29
Oats	98.65	214.54
Flax	224.95	652.78
Feed Peas	140.00	198.05
Conventional Prices Referenced from: http://estat.statcan.ca/cgi-win/CNSMCGI.EXE (Oct 5, 2006) CANSIM		
Organic Prices Referenced from: http://organic.usask.ca/pricedata.htm (Oct 5, 2006)		

2. Crop mix is defined as the selection and combination of crops in production by a producer and/or farm operation. However, in this study crop mix was fixed on account of the selected rotation.

3. Gross revenue represents the total sum of income collected from the sales of goods produced. The prices (as presented in Table 5.2) and production information provided in Table 5.1 were used to estimate it.

The total cost of production, including the fertilizer, chemical, fuel, repair, and other costs[7] associated with each of the crops for both conventional and organic agriculture is illustrated in Table 5.3 below. These items are based on the CRAM specification of total cost of production.

Table 5.3 Total production costs of conventional and organic production systems by crop, 2000

Crops	Fertilizer Cost ($'000)	Chemical Cost ($'000)	Fuel Cost ($'000)	Repairs Cost ($'000)	Other Cost ($'000)	Total Cost ($'000)
Total Conventional						
Alfalfa	44,765.58	0.00	10,252.76	31,776.62	25,116.58	111,911.54
Wheat	57,331.96	53,385.08	7,625.49	23,428.55	37,006.69	178,777.77
Barley	22,721.44	17,639.01	2,901.33	8,943.67	12,906.50	65,111.95
Oats	16,978.20	3,921.92	1,753.59	6,275.05	7,163.32	36,092.08
Flax	60,229.78	59,502.26	7,694.42	14,806.14	43,248.53	185,481.14
Field Peas	27,752.03	91,143.39	10,700.11	33,086.65	94,674.03	257,356.21
Total Organic						
Alfalfa	0.00	0.00	8,677.07	31,584.15	54,729.86	94,991.08
Wheat	0.00	0.00	6,742.03	33,919.12	34,347.22	75,008.37
Barley	0.00	0.00	2,848.13	10,946.70	10,932.27	24,727.09
Oats	0.00	0.00	1,637.42	8,470.77	7,518.50	17,626.69
Flax	0.00	0.00	7,173.26	24,686.62	47,574.79	79,434.68
Field Peas	0.00	0.00	8,020.48	27,646.95	157,496.96	193,164.39

Table 5.4 summarizes the differences in input costs associated with the two production systems. For all crops evaluated in the study the total costs were higher for conventional crop production than for the organic system, as indicated by the positive difference (conventional minus organic). The higher production costs result mainly from higher fertilizer, chemical, and other costs. Other costs vary significantly from crop to crop due to the level of labour required and machinery used. Organic farming system has higher other costs, such as higher labour

[7] Other costs is defined as the building repair, property taxes, insurance and licenses, machinery depreciation, building depreciation, machinery investment, building investment, land investment, utilities and labour.

costs. Conventional production system requires additional equipment, such as a sprayer, therefore resulting in higher depreciation costs.

Table 5.4 Cost difference between conventional and organic production systems by crop, 2000

Total Cost Difference (Conventional Costs - Organic Costs)						
Crop	**Fertilizer Cost ($'000)**	**Chemical Cost ($'000)**	**Fuel Cost ($'000)**	**Repairs Cost ($'000)**	**Other Cost ($'000)**	**Total Cost ($'000)**
Alfalfa	44,765.58	0.00	1,575.69	192.48	-29,613.28	16,920.47
Wheat	57,331.96	53,385.08	883.47	-10,490.57	2,659.47	103,769.41
Barley	22,721.44	17,639.01	53.20	-2,003.02	1,974.24	40,384.86
Oats	16,978.20	3,921.92	116.16	-2,195.71	-355.18	18,465.39
Flax	60,229.78	59,502.26	521.16	-9,880.48	-4,326.26	106,046.47
Field Peas	27,752.03	91,143.39	2,679.62	5,439.70	-62,822.92	64,191.82

Although the input costs of using conventional production system are higher, farm level preferences are typically guided by profit motives. Under a conventional production system, producers receive a net positive return for most crops in all three provinces. Table 5.5 shows net returns from the production of various crops under conventional production system, whereas Table 5.6 shows the same data for organic production system.

In Alberta, a positive return was estimated for all crops under conventional production system. For Saskatchewan and Manitoba, all crops except feed barley and oats, had a positive net return under the conventional production system. Saskatchewan and Manitoba producers did not receive positive returns for feed barley and oats under conventional agriculture because livestock, in particular the cattle feedlot industry, is not as significant as in Alberta, thus reducing farm gate prices for these crops. Table 5.6 provides estimated direct returns for organic production system. All commodities under the organic production system provide a net positive return to the producer.

Table 5.5 Total farm-level direct return from conventional production system by crops and province, 2000

Crop	Price	Production	Revenue (Thous. $)	Costs (Thous. $)	Revenue – Costs (Thous. $)
Alberta Conventional Production System					
Alfalfa	$ 66.00	871.68	$ 57,530.88	$ 32,630.74	$ 24,900.14
Feed Barley	$ 110.34	806.40	$ 88,978.18	$ 71,336.00	$ 17,642.18
Wheat	$ 98.99	217.00	$ 21,480.83	$ 17,210.11	$ 4,270.72
Flax	$ 226.27	548.80	$ 124,176.98	$ 72,981.57	$ 51,195.41
Feed Peas	$ 136.00	1416.80	$ 192,684.80	$ 118,300.95	$ 74,383.85
Saskatchewan Conventional Production System					
Alfalfa	$ 66.00	1271.52	$ 83,920.32	$ 43,848.26	$ 40,072.06
Feed Barley	$ 91.01	676.80	$ 61,595.57	$ 78,583.84	$ (16,988.27)
Wheat	$ 100.74	415.80	$ 41,887.69	$ 34,309.22	$ 7,578.47
Oats	$ 91.09	175.80	$ 16,013.62	$ 16,749.55	$ (735.93)
Flax	$ 225.36	421.20	$ 94,921.63	$ 91,756.46	$ 3,165.17
Feed Peas	$ 135.00	1079.20	$ 145,692.00	$ 121,867.48	$ 23,824.52
Manitoba Conventional Production System					
Alfalfa	$ 66.00	1073.80	$ 70,870.80	$ 35,432.54	$ 35,438.26
Feed Barley	$ 91.38	255.60	$ 23,356.73	$ 28,857.94	$ (5,501.21)
Wheat	$ 99.48	187.20	$ 18,622.66	$ 13,592.62	$ 5,030.03
Oats	$ 98.65	219.70	$ 21,673.41	$ 19,342.54	$ 2,330.87
Flax	$ 224.94	88.40	$ 19,884.70	$ 20,743.12	$ (858.42)
Feed Peas	$ 140.00	172.80	$ 24,192.00	$ 17,187.78	$ 7,004.22

Given data of Tables 5.5 and 5.6, one can estimate farm level desirability, from a producers' perspective, of the organic production system. Table 5.7 illustrates increases in total on-farm returns from converting 10 per cent of cropland in each of the three Prairie Provinces from conventional to organic system. With the exception of field peas, in Alberta and Manitoba, and alfalfa, in Alberta and Saskatchewan producer returns are higher for all other crops. The higher returns and lower input costs of organic production system outweigh the total production benefit associated with conventional production system. Although field peas are marginally profitable in Saskatchewan, such is not the case in Alberta and Manitoba. Here field pea price premiums do not compensate for the reduction in yields.

Table 5.6 Total farm-level direct return from organic production system, 2000

Crop	Price	Production	Revenue (Thous. $)	Costs (Thous. $)	Revenue – Costs (Thous. $)
Alberta Organic Production System					
Alfalfa	$ 66.00	743.68	$ 49,082.88	$ 32,203.31	$ 16,879.57
Feed Barley	$ 188.01	580.61	$ 109,160.11	$ 32,166.13	$ 76,993.98
Wheat	$ 255.51	162.75	$ 41,584.25	$ 7,026.39	$ 34,557.86
Flax	$ 767.22	296.35	$ 227,367.18	$ 35,299.69	$ 192,067.50
Feed Peas	$ 197.89	765.07	$ 151,400.10	$ 99,241.39	$ 52,158.70
Saskatchewan Organic Production System					
Alfalfa	$ 66.00	1239.26	$ 81,791.42	$ 44,983.21	$ 36,808.22
Feed Barley	$ 216.38	644.50	$ 139,456.04	$ 31,491.84	$ 107,964.20
Wheat	$ 287.49	369.75	$ 106,300.58	$ 12,702.75	$ 93,597.83
Oats	$ 212.33	168.80	$ 35,842.15	$ 9,108.32	$ 26,733.83
Flax	$ 810.73	260.68	$ 211,337.85	$ 36,331.79	$ 175,006.06
Feed Peas	$ 196.43	566.66	$ 111,308.24	$ 83,127.32	$ 28,180.92
Manitoba Organic Production System					
Alfalfa	$ 66.00	1073.80	$ 70,870.80	$ 17,804.56	$ 53,066.24
Feed Barley	$ 124.58	260.50	$ 32,452.59	$ 11,350.40	$ 21,102.20
Wheat	$ 259.29	166.54	$ 43,181.12	$ 4,997.95	$ 38,183.17
Oats	$ 214.54	202.90	$ 43,531.02	$ 8,518.37	$ 35,012.66
Flax	$ 652.78	68.54	$ 44,738.93	$ 7,803.20	$ 36,935.73
Feed Peas	$ 198.05	73.58	$ 14,573.31	$ 10,795.68	$ 3,777.63

The organic production system across the prairies adds increased value to the farm level economics of crop production. These data indicate that an organic production system can be a viable management system for prairie producers due to lower input costs and higher prices for commodities.

Table 5.7 Total on-farm returns from converting cropland from conventional to organic production system by province and crop, 2000 (organic minus conventional) in thous. dollars

	Alberta	Saskatchewan	Manitoba	Total
Alfalfa	$ (8,020.57)	$ (3,263.84)	$ 17,627.98	$ 6,343.57
Feed Barley	$ 59,351.80	$ 124,952.47	$ 26,603.40	$ 210,907.68
Wheat	$ 30,287.14	$ 86,019.35	$ 33,153.14	$ 149,459.63
Oats	$ -	$ 27,469.76	$ 32,681.79	$ 60,151.54
Flax	$ 140,872.09	$ 171,840.89	$ 37,794.15	$ 350,507.13
Feed Peas	$ (22,225.15)	$ 4,356.40	$ (3,226.59)	$ (21,095.34)

Change in value of farm level production together with various inputs used their production are the direct impacts of converting land from conventional to organic production system. A summary of these impacts in terms of production of various types of crops is shown in Table 5.8. These data suggest that Prairie producers, by converting ten per cent of their cropland to organic production system, could collectively gain $406.5 million per annum. This is a direct result of fewer inputs and higher prices for commodities.

Table 5.8 Direct impacts from a shift to an organic production system, 2000 (thousands of dollars) by Province

Province	Crop Input Classification	Change in Input Demand (Thous. $)
Alberta	Wheat, unmilled	$20,181.93
	Corn, barley, oats and other grains	($21,181.28)
	Canola, soybeans and other oil seeds	$103,190.20
	Hay and straw	($8,448.00)
	Total	$93,742.85
Saskatchewan	Wheat, unmilled	$77,860.47
	Corn, barley, oats and other grains	$49,857.66
	Canola, soybeans and other oil seeds	$116,416.22
	Hay and straw	($2,128.90)
	Total	$242,005.45
Manitoba	Wheat, unmilled	$9,095.86
	Corn, barley, oats and other grains	$36,797.38
	Canola, soybeans and other oil seeds	$24,854.23
	Hay and straw	$0.00
	Total	$70,747.47
Prairie Provinces	Wheat, unmilled	$107,138.26
	Corn, barley, oats and other grains	$65,473.76
	Canola, soybeans and other oil seeds	$244,460.65
	Hay and straw	($10,576.90)
	Total	$406,495.77

In terms of share of gains, it is estimated that Alberta experiences annual gains of $93.7 million, equating to approximately 23 per cent of the total regional gain, Saskatchewan realizes gains of $242 million or approximately 60 per cent, and Manitoba realizes gains of $70.7 million or approximately 17 per cent of net farm increases.

5.2 Comparison of GHG Emissions

Converting farm land under a conventional production system to an organic production system in Alberta, Saskatchewan, and Manitoba significantly reduces the total GHG emission associated with crop production. Results are shown in Table 5.9 for conventional production system, in Table 5.10 for organic production system, and in Table 5.11 as a net reduction from the conversion.

Under the conventional production system, Alberta accounts for the largest level of GHG emissions, estimated at 2,610 kilo-tonnes (kt) of CO_2 equivalent (CO_{2E}). Saskatchewan represents the second greatest contributor, with 2,264 kt of CO_{2E}, followed by Manitoba with 1,008 kt of CO_{2E}.

Table 5.10 shows that under an organic production system, GHG emissions are significantly reduced relative to those under a conventional production system. Under the organic production system, Saskatchewan is the largest contributor of GHG emission with 1,441 kt CO_{2E}. Alberta is the second largest emitter of GHG with 1,305 kt of CO_{2E}, followed by Manitoba with 494 kt of CO_{2E}.

Carbon dioxide emissions are generated from numerous activities related to crop production. The primary source of CO_2 is the burning of fossil fuels for stationary combustion.

Table 5.9 GHG emissions (kilo tonnes) from conventional production system for Canada by province and source, 2000

	Module A.1 **Crop Prod**	Module H **Indirect Emissions**	Module I.1 **Agroeco-System Emm**	Module A.2 **Other Crop Emissions**	Module C **On-Farm Trans/S.C.**	Module D **Farm Inputs**	Module E **Off-Farm Trns/Strg**	**Total**
				Carbon Dioxide				
AL	0.00	2.49	0.00	231.24	48.93	410.59	245.23	938.48
SA	0.00	1.00	0.00	2.90	28.55	252.96	477.11	762.52
MA	17.93	1.00	0.00	94.38	10.04	124.08	8.64	256.07
CAN	17.93	4.49	0.00	328.52	87.52	787.62	730.98	1,957.07
				Methane				
AL	0.00	0.00	2.01	0.03	0.01	10.06	0.02	12.13
SA	0.00	0.00	8.51	0.02	0.00	5.48	0.04	14.05
MA	0.00	0.00	4.29	0.01	0.00	0.11	0.00	4.41
CAN	0.00	0.00	36.71	0.06	0.02	15.64	0.07	52.50
				Nitrous Oxide				
AL	3.68	0.46	0.00	0.04	0.00	0.35	0.03	4.57
SA	3.20	0.40	0.00	0.03	0.00	0.19	0.07	3.89
MA	1.69	0.41	0.00	0.01	0.00	0.01	0.00	2.13
CAN	8.57	1.28	0.00	0.08	0.00	0.55	0.10	10.59
				Carbon Dioxide Equivalent				
AL	1,141.21	145.59	42.19	243.63	49.77	731.44	256.46	2,610.29
SA	990.59	125.24	178.63	13.08	28.98	428.01	499.31	2,263.83
MA	542.67	129.54	90.10	98.54	10.23	128.06	9.03	1,008.17
CAN	2,674.47	400.37	771.00	355.25	88.97	1,287.51	764.80	6,342.38

In addition, this type of use is also associated with GHG emissions through the manufacturing, transportation of products both on-farm and off-farm, and the operations of producing crops. Release of carbon typically occurs from the break-down of organic material and the release of carbon through the natural carbon cycle. Evaluation of the carbon dioxide emissions results reveals that they are 47 per cent lower under the organic system as compared to the conventional system. However, these emission reductions are not the same in all provinces. In Alberta CO_2 emissions decreased by 57 per cent, while in Saskatchewan and Manitoba only by 33 and 50 per cent, respectively.

Table 5.10 GHG emissions (kilo tonnes) from organic production system for Canada by province and source, 2000

	Module A.1	Module H	Module I.1	Module A.2	Module C	Module D	Module E	
	Crop Prod	**Indirect Emissions**	**Agroeco-System Emm**	**Other Crop Emissions**	**On-Farm Trans/S.C.**	**Farm Inputs**	**Off-Farm Trns/Strg**	**Total**
Carbon Dioxide								
AL	0.00	2.49	0.00	178.50	31.83	45.33	142.16	400.31
SA	0.00	1.00	0.00	-29.43	21.50	61.30	456.56	510.93
MA	17.93	1.00	0.00	90.66	8.24	2.77	6.67	127.28
CAN	17.93	4.49	0.00	239.73	61.56	109.40	605.39	1,038.51
Methane								
AL	0.00	0.00	2.01	0.02	0.01	8.14	0.01	10.20
SA	0.00	0.00	8.51	0.02	0.00	4.69	0.04	13.26
MA	0.00	0.00	4.29	0.01	0.00	0.10	0.00	4.41
CAN	0.00	0.00	36.71	0.05	0.01	12.94	0.06	49.77
Nitrous Oxide								
AL	1.87	0.03	0.00	0.03	0.00	0.28	0.02	2.23
SA	1.84	0.01	0.00	0.03	0.00	0.16	0.07	2.10
MA	0.85	0.01	0.00	0.01	0.00	0.00	0.00	0.88
CAN	4.56	0.05	0.00	0.07	0.00	0.45	0.09	5.21
Carbon Dioxide Equivalent								
AL	578.23	11.89	42.19	188.54	32.34	303.53	148.63	1,305.34
SA	569.42	4.14	178.63	-20.71	21.81	209.95	477.84	1,441.07
MA	282.82	4.58	90.10	94.66	8.39	6.10	6.98	493.64
CAN	1,430.47	20.60	771.00	262.50	62.54	519.58	633.45	3,700.14

Evaluation of emissions per hectare illustrates that organic farming system produces significantly lower emission, as shown in Table 5.12. Saskatchewan experiences the greatest reduction in GHG emissions with total reductions of 63.7 per cent per hectare. Alberta and Manitoba both experienced lower levels of reductions with 50 and 49 per cent per hectare reduction, respectively.

Further examination of emissions was done for individual GHGs. A closer evaluation at the individual modules in the model reveals that: Module A.1 - Crop Production, Module H - Indirect Agroecosystem Emissions, and Module I.1 – Agroecosystem have the same level of carbon dioxide emissions for both production systems. This may be because carbon dioxide emissions are not released due to management decisions but rather as a consequence of the natural carbon cycle in crop production.

Table 5.11 Reduction in GHG emissions (kilo tonnes) from conversion of cropland from conventional to organic production system, by province and source, 2000

	MODULE A.1	MODULE H	MODULE I.1	MODULE A.2	MODULE C	MODULE D	MODULE E	
	CROP PROD	**INDIRECT EMISSIONS**	**AGROECO-SYSTEM EMM**	**OTHER CROP EMISSIONS**	**ON-FARM TRANS/S.C.**	**FARM INPUTS**	**OFF-FARM TRNS/STRG**	**TOTAL**
Carbon Dioxide								
AL	0.00	0.00	0.00	52.74	17.11	365.25	103.08	538.18
SA	0.00	0.00	0.00	32.33	7.05	191.65	20.55	251.59
MA	0.00	0.00	0.00	3.72	1.80	121.31	1.96	128.79
CAN	0.00	0.00	0.00	88.79	25.96	678.22	125.59	918.56
Methane								
AL	0.00	0.00	0.00	0.01	0.00	1.91	0.01	1.93
SA	0.00	0.00	0.00	0.00	0.00	0.79	0.00	0.79
MA	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01
CAN	0.00	0.00	0.00	0.01	0.01	2.70	0.01	2.73
Nitrous Oxide								
AL	1.82	0.43	0.00	0.01	0.00	0.07	0.01	2.34
SA	1.36	0.39	0.00	0.00	0.00	0.03	0.00	1.79
MA	0.84	0.40	0.00	0.00	0.00	0.00	0.00	1.24
CAN	4.01	1.23	0.00	0.01	0.00	0.11	0.02	5.38
Carbon Dioxide Equivalent								
AL	562.98	133.70	0.00	55.09	17.43	427.91	107.83	1,304.95
SA	421.17	121.10	0.00	33.79	7.17	218.06	21.46	822.75
MA	259.85	124.96	0.00	3.88	1.84	121.95	2.06	514.54
CAN	1,244.00	379.77	0.00	92.76	26.44	767.93	131.35	2,642.24

Table 5.12 Comparison of reduction in GHG emissions (kilo tonnes) between conventional and organic production system, by province, 2000

		Conventional Agriculture		**Organic Agriculture**		**Difference Conv-Organic**	**Difference Conv-Organic (per cent)**
Province	**AREA ('000 HA)**	**CO_{2E} in kt**	**CO_{2E} in kt / ha**	**CO_{2E} in kt**	**CO_{2E} in kt/ ha**		
Alberta	1974.00	2610.29	1.32	1305.34	0.66	0.66	50.0%
Saskatchewan	2538.00	2263.83	0.89	1441.07	0.57	0.32	63.7%
Manitoba	704.00	1008.17	1.43	493.64	0.70	0.73	49.0%
Prairie Provinces	5216.00	5882.29	1.13	3240.05	0.62	0.51	55.1%

Conventional production system does, however, generate increasing levels of carbon dioxide emissions when it comes to fuel use for transportation and other farm level production related activities, as shown by the results for Module A.2 - Other Crop Production and Module C - On-farm Transportation and Storage, and Other Energy Use (Table 5.9). Fuel consumption is an extremely important input for the production of crops. The model reveals that conventional production system generates more CO_2 emissions per hectare than organic agriculture (119.95 kt per hectare higher across the Prairie Provinces, as indicated by the difference in CO_2 emissions outputs in Tables 5.10 and 5.11). Conventional agriculture also generates more transportation and storage related emissions. This is because conventional production results in a greater quantity of cereals, pulses, oilseeds, and forages to transport both on and off-farm, as seen in Module E - Off-farm Transportation and Storage. As illustrated in Section 5.1, due to higher production levels under conventional production system, transportation and storage emission levels are expected to be higher both for on- and off-farm activities.

Finally Module D - Farm Inputs shows the level of carbon dioxide emissions generated from the manufacturing of farm inputs. These activities yield the largest level of carbon dioxide emissions for agricultural production. It is estimated that fertilizer production generates 635.05 kt of carbon dioxide (see Appendix C), while total carbon dioxide emissions are estimated at 1,979.49 kt (from all carbon sources). Thus, production of fertilizers constitutes over 32 per cent of the total carbon dioxide emissions from conventional production. Appendix C illustrates the complete break-down of carbon dioxide emissions reductions resulting from the conversion of land under conventional production system to an organic system.

Methane emissions generated by both conventional and organic production systems are relatively similar (see Appendix D). The major agricultural emitter of methane is livestock.

As discussed earlier, livestock production actives were excluded from this study. However, through crop production activities, methane emissions under organic production system decreased by five per cent, relative to conventional production system. The reduction in methane emissions are not the same in all provinces. Methane emissions decreased by 15 per cent in Alberta, by five per cent in Saskatchewan and showed nearly no decline in Manitoba.

Production of farm inputs, as shown in Module D, is the only area that generates a significantly higher level of methane emissions under conventional production system as compared to the organic production system. The operation of conventional production system required increased use of fuel. Methane emissions are also generated from the production of fuel to be used on the farm. Module C, although relatively small, shows that organic agriculture has a higher level of on-farm transportation activity-related emissions. Consequently conventional agriculture creates approximately 2.7 kt more methane emissions annually than organic agriculture (see Appendix E)[8]. Appendix E illustrates the complete break-down of methane emissions reductions created as a result of converting conventionally managed agriculture land to organically managed land.

Evaluation of the N_2O emissions reduction reveals a 51 per cent decline under organic production system as compared to conventional system. The reduction in N_2O emissions are not the same in all provinces. N_2O emissions decreased by 44 per cent in Alberta, by 46 per cent in Saskatchewan and by 59 per cent in Manitoba (see Appendix E).

N_2O is the GHG of particular concern for Canadian agriculture due to its extremely high heat absorption capacity -- 310 times that of carbon dioxide. Agriculture is also the primary

[8] This 2.7 kt is the calculated difference between conventional and organic farming methane emissions in Module D.

contributor of N_2O into the atmosphere as a result of the production of inputs as well as from leaching and atmospheric deposition of nitrogen fertilizers and manure.

Organic production system eliminates the need for synthetically-produced inputs for crop production; however it does not completely eliminate emissions of N_2O into the atmosphere. This is because N_2O emissions occur naturally, in addition to synthetic sources. Nitrogen fixing plants, such as field peas, emit N_2O naturally. Conventional production system uses synthetic fertilizer to increase the available nutrients to crops and chemicals to reduce crop competition by pests, weeds and insects, thereby allowing crops to use all the available nutrients. Under organic production system, on the other hand, a producer manages these through crop rotations, such as pulse crops, allowing for the crop to help regenerate nutrients back into the soil. Organic production system also uses mechanical systems to reduce pest competition with crops. Appendix E demonstrates that although organic production does not have fertilizer emissions, only the natural agricultural cycles create N_2O emissions under this production system. Furthermore, the break-down of crop residues releases into atmosphere the nitrogen trapped in the plant. These reactions are a part of the nitrogen cycle and are unavoidable. Conventional production system release more nitrogen as a part of the nitrogen cycle than do organic production system.

As calculated in Module A1 of the GHGEM, fertilizer generated an additional 1.77 kt of N_2O emissions annually under the conventional production system as compared to the organic production system, as illustrated in the breakdown of N_2O emission in Appendix E. The other two sources are crop residues releasing 2.54 kt of N_2O, and nitrogen released from nitrogen fixing crops,[9] releasing 4.26 kt of N_2O emissions. This is a combined result of application losses, plants releasing emissions when converting nitrogen into usable form, over-application, and plant usage. Over-application refers to farms applying addition nitrogen beyond the requirements of the crop. Plant usage refers to the oxidation of nitrogen as the plant takes-up the nitrogen fertilizer.

The manufacturing of fertilizers is also a source of additional N_2O emissions, 110 kt are released into the atmosphere as the result of this industrial process. The conventional production system is also responsible for creating an additional 1.23 kt of indirect N_2O emissions, as shown in Module H. Atmospheric deposition and nitrogen leaching from fertilizer is primarily a product of poor management and application techniques. Generally speaking, under the conventional production system, application of fertilizer in the Prairies is done in three forms: granular, gas, and liquid. The most common application form is granular and anhydrous (gas) application. Granular nitrogen sources can be applied at multiple times of the year with a number of different techniques. The first technique is applying the fertilizer into the ground with the seed. This minimizes oxidation. However over-fertilization creates increased leaching. Granular fertilizers are also applied on top of the soil, with the nutrients leaching down to the plants. Fertilizer application produces losses into the atmosphere as the fertilizer particles break down. In this process, not the entire nitrogen source reaches the plants as a part of it is lost to the atmosphere. The second dominant method of application is through ammonia, a gaseous form of nitrogen. This application process releases nitrous gas into the atmosphere as the soil is unable to retain all the gas after application. Excess nitrogen applied this way is also leached into the soil. Finally liquid application, which is not widely used in

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9 In more recent review of the IPCC methodology, Canadian scientists have decided to exclude this source of emissions, on the basis that these are a part of the nitrogen cycle.

today's agriculture production but is growing to be increasingly popular, applies nitrogen in liquid form directly into the soil. This form, if over-applied, also causes leaching. Appendix E illustrates the complete break-down of nitrous oxide emissions reductions created as a result of converting conventional production system farm land to an organic system.

Emissions in CO_{2E}, as mentioned above, are the manner in which a valid comparison of the two production systems can be made. All three of the gases studied are now converted according to their global warming potential (GWP). Table 5.13 indicates that there is a total net difference of 2,642 kt of carbon equivalent emissions, representing a decline of 41 per cent from 6,342 kt of CO_{2E} emissions (as shown in Table 5.9) under conventional production system to 3,700 kt of CO_{2E} emissions generated by the organic production system (as shown in Table 5.10). This equates to 0.51 kt fewer CO_{2E} emissions per hectare for the Prairie Provinces as a whole with the suggested conversion of land from conventional to organic production system.

Table 5.13 Contributions of synthetic fertilizers in prairie agriculture under a conventional production system (kilo tonnes)

FERTILIZER CONTRIBUTIONS	(kt)
MODULE A1 -- CROP PRODUCTION	
Fertilizer	547.67
MODULE H -- INDIRECT AGROECOSYSTEM EMISSIONS	
Atmospheric Deposition -- Fertlizer	79.95
Nitrogen Leaching -- Fertlizer	299.81
MODULE D -- FARM INPUTS	
Fertilizer -- Domestic Use	638.30
TOTAL Fertilizer emissions from conventional agriculture	1,565.74
NET TOTAL DIFFERENTIAL (Conventional – Organic Emissions)	2,642.24
PERCENT OF TOTAL CO2 Equivalent	59%

As hypothesized earlier, the primary difference in GHG emissions between conventional and organic production system is the emissions generated from synthetic fertilizers and pest control mechanisms. The addition of synthetic inputs under a production system yields significant increases in the total level of GHG emissions generated from agriculture. As shown in

Table 5.13, some 59 per cent of the difference in GHG emissions between the two systems is a result of the use of synthetic fertilizers. These emissions are directly linked to conventional production system, and are avoided under organic system.

The second major source of GHG emissions under a conventional production system, relative to an organic one, is increased level of production. Additional production, although economically beneficial, increases GHG emissions. This is due to increased yield potential, relative to organically produced grains, oilseeds, and forages. Table 5.14 outlines the sources and net gains in total GHG emissions generated as a result of conventional production system. This table illustrates the additional GHG emissions that are released into the atmosphere under conventional production system, as opposed to under an organic system.

Table 5.14 Contributions of net GHG emissions through conversion, Prairie Provinces (conventional minus organic production system)

CONTRIBUTIONS FROM PRODUCTION INCREASES	(kt)
MODULE A1 -- CROP PRODUCTION	
Crop Residues	284.59
Crop Residues	411.74
MODULE A.2: OTHER CROP PRODUCTION	
Fuel for Farm Machinery	92.76
MODULE C -- ON-FARM TRANSPORTATION AND STORAGE, AND OTHER ENERGY USE	
Onfarm -- Crops -- Transportation	26.44
MODULE D -- FARM INPUTS	
Fuel -- Domestic Use	102.96
MODULE E: OFF-FARM TRANSPORTATION AND STORAGE	
Off-farm -- Crops -- Transportation	126.47
Off-farm -- Crops -- Storage	4.89
TOTAL	1,049.83
NET TOTAL DIFFERENTIAL	2,642.24
PERCENT OF TOTAL CO2 Equivalent	40%

Thus, contributions to total GHG emissions generated as a result of increased production account for 40 per cent of the total difference (not including food processing) between the two systems. Total conventional production system CO_{2E} was 6,342.38 kt, while total organic production system CO_{2E} was 3700.14 kt.

5.3 Regional Economic Changes

Direct impacts of conversion from conventional to organic production system are only a part of the total impact on the economy. Production of agricultural commodities in the Prairies generates many spin-off effects in these provinces, as well as in other parts of Canada. Changing the make-up of the way in which regional activities interact will ultimately change the dynamics and the characteristics of the regional economic activities. Using the CARDIOM, one is able to predict the economic changes in employment and GDP, both in the entire prairie region and in Canada. In this study, this model was used to evaluate impacts in terms of: Output (sales of goods and services by various industries or sectors), Gross Domestic Product (GDP) in market prices, household income, imports, and employment. Table 5.15 shows these results for each of the three Prairie Provinces, other parts of Canada, and Canada as a whole.

The CARDIOM results indicate that there will be an increase in GDP (market prices), household income and employment in all three Prairie Provinces that will be realized through the conversion of land from conventional to organic production system. Canada as a whole will also see gains in GDP, household income and employment, while regions of Canada outside the Prairie Provinces will see negative direct impacts to GDP and employments. When total impacts are evaluated however, only employment in other regions of Canada results in overall declines.

Increase in the economic activity in the Prairies is a direct result of higher values of farm level output. Due to the conversion of the cropland, there is an estimated additional 6,722 (fulltime equivalent) jobs across the Prairie Provinces. However, for Canada has a whole, a net gain of 6,606 jobs is estimated (Table 5.15). Prairie employment level increases are though gain in employment on grain farms, construction, wholesale trade, transportation and warehousing, professional and scientific services, as well as finance, insurance, and real estate services. The

CARDIOM predicts impacts on all facets of the Canadian economy, including food and food product manufacturing. The impacts on the food and food product manufacturing are through consumption – induced impacts.

Table 5.15 Regional economic impact of conversion of 10 per cent of cropland in the Prairie Provinces on the Canadian economy, by economic indicators, and by regions, 2000

Parameter	Output ($ '000)	GDP At Market Price ($ '000.)	Household Income ($ '000.)	Imports* in $ '000	Employment (FTE # Of Workers)
Alberta					
Direct and Indirect Impacts	93,742.85	55,323.87	28,706.74	6,393.51	994
Induced Impacts	74,046.71	30,533.13	27,101.06	16,053.09	511
Total Impacts	167,789.56	85,856.99	55,807.80	22,446.60	1,505
Saskatchewan					
Direct and Indirect Impacts	242,005.45	161,611.19	61,404.84	1,575.51	3,370
Induced Impacts	115,669.00	41,079.59	41,337.65	38,481.43	923
Total Impacts	357,674.45	202,690.78	102,742.49	40,056.94	4,293
Manitoba					
Direct and Indirect Impacts	70,747.47	40,608.06	26,091.03	2,596.58	660
Induced Impacts	38,435.75	15,698.32	15,909.51	11,427.70	265
Total Impacts	109,183.22	56,306.38	42,000.54	14,024.27	924
Other Regions of Canada					
Direct and Indirect Impacts	0.00	-9,792.20	8,313.15	-14,561.06	-472
Induced Impacts	118,216.90	47,391.88	50,843.26	-17,623.65	357
Total Impacts	118,216.90	37,599.68	59,156.41	-32,184.71	-116
Canada					
Direct and Indirect Impacts	406,495.77	247,750.91	124,515.76	(3,995.46)	4,551
Induced Impacts	346,368.36	134,702.92	135,191.49	48,338.56	2,055
Total Impacts	752,864.13	382,453.83	259,707.24	44,343.10	6,606

***** Inter-Provincial and / or International

The conversion to organic agriculture not only has an effect on input demand, and thus on sales of other industries, but also on household incomes, which are defined as a combination of wages and salaries, supplementary labour income, and mixed income in the CARDIOM.

The shift in agriculture away from conventional production system towards an organic one affects labour income directly through increases in the net farm income. Additional household incomes are generated through backward and forward linkages of agricultural production changes. By virtue of this conversion, all three Prairie Provinces experience an increase in household income. In Alberta there is an increase in these incomes of $55.8 million, whereas in Saskatchewan and Manitoba an increase of $102.7 million and $56.3 million, respectively, were realized.

5.4 Effect of Carbon Market on Desirability of Conversion to Organic Production System

Reduction in GHG emissions can create another source of revenue for organic producers. These reductions could be sold to other potential buyers. At this time, there are many carbon trading markets around the world that are searching for the value of carbon. EcoBusinessLinks (2010) provides a list of several carbon exchanges and their current posted value for carbon as of April 2010. Based upon this information, carbon is being valued at between USD$2.75 and USD$33.00 per tonne of carbon dioxide. Pacific Exchange (2010) indicates that the Canadian dollar was trading at $0.996 for the month of April. As reported int he previous section, the conversion of land from conventional to organic production system would reduce GHG emissions by 2,642.24 kt of CO_{2E}. If producers could sell these reduced emissions, using the price estimates from EcoBusinessLink, the value of reduced emissions is between CDN$7.3 million and CDN$87.5 million (Table 5.16). This will provide an additional inventive for producers to adopt organic production system. However, for this to happen, Canada will have to implement a cap and trade policy for carbon emissions. Opportunities to offset the financial risk of the conversion of production system from conventional to organic production would be partially offset by the value in the reduced GHG emissions.

Table 5.16 Expected producer returns for carbon equivalents

Price (US$ per tonne CO_2)*	Exchange Rate (US$/CDN$)**	Price (CDN$ per metric ton CO2)	Reduction in CO2E (kt)	Value of CO2E reduction ('000 of CDN$/CO2E)
2.75	0.996	2.74	2,642.24	7,239.74
15.00	0.996	14.94	2,642.24	39,475.07
33.00	0.996	32.87	2,642.24	86,850.43

Source: * EcoBusinessLinks (2010)
** Pacific Exchange (2010)

Although Canadian government has endorsed the reduction of GHG emissions in principle, not many concrete steps have been undertaken. Originally Canada signed the Kyoto Protocol in 1995, committing to reduce GHG emissions by six per cent below 1990 emissions levels. This was an estimated reduction in GHG emissions of 592 mega tonnes per year (Williams, 2009). However, during the recent Copenhagen Accord it was noted that Canada will not be able to meet these obligations. In 2009, Canada indicated that the global recovery is the top priority and that precede efforts to protect the environment (Delaney, 2009). Thus, development of a cap-and-trade system may have to wait until economic recovery is experienced.

5.5 Trade-off Analysis

Evaluation of the trade-offs that result from farmers adopting organic production system in the prairies was accomplished by taking into account the four indicators: GHG emissions, net farm income, economic development, and employment. These criteria were considered important in deciding whether or not a conversion of land under the conventional production system to an organic one is economically desirable. Let us review the four criteria selected for the TOA at the regional and national levels.

First, the conversion of ten per cent of the total agricultural land base in each of the three Prairie Provinces yielded reductions of total GHG emissions by 2.64 mega tonnes of carbon dioxide equivalent gases. Total emissions for conventional agriculture were 6.34 mega tonnes, while organic agriculture produced 3.7 mega tonnes. This is a significant level of reduction in GHG emissions and as stated earlier and is important to Canada's GHG emissions reduction strategy.

Second, due to the lack of application of some farm inputs, use of organic agriculture production results in a reduction of yields. These lower yields are, however, compensated by higher returns per unit produced. Consequently Prairie producers received a higher net farm income increasing from approximately $1.107 billion under conventional management to $1.514 billion under organic management. Direct net farm income across the prairies increased by $407 million.

Third, in the evaluation of regional economic impacts, it was estimated that each of the three regions observed an increase in their respective GDP, totalling $344.9 million. Conventional agriculture yields regional GDP of $4.009 billion, while organic agriculture resulted in a higher regional GDP, totalling $4.354 million.

Fourth, with respect to the impacts on regional employment, the CARDIOM estimated an increase in employment of 6,722 full time jobs across Alberta, Saskatchewan and Manitoba. Organic agriculture was calculated to produce 84,498 jobs while conventional agriculture was only calculated to produce 77,776 jobs.

Analysis of the total carbon dioxide equivalent emissions, farm level economic effect and regional economic results indicates a win-win scenario, Alberta, Saskatchewan, and Manitoba would all be better off. The radar diagram in Figure 5.1 is a multi scenario diagram that illustrates the relationship that a shift in farm management practices would yield. As shown here that a shift away from conventional towards organic production system results in a reduction in GHG emissions, increase in net farm income, improvements in the local regional GDP, and increased regional employment. The radar diagram indicates that from a regional accounting stance, adoption of organic production system is desirable move.

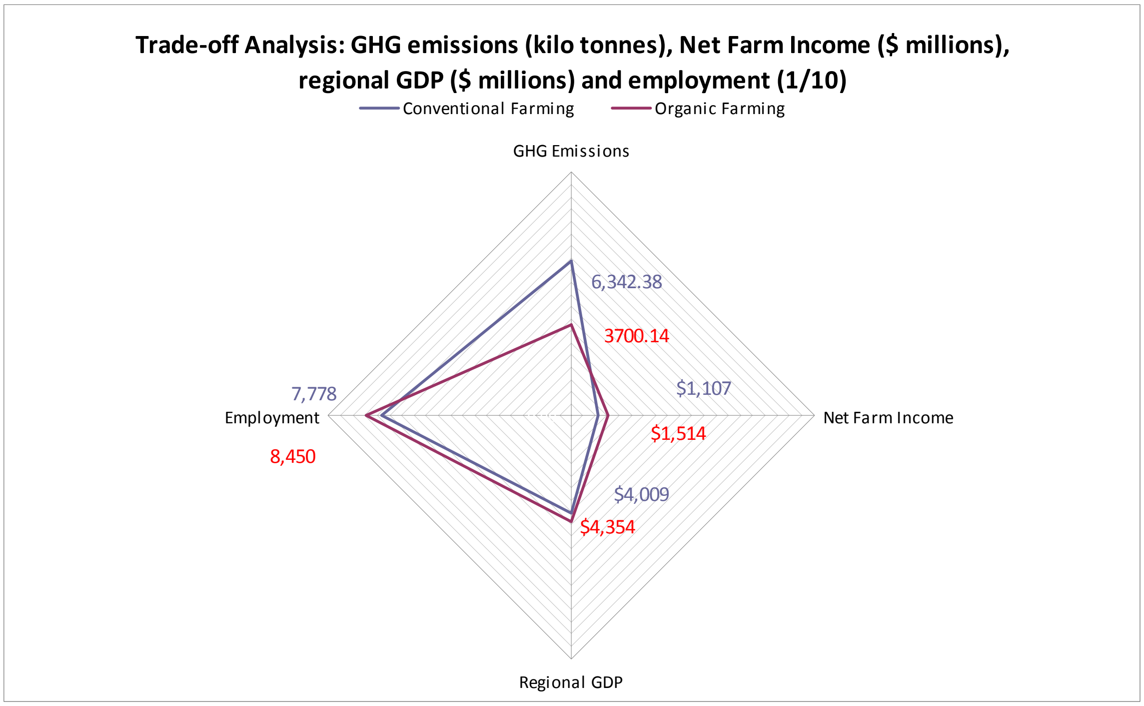

Figure 5.1 Radar diagram: Regional trade-off analysis of conversion of cropland to organic production

The use of the radar diagram illustrates that the null hypothesis is correct, as indicated by improvements of the four criteria (GHG emissions, net farm income, GDP and employment).

H_O: Conversion of production system from a conventional production system to an organic production system results in a win-win scenario.

H_1: Conversion of production system from a conventional production system to an organic production system does not result in a win-win scenario.

The TOA was also undertaken from a national perspective. This is shown in Figure 5.2. Using a national accounting stance, conversion of conventional to organic production system is also supported on economic grounds. Here the GHG emissions are reduced for the country, the net farm income improves, and the national GDP and employment increases. However, the negative changes are estimated for regions outside the Prairie Provinces, which do not gain under the said conversion.

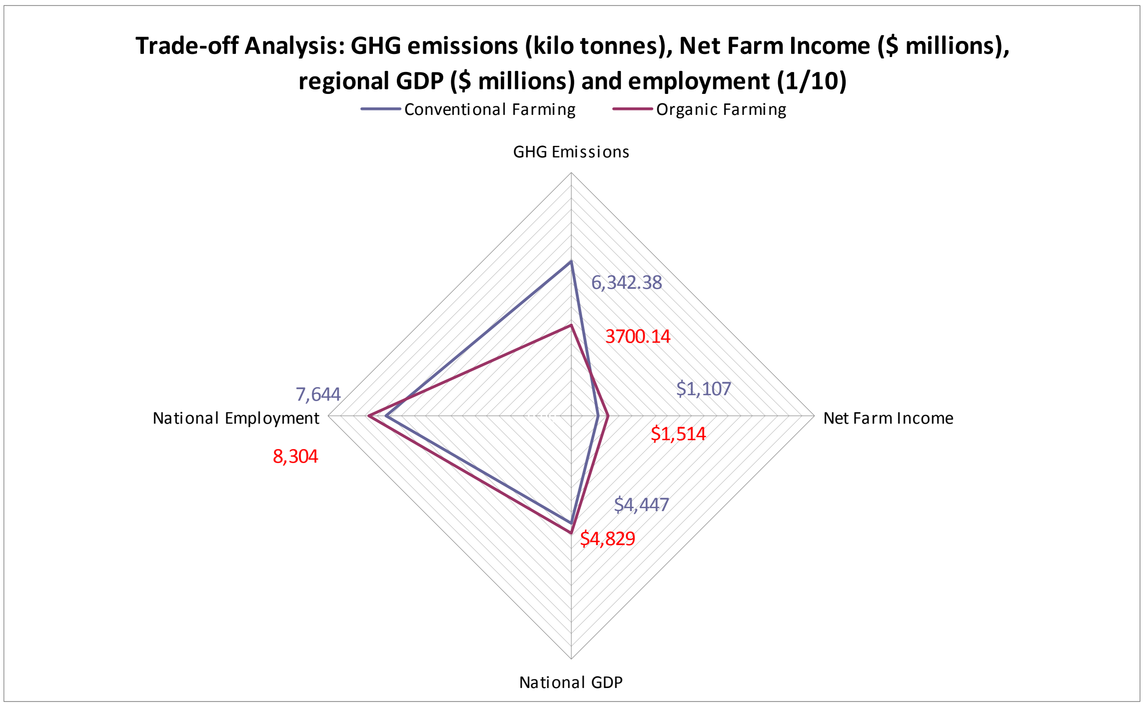

Figure 5.2 Radar diagram: National trade-off analysis of conversion of cropland to organic production

The above results are under the present situation of a lack of market for selling carbon credits. However, if a trading mechanism was in place and a value of carbon could be established, this would provide additional economic incentive, on a national as well as regional basis, to encourage such a conversion.

5.6 Summary

Conversion of agricultural land from a conventional production system to an organic production system has both positive and negative effects on the Canadian economy. This chapter evaluated the results on production, GHG emissions, household income, GDP, and employment. Converting land to organic production was more beneficial for the Prairie Provinces and less beneficial to regions outside the Prairie Provinces. Provincially Alberta, Saskatchewan, and Manitoba had reductions in total crop production due to the conversion, but produces were compensated for this through higher crop prices. Conversely all three provinces GHG emissions were reduced, but the GDP and employment increased. Canada as a whole, experienced reductions in crop production but increase in net farm returns, reductions in GHG emissions, but increase in GDP, household income and employment.

Completion of a TOA using environmental and economic criteria confirms the null hypothesis that conversion of cultivated land from a conventional production system to an organic production system results in a win-win scenario for the three Prairie Provinces and Canada, based on the four criteria (GHG emissions, net farm income, GDP and employment). Areas of Canada outside the three Prairie Provinces will see overall employment levels decrease slightly, however they will experience overall gains in GDP.

Chapter 6

Summary and Conclusions

6.1 Summary

Agricultural production has been noted for creating some environmental externalities. One such externality created is the emissions of greenhouse gases (GHG). These emissions are generated from a number of sources, including the earth's natural cycles. Conventional agriculture production has been identified as one of the most significant sources of GHG emissions, due to the synthetic inputs that are used for fertilizer, pest control, and the use of machinery for crop production. Organic agriculture has been suggested as one possible method of reducing GHG emissions generated by agriculture, due to the decreased dependence on synthetic inputs. Organic agriculture has been identified not only as a way to reduce GHG emissions but has been identified in some European countries as a way to help stimulate the rural economy.

In this study, overall desirability of converting a part of the cropland from conventional production system to organic one was done using four criteria: Change in net farm returns, change in GHG emissions, change in regional and / or national gross domestic product, and change in employment. These criteria were estimated using three models -- Canadian Regional Agriculture Model (CRAM), Greenhouse Gas Emission Module (GHGEM), and Canadian Regional Disaggregated Input-Output Model (CARDIOM). The scope of this study was the three Prairie Provinces – Manitoba, Saskatchewan and Alberta. Information was gathered from Saskatchewan Agriculture crop production guides, organic crop production guide from the University of Saskatchewan, Alberta Agriculture, and Manitoba Agriculture. Using this information, an estimation of input usage was determined for crop production in each of the crop regions included in the CRAM. The CRAM output levels were used as inputs for the GHGEM to determine the regional and national GHG emissions that were generated as a consequence of changing production system from a conventional system to an organic one. Finally using the CRAM output levels as inputs for the CARDIOM, regional and national gross domestic product (GDP), household incomes, and employment information were generated. Using these three models not only facilitated the evaluation of the direct impacts to agriculture, such as production and net farm income, but also facilitated the measuring of the extent of externalities, such as GHG emissions, regional and national economic development, and employment. A comparison of the overall economic desirability of the two production systems was done using the Trade-off Analsyis.

6.2 Conclusion

Conversion of land under a conventional production system to an organic production system was generally positive for both the Prairie Provinces and Canada. GHG emissions were reduced by 2.64 mega tonnes of CO_2 equivalents per year (amounting to 0.5 kt per hectare per year) generating a major environmental benefit from the conversion to organic agriculture. Net farm income was estimated to increase $406 million. The regional GDP and employment were also estimated to increase. Employment levels were estimated to increase by 6,722 full time equivalents in the Prairie Provinces. This was primarily in the grains and oilseed sector and related industries. In addition to increased employment, there was also an increase in regional GDP of $344.9 million for all three Prairie Provinces. There were also significant benefits observed at the Canadian level through increased economic activity and resulting in higher in GDP and employment levels. GDP for Canada as a whole was estimated to increase $384.5 million and employment was estimated to increase by 6,606 jobs. There was a significant decline in total crop production for nearly all crops. In spite of this decrease, net farm income levels were offset through higher prices for organic products.

The conversion of agricultural land from conventional to organic agriculture provided a win-win relationship for the regional and national economies. There is, however, a reduction in the GDP in regions outside the three Prairie Provinces further exemplifies by negative impacts on employment.

Although a proper basis to undertake a policy recommendation is a benefit-cost analysis, which was not the focus of this study, the result does support economic desirability of converting agriculture from conventional to organic productions system. If Canadian society places a higher weight on reducing GHG emissions, this conversion would be instrumental in meeting the national objective. Given that the conversion does not reduce the level of regional economic development the measure is a desirable one from both regional and national perspective. Expansion of organic agriculture has the potential to increase regional GDP, expansion of employment, and reduction in GHG emissions.

6.3 Limitations of the Study

Due to the scope of the project, a number of limitations of the study can be identified. First, producers following either conventional or organic production system have a choice of a number of different crop rotations. This study evaluates a single crop rotation. This may have limited the ability to examine potential production and economic returns under alternate conditions.

Second, production practices are limited under an organic agricultural system. Due to the importance of tillage for pest control, organic agriculture is unable to adapt zero-till production, a tillage system that is credited with changing prairie agriculture from a net source to a net sink of carbon.

Third, the study uses production cost estimation from provincial and university sources for inputs into the CRAM model. These production cost estimation are based on provincial data and may not reflect the actual input use levels of prairie producers.

Fourth, organic markets continue to fluctuate over time. It is difficult to predict what the future of the market will be for organic products. Demand will influence price and increased production around the world may decrease the premiums on these products obtained by producers. A forecast of such demand and its use in future analysis deserves mentioning, but was deemed unusable for the current analysis.

6.4 Further Studies

There are a number of studies that could be undertaken in the future. This study focused on GHG emissions under a single crop rotation in both conventional and organic agriculture. Future studies could be done by including all major crop rotations followed by producers under conventional and organic production systems. Varying crop rotation could be evaluated in two formats. (1) Evaluation of different crop rotations for all provinces and areas, further disaggregated by regions; and (2) The study could also be tailored to focus on economic returns and employment levels. Using the existing crop rotations, a number of scenarios could be evaluated in terms of impacts in GDP and employment based upon varying commodity prices for both conventional and organic production system.

This study identified and measured the change in four criteria of economic desirability. Other criteria could be added to this list. A more comprehensive investigation of need for a policy for encouraging conversion of area to organic production system needs to be carried out. A part of this investigation should also be on the need for subsidies and their respective levels.

Finally, this study only focussed on one environmental externality – GHG emissions. The conversion of land to organic production system may generate other ecological goods and services. These require a further study.

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Appendix A

Conventional Crop Planning Guild

CROP PRODUCTION COSTS ($/ACRE) BLACK SOIL ZONE 2000

	Conventional Seeded Stubble Crops								
	Spring Wheat	CPS Wheat	Feed Barley	Oats	Lentil	Feed Peas	Flax	Canary Seed	Canola
REVENUE PER ACRE									
Estimated Yield (bu/ac,lb/ac) (A)	33.0	41.4	56.7	65.0	1077.6	27.3	20.9	956.0	21.6
Est. On Farm Market Price/bus,lb (B)	3.00	2.50	1.52	1.25	0.17	3.15	4.25	0.11	4.50
Estimated Gross Revenue/ac (AxB) (C)	**99.00**	**103.50**	**86.18**	**81.25**	**183.19**	**86.00**	**88.83**	**105.16**	**97.20**
EXPENSES PER ACRE									
Variable Expenses/acre									
Seed	6.14	6.17	5.25	5.76	23.40	16.20	4.73	4.55	12.00
Fertilizer - Nitrogen	13.20	13.20	13.20	13.20	1.32	1.32	13.20	13.20	13.20
- Phosphorus	8.10	8.10	8.10	8.10	6.75	6.75	8.10	8.10	8.10
- Sulfur & Other	0.00	0.00	0.00	0.00	0.00	2.70	0.00	0.00	5.40
Chemical - Herbicides	17.40	14.95	15.11	7.77	30.26	21.60	21.87	17.92	17.55
- Insecticides/Fungicides	1.97	1.97	0.00	0.00	2.00	0.00	0.00	1.33	1.28
- Others	1.88	2.25	1.98	1.91	1.80	3.60	0.88	0.88	3.24
Machinery Operating - Fuel	8.20	8.20	8.20	8.20	9.02	9.02	9.02	8.20	8.61
- Repair	8.00	8.00	8.00	8.00	11.40	11.40	9.60	8.00	8.00
Custom Work & Hired Labour	6.25	6.25	4.25	4.25	3.00	3.00	4.25	5.25	4.25
Crop Insurance Premium	3.16	4.19	3.04	2.91	9.16	3.27	4.40	3.20	4.91
Utilities & Miscellaneous	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14
Interest on Variable Expenses	2.90	2.87	2.64	2.37	3.80	3.07	2.97	2.77	3.36
Total Variable Expenses (D)	**80.34**	**79.28**	**72.90**	**65.61**	**105.05**	**85.07**	**82.15**	**76.53**	**93.04**
Other Expenses/acre									
Building Repair	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60
Property Taxes	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97
Insurance & Licences	2.04	2.04	2.04	2.04	2.04	2.04	2.04	2.04	2.04
Machinery Depreciation	16.00	16.00	16.00	16.00	19.00	19.00	16.00	16.00	16.00
Building Depreciation	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60
Machinery Investment	12.00	12.00	12.00	12.00	14.25	14.25	12.00	12.00	12.00
Building Investment	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40
Land Investment	17.33	17.33	17.33	17.33	17.33	17.33	17.33	17.33	17.33
Total Other Expenses (E)	57.94	57.94	57.94	57.94	63.19	63.19	57.94	57.94	57.94
Total Expenses (D+E) (F) *	**138.28**	**137.22**	**130.84**	**123.55**	**168.24**	**148.26**	**140.09**	**134.47**	**150.98**
RETURNS PER ACRE									
Return over Variable Expenses (C-D)	**18.66**	**24.22**	**13.28**	**15.64**	**78.14**	**0.92**	**6.68**	**28.63**	**4.16**
Return over Total Expenses (C-F)	**-39.28**	**-33.72**	**-44.66**	**-42.30**	**14.95**	**-62.27**	**-51.26**	**-29.31**	**-53.78**
BREAK-EVEN YIELD PER ACRE **									
To Cover Variable Expenses	**26.8**	**31.7**	**48.0**	**52.5**	**617.9**	**27.0**	**19.3**	**695.7**	**20.7**
To Cover Total Expenses	**46.1**	**54.9**	**86.1**	**98.8**	**989.6**	**47.1**	**33.0**	**1222.4**	**33.6**
BREAK-EVEN PRICE PER BUS/LB **									
To Cover Variable Expenses	**2.43**	**1.92**	**1.29**	**1.01**	**0.10**	**3.12**	**3.93**	**0.08**	**4.31**
To Cover Total Expenses	**4.19**	**3.31**	**2.31**	**1.90**	**0.16**	**5.43**	**6.70**	**0.14**	**6.99**

* These budgets do not include an estimate for owner/operator labour and management. This value varies greatly and depends on both the farm manager's needs as well as the ability of the farm business to generate income. Farm managers need to determine their own actual labour and management cost and add it to total expenses.

** The break-even yields and prices for summerfallow crops include the previous years tillage fallow expenses.

CROP PRODUCTION COSTS ($/ACRE) BROWN SOIL ZONE 2000

	Conventional Seeded Stubble Crops								
	Spring Wheat	Durum Wheat	CPS Wheat	Feed Barley	Oats	Flax	Lentil	Canary Seed	Mustard
REVENUE PER ACRE									
Estimated Yield (bu/ac,lb/ac) (A)	21.7	21.7	25.4	34.2	38.9	11.6	878.4	591.6	15.2
Est. On Farm Market Price/bus,lb (B)	3.00	3.50	2.50	1.52	1.25	4.25	0.17	0.11	5.63
Estimated Gross Revenue/ac (AxB) (C)	**65.10**	**75.95**	**63.50**	**51.98**	**48.63**	**49.30**	**149.33**	**65.08**	**85.58**
EXPENSES PER ACRE									
Variable Expenses/acre									
Seed	5.65	7.79	5.34	4.77	5.12	4.05	23.40	4.55	3.10
Fertilizer - Nitrogen	9.90	9.90	9.90	9.90	9.90	9.90	1.32	9.90	9.90
- Phosphorus	5.40	5.40	5.40	5.40	5.40	5.40	6.75	5.40	5.40
- Sulfur & Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.70
Chemical - Herbicides	10.91	10.91	10.91	10.99	7.32	21.42	30.26	13.62	15.82
- Insecticides/Fungicides	0.99	0.99	0.99	0.00	0.00	0.00	2.00	1.33	0.51
- Others	1.73	1.95	1.95	1.80	1.70	0.75	1.80	0.88	5.40
Machinery Operating - Fuel	8.20	8.20	8.20	8.20	8.20	9.02	9.02	8.20	8.61
- Repair	6.00	6.00	6.00	6.00	6.00	7.20	9.00	6.00	6.00
Custom Work & Hired Labour	5.00	5.00	5.00	4.00	4.00	4.00	3.00	4.00	3.50
Crop Insurance Premium	2.29	2.42	3.15	3.66	2.52	4.62	8.97	3.11	4.31
Utilities & Miscellaneous	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09
Interest on Variable Expenses	2.18	2.27	2.21	2.13	1.96	2.57	3.66	2.22	2.53
Total Variable Expenses (D)	**60.33**	**62.92**	**61.14**	**58.94**	**54.21**	**71.02**	**101.27**	**61.29**	**69.87**
Other Expenses/acre									
Building Repair	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Property Taxes	3.92	3.92	3.92	3.92	3.92	3.92	3.92	3.92	3.92
Insurance & Licences	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12
Machinery Depreciation	12.00	12.00	12.00	12.00	12.00	12.00	15.00	12.00	12.00
Building Depreciation	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Machinery Investment	9.00	9.00	9.00	9.00	9.00	9.00	11.25	9.00	9.00
Building Investment	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.35
Land Investment	13.95	13.95	13.95	13.95	13.95	13.95	13.95	13.95	13.95
Total Other Expenses (E)	43.14	43.14	43.14	43.14	43.14	43.14	48.39	43.14	43.14
Total Expenses (D+E) (F) *	**103.47**	**106.06**	**104.28**	**102.08**	**97.35**	**114.16**	**149.66**	**104.43**	**113.01**
RETURNS PER ACRE									
Return over Variable Expenses (C-D)	**4.77**	**13.03**	**2.36**	**-6.96**	**-5.58**	**-21.72**	**48.06**	**3.79**	**15.71**
Return over Total Expenses (C-F)	**-38.37**	**-30.11**	**-40.78**	**-50.10**	**-48.72**	**-64.86**	**-0.33**	**-39.35**	**-27.43**
BREAK-EVEN YIELD PER ACRE **									
To Cover Variable Expenses	**20.1**	**18.0**	**24.5**	**38.8**	**43.4**	**16.7**	**595.7**	**557.1**	**12.4**
To Cover Total Expenses	**34.5**	**30.3**	**41.7**	**67.2**	**77.9**	**26.9**	**880.4**	**949.3**	**20.1**
BREAK-EVEN PRICE PER BUS/LB **									
To Cover Variable Expenses	**2.78**	**2.90**	**2.41**	**1.72**	**1.39**	**6.12**	**0.12**	**0.10**	**4.60**
To Cover Total Expenses	**4.77**	**4.89**	**4.11**	**2.98**	**2.50**	**9.84**	**0.17**	**0.18**	**7.43**

* These budgets do not include an estimate for owner/operator labour and management. This value varies greatly and depends on both the farm manager's needs as well as the ability of the farm business to generate income. Farm managers need to determine their own actual labour and management cost and add it to total expenses.

** The break-even yields and prices for summerfallow crops include the previous years tillage fallow expenses.

CROP PRODUCTION COSTS ($/ACRE) DARK BROWN SOIL ZONE 2000

Conventional Seeded Stubble Crops

	Spring Wheat	Durum Wheat	CPS Wheat	Feed Barley	Lentil	Feed Peas	Flax	Canary Seed	Canola
REVENUE PER ACRE									
Estimated Yield (bu/ac,lb/ac) (A)	26.8	28.3	32.9	42.6	1188.0	25.2	17.3	935.0	16.7
Est. On Farm Market Price/bus,lb (B)	3.00	3.50	2.50	1.52	0.17	3.15	4.25	0.11	4.50
Estimated Gross Revenue/ac (AxB) (C)	**80.40**	**99.05**	**82.25**	**64.75**	**201.96**	**79.38**	**73.53**	**102.85**	**75.15**
EXPENSES PER ACRE									
Variable Expenses/acre									
Seed	6.14	8.99	6.17	5.25	23.40	16.20	4.73	4.55	12.00
Fertilizer - Nitrogen	11.00	11.00	11.00	11.00	1.32	1.32	11.00	11.00	11.00
- Phosphorus	6.75	6.75	6.75	6.75	6.75	6.75	6.75	6.75	6.75
- Sulfur & Other	0.00	0.00	0.00	0.00	0.00	2.70	0.00	0.00	4.05
Chemical - Herbicides	14.95	14.95	14.95	15.11	30.26	18.71	21.87	14.07	17.55
- Insecticides/Fungicides	0.99	0.99	0.99	0.00	2.00	0.00	0.00	1.33	1.28
- Others	1.88	2.25	2.25	1.98	1.80	3.60	0.88	0.88	3.24
Machinery Operating - Fuel	8.20	8.20	8.20	8.20	9.02	9.02	9.02	8.20	8.61
- Repair	7.25	7.25	7.25	7.25	10.50	10.50	8.70	7.25	7.25
Custom Work & Hired Labour	5.25	5.25	5.25	4.25	3.00	3.00	4.25	5.25	4.25
Crop Insurance Premium	2.25	2.46	3.14	3.42	9.14	2.63	3.38	3.02	4.57
Utilities & Miscellaneous	3.09	3.09	3.09	3.09	3.09	3.09	3.09	3.09	3.09
Interest on Variable Expenses	2.54	2.67	2.59	2.49	3.76	2.91	2.76	2.45	3.14
Total Variable Expenses (D)	**70.28**	**73.84**	**71.62**	**68.78**	**104.04**	**80.43**	**76.42**	**67.83**	**86.77**
Other Expenses/acre									
Building Repair	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
Property Taxes	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45
Insurance & Licences	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72
Machinery Depreciation	14.50	14.50	14.50	14.50	17.50	17.50	14.50	14.50	14.50
Building Depreciation	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
Machinery Investment	10.88	10.88	10.88	10.88	13.13	13.13	10.88	10.88	10.88
Building Investment	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80
Land Investment	15.30	15.30	15.30	15.30	15.30	15.30	15.30	15.30	15.30
Total Other Expenses (E)	51.05	51.05	51.05	51.05	56.30	56.30	51.05	51.05	51.05
Total Expenses (D+E) (F) *	**121.32**	**124.88**	**122.66**	**119.83**	**160.34**	**136.72**	**127.47**	**118.88**	**137.82**
RETURNS PER ACRE									
Return over Variable Expenses (C-D)	**10.12**	**25.21**	**10.63**	**-4.03**	**97.92**	**-1.05**	**-2.90**	**35.02**	**-11.62**
Return over Total Expenses (C-F)	**-40.92**	**-25.83**	**-40.41**	**-55.08**	**41.62**	**-57.34**	**-53.94**	**-16.03**	**-62.67**
BREAK-EVEN YIELD PER ACRE **									
To Cover Variable Expenses	**23.4**	**21.1**	**28.6**	**45.3**	**612.0**	**25.5**	**18.0**	**616.7**	**19.3**
To Cover Total Expenses	**40.4**	**35.7**	**49.1**	**78.8**	**943.2**	**43.4**	**30.0**	**1080.7**	**30.6**
BREAK-EVEN PRICE PER BUS/LB **									
To Cover Variable Expenses	**2.62**	**2.61**	**2.18**	**1.61**	**0.09**	**3.19**	**4.42**	**0.07**	**5.20**
To Cover Total Expenses	**4.53**	**4.41**	**3.73**	**2.81**	**0.13**	**5.43**	**7.37**	**0.13**	**8.25**

* These budgets do not include an estimate for owner/operator labour and management. This value varies greatly and depends on both the farm manager's needs as well as the ability of the farm business to generate income. Farm managers need to determine their own actual labour and management cost and add it to total expenses.

** The break-even yields and prices for summerfallow crops include the previous years tillage fallow expenses.

Appendix B

Organic Crop Planning Guilds

CROP PRODUCTION COSTS ($/ACRE) BLACK SOIL ZONE 2005							
	Certified Organic Crops						
	Spring Wheat	CPS Wheat	Feed Barley	Oats	Large Green Lentils	Food Green Peas	Brown Flax
REVENUE PER ACRE							
Estimated Yield (bu/ac,lb/ac,tonne/ac) (A)	26.9	34.8	43.1	51.2	477.0	15.2	10.5
Est. On Farm Market Price/bus,lb,tonne (B)	8.02	8.53	4.24	3.75	0.55	10.21	28.70
Estimated Gross Revenue/ac (AxB)=(C)	215.34	296.84	182.53	191.81	262.35	155.19	299.92
EXPENSES PER ACRE							
Variable Expenses/acre							
Seed	12.56	13.32	6.89	10.25	50.40	31.68	20.13
Innoculant					4.00	4.00	
Forage Costs - Seeding							
- Harvesting							
- Breaking							
Machinery Operating - Fuel	14.04	14.04	14.04	14.04	14.04	14.04	14.04
- Repair	11.83	11.83	11.83	11.83	11.83	11.83	11.83
Custom Work & Hired Labour	5.16	5.16	5.16	5.16	5.16	5.16	5.16
Crop Insurance Premium	6.52	8.75	6.36	8.06	20.45	9.00	8.58
Utilities & Miscellaneous	4.93	4.93	4.93	4.93	4.93	4.93	4.93
Interest on Variable Expenses	1.46	1.54	1.30	1.44	2.94	2.14	1.71
Total Variable Expenses (D)	56.49	59.57	50.51	55.71	113.75	82.78	66.39
Other Expenses/acre							
Building Repair	2.86	2.86	2.86	2.86	2.86	2.86	2.86
Property Taxes	5.55	5.55	5.55	5.55	5.55	5.55	5.55
Insurance & Licences	2.25	2.25	2.25	2.25	2.25	2.25	2.25
Machinery Depreciation	16.71	16.71	16.71	16.71	20.21	20.21	16.71
Building Depreciation	1.60	1.60	1.60	1.60	1.60	1.60	1.60
Machinery Investment	8.02	8.02	8.02	8.02	9.70	9.70	8.02
Building Investment	1.54	1.54	1.54	1.54	1.54	1.54	1.54
Land Investment	17.33	17.33	17.33	17.33	17.33	17.33	17.33
Total Other Expenses (E)	55.85	55.85	55.85	55.85	61.03	61.03	55.85
Labour and Management (F)*							
Total Expenses (D+E+F)=(G)	112.34	115.41	106.36	111.56	174.78	143.81	122.24
Green Manure Total Cost (H)**	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Rotational Expense (G+H)=(I)	112.34	115.41	106.36	111.56	174.78	143.81	122.24
RETURNS PER ACRE							
Return over Variable Expenses (C-D)	158.85	237.28	132.02	136.10	148.60	72.41	233.53
Return over Total Rotational Expenses (C-I)	103.00	181.43	76.17	80.25	87.57	11.38	177.68
BREAK-EVEN YIELD PER ACRE							
To Cover Variable Expenses	7.0	7.0	11.9	14.9	206.8	8.1	2.3
To Cover Total Rotational Expenses	14.0	13.5	25.1	29.7	317.8	14.1	4.3
BREAK-EVEN PRICE PER BUS/LB							
To Cover Variable Expenses	2.21	1.79	1.24	1.15	0.24	5.63	6.63
To Cover Total Rotational Expenses	4.18	3.32	2.47	2.18	0.37	9.46	11.70

† The budget for alfalfa in year 1 is represenative of seeding alfalfa separately. This budget cannot be used if the alfalfa is underseeded into the previous crop.
*These budgets do not include an estimate for owner/operator labour and management. This value varies greatly and depends on both the farm manager's needs as well as the ability of the farm business to generate income. Farm managers need to determine their own actual labor and management cost and add it to total expenses.
**The harvested crop budgets do not include any costs from the green manure year(s). Farm managers need to include the cost of a green manure crop when calculating the cost of a crop rotation, either by adding to the cost of other crops (Item H), or adding the green manure as a separate crop as part of a total rotation cost calculation.

CROP PRODUCTION COSTS ($/ACRE) BROWN SOIL ZONE 2005								
	Certified Organic Crops							
	Spring Wheat	Durum Wheat	CPS Wheat	Feed Barley	Oats	Large Green Lentils	Mustard	Brown Flax
REVENUE PER ACRE								
Estimated Yield (bu/ac,lb/ac,tonne/ac) (A)	18.6	20.1	22.2	28.2	32.9	502.5	7.7	7.0
Est. On Farm Market Price/bus,lb,tonne (B)	8.02	9.00	8.53	4.24	3.75	0.55	34.33	28.70
Estimated Gross Revenue/ac (AxB)=(C)	149.17	180.90	189.37	119.57	123.47	276.38	264.34	199.47
EXPENSES PER ACRE								
Variable Expenses/acre								
Seed	12.56	14.03	13.32	6.89	10.25	50.40	3.74	20.13
Innoculant						4.00		
Forage Costs - Seeding								
- Harvesting								
- Breaking								
Machinery Operating - Fuel	9.48	9.48	9.48	9.48	9.48	9.48	9.48	9.48
- Repair	9.38	9.38	9.38	9.38	9.38	9.38	9.38	9.38
Custom Work & Hired Labour	4.84	4.84	4.84	4.84	4.84	4.84	4.84	4.84
Crop Insurance Premium	4.88	5.58	6.45	6.12	6.22	22.94	8.98	10.24
Utilities & Miscellaneous	3.28	3.28	3.28	3.28	3.28	3.28	3.28	3.28
Interest on Variable Expenses	1.18	1.23	1.24	1.06	1.15	2.76	1.05	1.52
Total Variable Expenses (D)	45.60	47.82	47.99	41.04	44.60	107.09	40.75	58.88
Other Expenses/acre								
Building Repair	2.26	2.26	2.26	2.26	2.26	2.26	2.26	2.26
Property Taxes	4.38	4.38	4.38	4.38	4.38	4.38	4.38	4.38
Insurance & Licences	1.24	1.24	1.24	1.24	1.24	1.24	1.24	1.24
Machinery Depreciation	12.09	12.09	12.09	12.09	12.09	15.59	12.09	12.09
Building Depreciation	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
Machinery Investment	5.80	5.80	5.80	5.80	5.80	7.48	5.80	5.80
Building Investment	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
Land Investment	13.95	13.95	13.95	13.95	13.95	13.95	13.95	13.95
Total Other Expenses (E)	42.08	42.08	42.08	42.08	42.08	47.26	42.08	42.08
Labour and Management (F)*								
Total Expenses (D+E+F)=(G)	87.67	89.89	90.06	83.12	86.68	154.34	82.82	100.95
Green Manure Total Cost (H)**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Rotational Expense (G+H)=(I)	87.67	89.89	90.06	83.12	86.68	154.34	82.82	100.95
RETURNS PER ACRE								
Return over Variable Expenses (C-D)	103.58	133.08	141.38	78.52	78.87	169.29	223.59	140.59
Return over Total Rotational Expenses (C-I)	61.50	91.01	99.31	36.45	36.79	122.03	181.52	98.51
BREAK-EVEN YIELD PER ACRE								
To Cover Variable Expenses	5.7	5.3	5.6	9.7	11.9	194.7	1.2	2.1
To Cover Total Rotational Expenses	10.9	10.0	10.6	19.6	23.1	280.6	2.4	3.5
BREAK-EVEN PRICE PER BUS/LB								
To Cover Variable Expenses	2.57	2.49	2.26	1.54	1.42	0.22	5.59	8.80
To Cover Total Rotational Expenses	4.71	4.47	4.06	2.95	2.63	0.31	10.76	14.53

† The budget for grass/alfalfa in year 1 is represenative of seeding grass/alfalfa separately. This budget cannot be used if the grass/alfalfa is underseeded into the previous crop.
*These budgets do not include an estimate for owner/operator labour and management. This value varies greatly and depends on both the farm manager's needs as well as the ability of the farm business to generate income. Farm managers need to determine their own actual labor and management cost and add it to total expenses.
**The harvested crop budgets do not include any costs from the green manure year(s). Farm managers need to include the cost of a green manure crop when calculating the cost of a crop rotation, either by adding to the cost of other crops (Item H), or adding the green manure as a separate crop as part of a total rotation cost calculation.

CROP PRODUCTION COSTS ($/ACRE) DARK BROWN SOIL ZONE 2005								
	Certified Organic Crops							
	Spring Wheat	Durum Wheat	CPS Wheat	Feed Barley	Oats	Large Green Lentils	Food Green Peas	Brown Flax
REVENUE PER ACRE								
Estimated Yield (bu/ac,lb/ac,tonne/ac) (A)	22.6	25.5	27.6	35.3	42.0	577.5	15.9	10.2
Est. On Farm Market Price/bus,lb,tonne (B)	8.02	9.00	8.53	4.24	3.75	0.55	10.21	28.70
Estimated Gross Revenue/ac (AxB)=(C)	181.05	229.50	235.43	149.46	157.50	317.63	161.83	291.31
EXPENSES PER ACRE								
Variable Expenses/acre								
Seed	12.56	14.03	13.32	6.89	10.25	50.40	31.68	20.13
Innoculant						4.00	4.00	
Forage Costs - Seeding								
- Harvesting								
- Breaking								
Machinery Operating - Fuel	10.76	10.76	10.76	10.76	10.76	10.76	10.76	10.76
- Repair	10.51	10.51	10.51	10.51	10.51	10.51	10.51	10.51
Custom Work & Hired Labour	3.15	3.15	3.15	3.15	3.15	3.15	3.15	3.15
Crop Insurance Premium	5.47	6.70	6.72	7.44	4.80	25.11	7.99	8.48
Utilities & Miscellaneous	4.85	4.85	4.85	4.85	4.85	4.85	4.85	4.85
Interest on Variable Expenses	1.25	1.33	1.31	1.16	1.17	2.88	1.93	1.53
Total Variable Expenses (D)	48.55	51.33	50.62	44.76	45.50	111.67	74.88	59.42
Other Expenses/acre								
Building Repair	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12
Property Taxes	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97
Insurance & Licences	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90
Machinery Depreciation	12.09	12.09	12.09	12.09	12.09	15.59	15.59	12.09
Building Depreciation	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
Machinery Investment	5.80	5.80	5.80	5.80	5.80	7.48	7.48	5.80
Building Investment	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
Land Investment	15.30	15.30	15.30	15.30	15.30	15.30	15.30	15.30
Total Other Expenses (E)	44.53	44.53	44.53	44.53	44.53	49.71	49.71	44.53
Labour and Management (F)*								
Total Expenses (D+E+F)=(G)	93.09	95.86	95.16	89.29	90.04	161.39	124.60	103.95
Green Manure Total Cost (H)**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Rotational Expense (G+H)=(I)	93.09	95.86	95.16	89.29	90.04	161.39	124.60	103.95
RETURNS PER ACRE								
Return over Variable Expenses (C-D)	132.50	178.17	184.81	104.70	112.00	205.95	86.94	231.88
Return over Total Rotational Expenses (C-I)	87.96	133.64	140.27	60.17	67.46	156.24	37.23	187.35
BREAK-EVEN YIELD PER ACRE								
To Cover Variable Expenses	6.1	5.7	5.9	10.6	12.1	203.0	7.3	2.1
To Cover Total Rotational Expenses	11.6	10.7	11.2	21.1	24.0	293.4	12.2	3.6
BREAK-EVEN PRICE PER BUS/LB								
To Cover Variable Expenses	2.24	2.10	1.91	1.33	1.13	0.20	4.86	6.06
To Cover Total Rotational Expenses	4.12	3.76	3.45	2.53	2.14	0.28	7.86	10.24

† The budget for alfalfa in year 1 is represenative of seeding alfalfa separately. This budget cannot be used if the alfalfa is underseeded into the previous crop.
*These budgets do not include an estimate for owner/operator labour and management. This value varies greatly and depends on both the farm manager's needs as well as the ability of the farm business to generate income. Farm managers need to determine their own actual labor and management cost and add it to total expenses.
**The harvested crop budgets do not include any costs from the green manure year(s). Farm managers need to include the cost of a green manure crop when calculating the cost of a crop rotation, either by adding to the cost of other crops (Item H), or adding the green manure as a separate crop as part of a total rotation cost calculation.

Appendix C

Break-down of Carbon Dioxide Emissions

EMISSIONS OF CARBON DIOXIDE FROM CANADIAN AGRICULTURE AND FOOD SYSTEM, 2000					
MODULE	ACTIVITY	AL	SA	MA	CANADA
MODULE A1 -- CROP PRODUCTION					
	Crop Residues	-	-	-	-
	Fertilizer	-	-	-	-
	Nitrogen-Fixing Crops	-	-	-	-
	Soil Organic Matter -SOURCE	-	-	17.93	17.93
	SUB-TOTAL - CROPS	**-**	**-**	**17.93**	**17.93**
MODULE H -- INDIRECT AGROECOSYSTEM EMISSIONS					
	Atmospheric Deposition -- Fertlizer	-	-	-	-
	Atmospheric Deposition -- Manure	-	-	-	-
	Nitrogen Leaching -- Fertlizer	-	-	-	-
	Nitrogen Leaching -- Manure	-	-	-	-
	Histosols	2.49	1.00	1.00	4.49
	Human Sewage	-	-	-	-
	SUB-TOTAL INDIRECT EMISSIONS	**2.49**	**1.00**	**1.00**	**4.49**
MODULE I.1 -- AGROECOSYSTEM					
	Agricultural Soils uptake	-	-	-	-
	Wetlands	-	-	-	-
	SUB-TOTAL AGROECOSYSTEM	**-**	**-**	**-**	**-**
MODULE A.2: OTHER CROP PRODUCTION					
	Fuel for Farm Machinery	278.56	226.02	94.38	598.96
	Soil Organic Matter -SINK	(47.32)	(223.12)	-	(270.44)
	SUB-TOTAL OTHER CROP PRODUCTION	**231.24**	**2.90**	**94.38**	**328.52**
MODULE C -- ON-FARM TRANSPORTATION AND STORAGE, AND OTHER ENERGY USE					
	Onfarm -- Crops -- Transportation	42.17	22.52	8.93	73.62
	Onfarm -- Crops -- Other Uses	6.76	6.03	1.11	13.90
	Onfarm -- Livestock -- Transportation	-	-	-	-
	Onfarm -- Livestock -- Other Uses	-	-	-	-
	SUB-TOTAL OTHER ON-FARM	**48.93**	**28.55**	**10.04**	**87.52**
MODULE D -- FARM INPUTS					
	Fertilizer -- Domestic Use	346.28	169.30	119.47	635.05
	Fuel -- Domestic Use	54.39	65.85	0.45	120.69
	Pesticides -- Domestic Use	0.20	0.08	0.04	0.32
	Machinery/Implements -- Domestic	0.46	2.19	1.90	4.54
	Transportation -- Domestic	9.25	15.54	2.23	27.02
	SUB-TOTAL FARM INPUTS- TOTAL	**410.59**	**252.96**	**124.08**	**787.62**
MODULE E: OFF-FARM TRANSPORTATION AND STORAGE					
	Off-farm -- Crops -- Transportation	235.41	466.27	8.35	710.03
	Off-farm -- Crops -- Storage	9.83	10.84	0.28	20.95
	Off-farm -- Livestock -- Transportation	-	-	-	-
	SUB-TOTAL OFF-FARM TRAN-STOR	**245.23**	**477.11**	**8.64**	**730.98**
GRAND TOTAL AGRICULTURE AND FOOD		**938.49**	**762.52**	**256.07**	**1,957.07**
	% OF TOTAL CANADIAN CO2 EMISSIONS	**47.95%**	**38.96%**	**13.08%**	**100.00%**

EMISSIONS OF CARBON DIOXIDE FROM CANADIAN AGRICULTURE AND FOOD SYSTEM, 2000					
MODULE	ACTIVITY	AL	SA	MA	CANADA
MODULE A1 -- CROP PRODUCTION					
	Crop Residues	-	-	-	-
	Fertilizer	-	-	-	-
	Nitrogen-Fixing Crops	-	-	-	-
	Soil Organic Matter -SOURCE	-	-	17.93	17.93
	SUB-TOTAL - CROPS	**-**	**-**	**17.93**	**17.93**
MODULE H -- INDIRECT AGROECOSYSTEM EMISSIONS					
	Atmospheric Deposition -- Fertlizer	-	-	-	-
	Atmospheric Deposition -- Manure	-	-	-	-
	Nitrogen Leaching -- Fertlizer	-	-	-	-
	Nitrogen Leaching -- Manure	-	-	-	-
	Histosols	2.49	1.00	1.00	4.49
	Human Sewage	-	-	-	-
	SUB-TOTAL INDIRECT EMISSIONS	**2.49**	**1.00**	**1.00**	**4.49**
MODULE I.1 -- AGROECOSYSTEM					
	Agricultural Soils uptake	-	-	-	-
	Wetlands	-	-	-	-
	SUB-TOTAL AGROECOSYSTEM	**-**	**-**	**-**	**-**
MODULE A.2: OTHER CROP PRODUCTION					
	Fuel for Farm Machinery	225.82	193.69	90.66	510.17
	Soil Organic Matter -SINK	(47.32)	(223.12)	-	(270.44)
	SUB-TOTAL OTHER CROP PRODUCTION	**178.50**	**(29.43)**	**90.66**	**239.73**
MODULE C -- ON-FARM TRANSPORTATION AND STORAGE, AND OTHER ENERGY USE					
	Onfarm -- Crops -- Transportation	25.07	15.47	7.13	47.67
	Onfarm -- Crops -- Other Uses	6.76	6.03	1.11	13.90
	Onfarm -- Livestock -- Transportation	-	-	-	-
	Onfarm -- Livestock -- Other Uses	-	-	-	-
	SUB-TOTAL OTHER ON-FARM	**31.83**	**21.50**	**8.24**	**61.56**
MODULE D -- FARM INPUTS					
	Fertilizer -- Domestic Use	-	-	-	-
	Fuel -- Domestic Use	44.09	58.45	0.43	102.97
	Pesticides -- Domestic Use	-	-	-	-
	Machinery/Implements -- Domestic	0.58	2.31	2.11	4.99
	Transportation -- Domestic	0.66	0.55	0.23	1.44
	SUB-TOTAL FARM INPUTS- TOTAL	**45.33**	**61.30**	**2.77**	**109.40**
MODULE E: OFF-FARM TRANSPORTATION AND STORAGE					
	Off-farm -- Crops -- Transportation	135.52	447.37	6.40	589.29
	Off-farm -- Crops -- Storage	6.64	9.19	0.27	16.10
	Off-farm -- Livestock -- Transportation	-	-	-	-
	SUB-TOTAL OFF-FARM TRAN-STOR	**142.16**	**456.56**	**6.67**	**605.39**
GRAND TOTAL AGRICULTURE AND FOOD		**400.31**	**510.93**	**127.28**	**1,038.51**
	% OF TOTAL CANADIAN CO2 EMISSIONS	**38.55%**	**49.20%**	**12.26%**	**100.00%**

Appendix D

Break-down of Methane Emissions

EMISSIONS OF METHANE FROM CANADIAN AGRICULTURE AND FOOD SYSTEM, 2000					
MODULE	ACTIVITY	AL	SA	MA	CANADA
MODULE A1 -- CROP PRODUCTION					
	Crop Residues	-	-	-	-
	Fertilizer	-	-	-	-
	Nitrogen-Fixing Crops	-	-	-	-
	Soil Organic Matter -SOURCE	-	-	-	-
	SUB-TOTAL - CROPS	**-**	**-**	**-**	**-**
MODULE H -- INDIRECT AGROECOSYSTEM EMISSIONS					
	Atmospheric Deposition -- Fertlizer	-	-	-	-
	Atmospheric Deposition -- Manure	-	-	-	-
	Nitrogen Leaching -- Fertlizer	-	-	-	-
	Nitrogen Leaching -- Manure	-	-	-	-
	Histosols	-	-	-	-
	Human Sewage	-	-	-	-
	SUB-TOTAL INDIRECT EMISSIONS	**-**	**-**	**-**	**-**
MODULE I.1 -- AGROECOSYSTEM					
	Agricultural Soils uptake	(0.30)	(0.38)	(0.11)	(0.79)
	Wetlands	2.31	8.88	4.40	37.50
	SUB-TOTAL AGROECOSYSTEM	**2.01**	**8.51**	**4.29**	**36.71**
MODULE A.2: OTHER CROP PRODUCTION					
	Fuel for Farm Machinery	0.03	0.02	0.01	0.06
	Soil Organic Matter -SINK	-	-	-	-
	SUB-TOTAL OTHER CROP PRODUCTION	**0.03**	**0.02**	**0.01**	**0.06**
MODULE C -- ON-FARM TRANSPORTATION AND STORAGE, AND OTHER ENERGY USE					
	Onfarm -- Crops -- Transportation	0.01	0.00	0.00	0.01
	Onfarm -- Crops -- Other Uses	0.00	0.00	0.00	0.00
	Onfarm -- Livestock -- Transportation	-	-	-	-
	Onfarm -- Livestock -- Other Uses	-	-	-	-
	SUB-TOTAL OTHER ON-FARM	**0.01**	**0.00**	**0.00**	**0.02**
MODULE D -- FARM INPUTS					
	Fertilizer -- Domestic Use	0.01	0.00	0.00	0.01
	Fuel -- Domestic Use	10.05	5.47	0.11	15.63
	Pesticides -- Domestic Use	0.00	0.00	0.00	0.00
	Machinery/Implements -- Domestic	0.00	0.00	0.00	0.00
	Transportation -- Domestic	0.00	0.00	0.00	0.00
	SUB-TOTAL FARM INPUTS- TOTAL	**10.06**	**5.48**	**0.11**	**15.64**
MODULE E: OFF-FARM TRANSPORTATION AND STORAGE					
	Off-farm -- Crops -- Transportation	0.02	0.04	0.00	0.07
	Off-farm -- Crops -- Storage	0.00	0.00	0.00	0.00
	Off-farm -- Livestock -- Transportation	-	-	-	-
	SUB-TOTAL OFF-FARM TRAN-STOR	**0.02**	**0.04**	**0.00**	**0.07**
GRAND TOTAL AGRICULTURE AND FOOD		**12.08**	**14.06**	**4.42**	**30.56**
	% OF TOTAL CANADIAN CH4 EMISSIONS	**39.53%**	**46.01%**	**14.46%**	**100.00%**

EMISSIONS OF METHANE FROM CANADIAN AGRICULTURE AND FOOD SYSTEM, 2000					
MODULE	ACTIVITY	AL	SA	MA	CANADA
MODULE A1 -- CROP PRODUCTION					
	Crop Residues	-	-	-	-
	Fertilizer	-	-	-	-
	Nitrogen-Fixing Crops	-	-	-	-
	Soil Organic Matter -SOURCE	-	-	-	-
	SUB-TOTAL - CROPS	-	-	-	-
MODULE H -- INDIRECT AGROECOSYSTEM EMISSIONS					
	Atmospheric Deposition -- Fertlizer	-	-	-	-
	Atmospheric Deposition -- Manure	-	-	-	-
	Nitrogen Leaching -- Fertlizer	-	-	-	-
	Nitrogen Leaching -- Manure	-	-	-	-
	Histosols	-	-	-	-
	Human Sewage	-	-	-	-
	SUB-TOTAL INDIRECT EMISSIONS	-	-	-	-
MODULE I.1 -- AGROECOSYSTEM					
	Agricultural Soils uptake	(0.30)	(0.38)	(0.11)	(0.79)
	Wetlands	2.31	8.88	4.40	37.50
	SUB-TOTAL AGROECOSYSTEM	**2.01**	**8.51**	**4.29**	**36.71**
MODULE A.2: OTHER CROP PRODUCTION					
	Fuel for Farm Machinery	0.02	0.02	0.01	0.05
	Soil Organic Matter -SINK	-	-	-	-
	SUB-TOTAL OTHER CROP PRODUCTION	**0.02**	**0.02**	**0.01**	**0.05**
MODULE C -- ON-FARM TRANSPORTATION AND STORAGE, AND OTHER ENERGY USE					
	Onfarm -- Crops -- Transportation	0.00	0.00	0.00	0.01
	Onfarm -- Crops -- Other Uses	0.00	0.00	0.00	0.00
	Onfarm -- Livestock -- Transportation	-	-	-	-
	Onfarm -- Livestock -- Other Uses	-	-	-	-
	SUB-TOTAL OTHER ON-FARM	**0.01**	**0.00**	**0.00**	**0.01**
MODULE D -- FARM INPUTS					
	Fertilizer -- Domestic Use	-	-	-	-
	Fuel -- Domestic Use	8.14	4.69	0.10	12.94
	Pesticides -- Domestic Use	-	-	-	-
	Machinery/Implements -- Domestic	0.00	0.00	0.00	0.00
	Transportation -- Domestic	0.00	0.00	0.00	0.00
	SUB-TOTAL FARM INPUTS- TOTAL	**8.14**	**4.69**	**0.10**	**12.94**
MODULE E: OFF-FARM TRANSPORTATION AND STORAGE					
	Off-farm -- Crops -- Transportation	0.01	0.04	0.00	0.06
	Off-farm -- Crops -- Storage	0.00	0.00	0.00	0.00
	Off-farm -- Livestock -- Transportation	-	-	-	-
	SUB-TOTAL OFF-FARM TRAN-STOR	**0.01**	**0.04**	**0.00**	**0.06**
GRAND TOTAL AGRICULTURE AND FOOD		**10.20**	**13.26**	**4.41**	**27.86**
	% OF TOTAL CANADIAN CH4 EMISSIONS	**36.59%**	**47.59%**	**15.82%**	**100.00%**

Appendix E

Break-down of Nitrous Oxide Emissions

Conventional Agriculture

EMISSIONS OF NITROUS OXIDE FROM CANADIAN AGRICULTURE AND FOOD SYSTEM, 2000					
MODULE	ACTIVITY	AL	SA	MA	CANADA
MODULE A1 -- CROP PRODUCTION					
	Crop Residues	1.22	1.02	0.31	2.54
	Fertilizer	0.58	0.52	0.67	1.77
	Nitrogen-Fixing Crops	1.88	1.66	0.72	4.26
	Soil Organic Matter -SOURCE	-	-	-	-
	SUB-TOTAL - CROPS	**3.68**	**3.20**	**1.69**	**8.57**
MODULE H -- INDIRECT AGROECOSYSTEM EMISSIONS					
	Atmospheric Deposition -- Fertlizer	0.09	0.08	0.08	0.26
	Atmospheric Deposition -- Manure	-	-	-	-
	Nitrogen Leaching -- Fertlizer	0.34	0.31	0.32	0.97
	Nitrogen Leaching -- Manure	-	-	-	-
	Histosols	0.00	0.00	0.00	0.00
	Human Sewage	0.03	0.01	0.01	0.05
	SUB-TOTAL INDIRECT EMISSIONS	**0.46**	**0.40**	**0.41**	**1.28**
MODULE I.1 -- AGROECOSYSTEM					
	Agricultural Soils uptake	-	-	-	-
	Wetlands	-	-	-	-
	SUB-TOTAL AGROECOSYSTEM	-	-	-	-
MODULE A.2: OTHER CROP PRODUCTION					
	Fuel for Farm Machinery	0.04	0.03	0.01	0.08
	Soil Organic Matter -SINK	-	-	-	-
	SUB-TOTAL OTHER CROP PRODUCTION	**0.04**	**0.03**	**0.01**	**0.08**
MODULE C -- ON-FARM TRANSPORTATION AND STORAGE, AND OTHER ENERGY USE					
	Onfarm -- Crops -- Transportation	0.00	0.00	0.00	0.00
	Onfarm -- Crops -- Other Uses	0.00	0.00	0.00	0.00
	Onfarm -- Livestock -- Transportation	-	-	-	-
	Onfarm -- Livestock -- Other Uses	-	-	-	-
	SUB-TOTAL OTHER ON-FARM	**0.00**	**0.00**	**0.00**	**0.00**
MODULE D -- FARM INPUTS					
	Fertilizer -- Domestic Use	0.01	0.00	0.00	0.01
	Fuel -- Domestic Use	0.35	0.19	0.00	0.54
	Pesticides -- Domestic Use	0.00	0.00	0.00	0.00
	Machinery/Implements -- Domestic	0.00	0.00	0.00	0.00
	Transportation -- Domestic	0.00	0.00	0.00	0.00
	SUB-TOTAL FARM INPUTS- TOTAL	**0.35**	**0.19**	**0.01**	**0.55**
MODULE E: OFF-FARM TRANSPORTATION AND STORAGE					
	Off-farm -- Crops -- Transportation	0.03	0.07	0.00	0.10
	Off-farm -- Crops -- Storage	0.00	0.00	0.00	0.00
	Off-farm -- Livestock -- Transportation	-	-	-	-
	SUB-TOTAL OFF-FARM TRAN-STOR	**0.03**	**0.07**	**0.00**	**0.10**
GRAND TOTAL AGRICULTURE AND FOOD		**4.58**	**3.89**	**2.13**	**10.60**
	% OF TOTAL CANADIAN N2O EMISSIONS	**43.18%**	**36.73%**	**20.09%**	**100.00%**

EMISSIONS OF NITROUS OXIDE FROM CANADIAN AGRICULTURE AND FOOD SYSTEM, 2000					
MODULE	ACTIVITY	AL	SA	MA	CANADA
MODULE A1 -- CROP PRODUCTION					
	Crop Residues	0.71	0.68	0.24	1.63
	Fertilizer	-	-	-	-
	Nitrogen-Fixing Crops	1.15	1.16	0.62	2.93
	Soil Organic Matter -SOURCE	-	-	-	-
	SUB-TOTAL - CROPS	**1.87**	**1.84**	**0.85**	**4.56**
MODULE H -- INDIRECT AGROECOSYSTEM EMISSIONS					
	Atmospheric Deposition -- Fertlizer	-	-	-	-
	Atmospheric Deposition -- Manure	-	-	-	-
	Nitrogen Leaching -- Fertlizer	-	-	-	-
	Nitrogen Leaching -- Manure	-	-	-	-
	Histosols	0.00	0.00	0.00	0.00
	Human Sewage	0.03	0.01	0.01	0.05
	SUB-TOTAL INDIRECT EMISSIONS	**0.03**	**0.01**	**0.01**	**0.05**
MODULE I.1 -- AGROECOSYSTEM					
	Agricultural Soils uptake	-	-	-	-
	Wetlands	-	-	-	-
	SUB-TOTAL AGROECOSYSTEM	**-**	**-**	**-**	**-**
MODULE A.2: OTHER CROP PRODUCTION					
	Fuel for Farm Machinery	0.03	0.03	0.01	0.07
	Soil Organic Matter -SINK	-	-	-	-
	SUB-TOTAL OTHER CROP PRODUCTION	**0.03**	**0.03**	**0.01**	**0.07**
MODULE C -- ON-FARM TRANSPORTATION AND STORAGE, AND OTHER ENERGY USE					
	Onfarm -- Crops -- Transportation	0.00	0.00	0.00	0.00
	Onfarm -- Crops -- Other Uses	0.00	0.00	0.00	0.00
	Onfarm -- Livestock -- Transportation	-	-	-	-
	Onfarm -- Livestock -- Other Uses	-	-	-	-
	SUB-TOTAL OTHER ON-FARM	**0.00**	**0.00**	**0.00**	**0.00**
MODULE D -- FARM INPUTS					
	Fertilizer -- Domestic Use	-	-	-	-
	Fuel -- Domestic Use	0.28	0.16	0.00	0.45
	Pesticides -- Domestic Use	-	-	-	-
	Machinery/Implements -- Domestic	0.00	0.00	0.00	0.00
	Transportation -- Domestic	0.00	0.00	0.00	0.00
	SUB-TOTAL FARM INPUTS- TOTAL	**0.28**	**0.16**	**0.00**	**0.45**
MODULE E: OFF-FARM TRANSPORTATION AND STORAGE					
	Off-farm -- Crops -- Transportation	0.02	0.07	0.00	0.09
	Off-farm -- Crops -- Storage	0.00	0.00	0.00	0.00
	Off-farm -- Livestock -- Transportation	-	-	-	-
	SUB-TOTAL OFF-FARM TRAN-STOR	**0.02**	**0.07**	**0.00**	**0.09**
GRAND TOTAL AGRICULTURE AND FOOD		**2.23**	**2.10**	**0.88**	**5.22**
	% OF TOTAL CANADIAN N2O EMISSIONS	**42.76%**	**40.29%**	**16.95%**	**100.00%**

Appendix F

Break-down of Carbon Dioxide Equivalent Emissions

Conventional Agriculture

EMISSIONS OF CARBON DIOXIDE EQUIVALENTS FROM CANADIAN AGRICULTURE AND FOOD SYSTEM, 2000					
MODULE	ACTIVITY	AL	SA	MA	CANADA
MODULE A1 -- CROP PRODUCTION					
	Crop Residues	379.24	314.80	94.75	788.78
	Fertilizer	179.86	160.82	206.99	547.67
	Nitrogen-Fixing Crops	582.11	514.97	222.99	1,320.08
	Soil Organic Matter -SOURCE	-	-	17.93	17.93
	SUB-TOTAL - CROPS	**1,141.21**	**990.59**	**542.67**	**2,674.47**
MODULE H -- INDIRECT AGROECOSYSTEM EMISSIONS					
	Atmospheric Deposition -- Fertlizer	28.15	25.50	26.31	79.95
	Atmospheric Deposition -- Manure	-	-	-	-
	Nitrogen Leaching -- Fertlizer	105.55	95.61	98.65	299.81
	Nitrogen Leaching -- Manure	-	-	-	-
	Histosols	3.09	1.24	1.25	5.58
	Human Sewage	8.79	2.90	3.33	15.02
	SUB-TOTAL INDIRECT EMISSIONS	**145.59**	**125.24**	**129.54**	**400.37**
MODULE I.1 -- AGROECOSYSTEM					
	Agricultural Soils uptake	(6.28)	(7.91)	(2.31)	(16.50)
	Wetlands	48.47	186.53	92.41	787.50
	SUB-TOTAL AGROECOSYSTEM	**42.19**	**178.63**	**90.10**	**771.00**
MODULE A.2: OTHER CROP PRODUCTION					
	Fuel for Farm Machinery	290.95	236.19	98.54	625.69
	Soil Organic Matter -SINK	(47.32)	(223.12)	-	(270.44)
	SUB-TOTAL OTHER CROP PRODUCTION	**243.63**	**13.08**	**98.54**	**355.25**
MODULE C -- ON-FARM TRANSPORTATION AND STORAGE, AND OTHER ENERGY USE					
	Onfarm -- Crops -- Transportation	42.98	22.89	9.12	74.99
	Onfarm -- Crops -- Other Uses	6.79	6.08	1.11	13.98
	Onfarm -- Livestock -- Transportation	-	-	-	-
	Onfarm -- Livestock -- Other Uses	-	-	-	-
	SUB-TOTAL OTHER ON-FARM	**49.77**	**28.98**	**10.23**	**88.97**
MODULE D -- FARM INPUTS					
	Fertilizer -- Domestic Use	348.23	170.19	119.88	638.30
	Fuel -- Domestic Use	372.85	239.27	3.90	616.02
	Pesticides -- Domestic Use	0.20	0.08	0.04	0.33
	Machinery/Implements -- Domestic	0.46	2.20	1.91	4.56
	Transportation -- Domestic	9.69	16.28	2.33	28.30
	SUB-TOTAL FARM INPUTS- TOTAL	**731.44**	**428.01**	**128.06**	**1,287.51**
MODULE E: OFF-FARM TRANSPORTATION AND STORAGE					
	Off-farm -- Crops -- Transportation	246.57	488.39	8.75	743.71
	Off-farm -- Crops -- Storage	9.89	10.92	0.29	21.10
	Off-farm -- Livestock -- Transportation	-	-	-	-
	SUB-TOTAL OFF-FARM TRAN-STOR	**256.46**	**499.31**	**9.03**	**764.80**
GRAND TOTAL AGRICULTURE AND FOOD		**2,610.29**	**2,263.83**	**1,008.17**	**5,882.29**
	% OF TOTAL CANADIAN CO2 EMISSIONS	**44.38%**	**38.49%**	**17.14%**	**100.00%**

EMISSIONS OF CARBON DIOXIDE EQUIVALENTS FROM CANADIAN AGRICULTURE AND FOOD SYSTEM, 2000					
MODULE	ACTIVITY	AL	SA	MA	CANADA
MODULE A1 -- CROP PRODUCTION					
	Crop Residues	221.01	210.12	73.07	504.20
	Fertilizer	-	-	-	-
	Nitrogen-Fixing Crops	357.23	359.30	191.82	908.34
	Soil Organic Matter -SOURCE	-	-	17.93	17.93
	SUB-TOTAL - CROPS	**578.23**	**569.42**	**282.82**	**1,430.47**
MODULE H -- INDIRECT AGROECOSYSTEM EMISSIONS					
	Atmospheric Deposition -- Fertlizer	-	-	-	-
	Atmospheric Deposition -- Manure	-	-	-	-
	Nitrogen Leaching -- Fertlizer	-	-	-	-
	Nitrogen Leaching -- Manure	-	-	-	-
	Histosols	3.09	1.24	1.25	5.58
	Human Sewage	8.79	2.90	3.33	15.02
	SUB-TOTAL INDIRECT EMISSIONS	**11.89**	**4.14**	**4.58**	**20.60**
MODULE I.1 -- AGROECOSYSTEM					
	Agricultural Soils uptake	(6.28)	(7.91)	(2.31)	(16.50)
	Wetlands	48.47	186.53	92.41	787.50
	SUB-TOTAL AGROECOSYSTEM	**42.19**	**178.63**	**90.10**	**771.00**
MODULE A.2: OTHER CROP PRODUCTION					
	Fuel for Farm Machinery	235.86	202.41	94.66	532.93
	Soil Organic Matter -SINK	(47.32)	(223.12)	-	(270.44)
	SUB-TOTAL OTHER CROP PRODUCTION	**188.54**	**(20.71)**	**94.66**	**262.50**
MODULE C -- ON-FARM TRANSPORTATION AND STORAGE, AND OTHER ENERGY USE					
	Onfarm -- Crops -- Transportation	25.55	15.73	7.28	48.55
	Onfarm -- Crops -- Other Uses	6.79	6.08	1.11	13.98
	Onfarm -- Livestock -- Transportation	-	-	-	-
	Onfarm -- Livestock -- Other Uses	-	-	-	-
	SUB-TOTAL OTHER ON-FARM	**32.34**	**21.81**	**8.39**	**62.54**
MODULE D -- FARM INPUTS					
	Fertilizer -- Domestic Use	-	-	-	-
	Fuel -- Domestic Use	302.25	207.06	3.75	513.06
	Pesticides -- Domestic Use	-	-	-	-
	Machinery/Implements -- Domestic	0.58	2.32	2.12	5.02
	Transportation -- Domestic	0.69	0.58	0.24	1.51
	SUB-TOTAL FARM INPUTS- TOTAL	**303.53**	**209.95**	**6.10**	**519.58**
MODULE E: OFF-FARM TRANSPORTATION AND STORAGE					
	Off-farm -- Crops -- Transportation	141.95	468.58	6.71	617.24
	Off-farm -- Crops -- Storage	6.68	9.26	0.27	16.21
	Off-farm -- Livestock -- Transportation	-	-	-	-
	SUB-TOTAL OFF-FARM TRAN-STOR	**148.63**	**477.84**	**6.98**	**633.45**
GRAND TOTAL AGRICULTURE AND FOOD		**1,305.34**	**1,441.07**	**493.64**	**3,240.05**
	% OF TOTAL CANADIAN CO2 EMISSIONS	**40.29%**	**44.48%**	**15.24%**	**100.00%**