# Options for Mitigation of Greenhouse Gas Emissions from Agriculture: An Economic Perspective for Saskatchewan Farmers[1]

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## Abstract

The Government of Canada, in order to achieve the commitments made under the Kyoto Protocol to reduce greenhouse gas emissions, has decided to develop a National Implementation Strategy for the various economic sectors of Canada. As a part of this development, sixteen Issue Tables were appointed. The Agriculture and Agri-Food Climate Change Table has developed a set of GHG reduction strategies that could be selected by producers or governments from either a national and/or regional perspective. In this study, an analysis of these strategies is presented for Saskatchewan agriculture. Two indicators are selected: (1) reduction in the emissions of greenhouse gases from the region; and (2) economic impacts on producers. Saskatchewan agriculture's ability to meet its share of the Kyoto commitment depends very heavily on the recognition of agricultural soils as sinks. With sinks included, it is estimated that Saskatchewan would have no difficulty in meeting the required reduction of GHG emissions, and could sequester additional carbon for possible credit through mechanisms such as emissions trading. Many of the strategies that involve soils as sinks are also "win-win" strategies. If, however, the international community does not agree to have agricultural soils as sinks included in the credit for reduction, the costs of abatement to Saskatchewan agriculture may be significant.

## Introduction

The agriculture industry in Saskatchewan occupies a prominent place in its landscape. Not only is the presence of agriculture felt all around, much of the economic progress of the provincial economy is determined by the economic health of the industry. Agricultural practices are also important in another respect: these activities are linked to global warming through the emission of greenhouse gases (GHGs). In addition to several minor GHGs, three main gases are emitted – carbon dioxide, methane and nitrous oxide. Each of these gases contribute to global warming differently, and therefore, would require different strategies for mitigation.

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[1] Any policy view, whether explicitly stated, inferred or interpreted from the contents of this paper, should not be represented as reflecting the views of Agriculture and Agri-Food Canada.

In the context of GHGs, agriculture is different from other sectors that are linked to emitting these gases in two respects:

- The nature of emissions from agriculture are different from those of other sectors in Saskatchewan. GHG emissions from other sectors are composed primarily of $CO_2$ and are related to energy use. This is not the case for agriculture.

- Agriculture can be a part of the solution, in addition to being a part of the problem. The former comes from the ability of agricultural practices to sequester carbon in the soil, thereby reducing the release of carbon dioxide from crop production.

The need for a reduction in global GHG emissions resulted in Canada signing the Kyoto Protocol. Under the terms of the Protocol, Canada is to reduce its emissions to 6% below 1990 levels during the commitment period (2008 - 2012). In order to develop an effective mechanism to achieve this goal, the federal government implemented a program leading to the development of the "National Implementation Strategy". Under this initiative, a climate change action fund was created, leading to the establishment of the Climate Change Secretariat. Among other activities of the Secretariat, 16 Issue Tables were established. One of these Tables was tasked with developing strategies for reducing GHG emissions from agriculture.

**Need for the Study**

Although the exact role of each sector and each region in meeting the Kyoto Protocol commitment is not made explicit, it is the understanding that each region of Canada (and each sector within it) would devise means to reduce emissions to help meet this target. It is conceivable that in the final analysis, regions and economic sectors with a competitive advantage would probably participate more than those regions where costs to society are high. However, this still requires that the cost of reducing emissions be examined for all sectors/regions, and Saskatchewan agriculture is no exception. Thus, a need exists for estimating both the potential for reduction of GHGs from Saskatchewan agriculture, as well as the economic costs to be borne by farmers.

**Objectives of the Study**

The major objectives of this study are two-fold:

- To estimate the level of emissions of GHGs from agricultural production activities for the base period (1990) and the commitment period. Since the commitment period is five-years in duration, the middle year was taken as the target.

- To estimate the emissions under selected mitigation strategies for GHG emissions, along with any economic cost to farmers. The strategies examined here are those selected by the Agriculture and Agri-Food Climate Change Table.

## Study Methodology

Emissions of GHGs from Saskatchewan agriculture were estimated using the Canadian Economic and Emissions Model for Agriculture (CEEMA). This model is regional in nature. Saskatchewan crop production was divided into nine regions, based on census of agriculture regions. However, livestock production was modelled at the provincial level. As shown in Figure 1, estimation of crop and livestock production was done with an economic optimization model, which was used for simulating the effect of various mitigation scenarios on farmers' decision making.

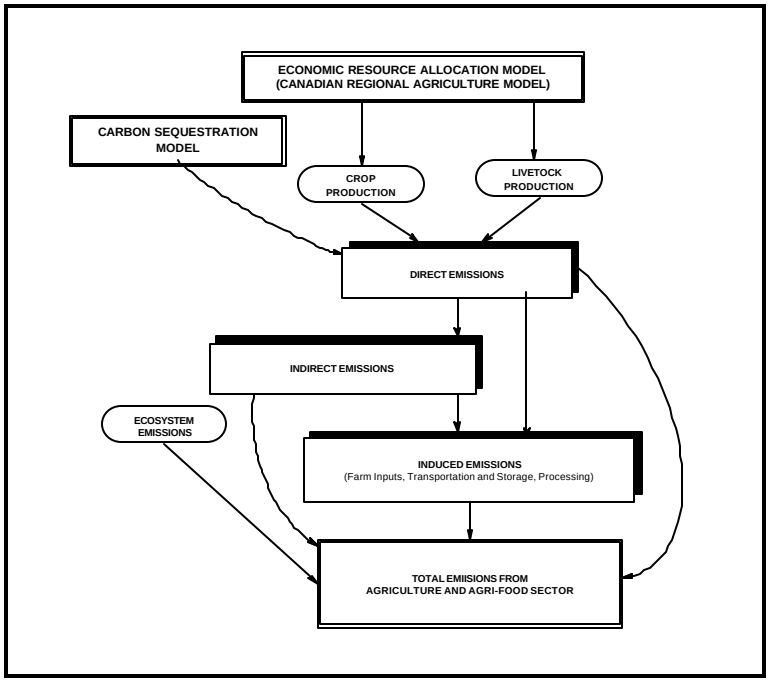



**Figure 1**. An Overview of Study Model to Estimate Greenhouse Gas Emissions

Estimation of GHG emissions from Saskatchewan agriculture required two pieces of information: (1) the level of agricultural activities as estimated by the economic model; and (2) the science of GHG emissions, which led to the development of GHG emission coefficients (EC). The emission coefficients associated with the activity levels are based on the methodology approved under the Kyoto Protocol, as reported by the Intergovernmental Panel on Climate Change (see IPCC), and modified for Canadian conditions by Janzen et al. (1999). In addition, since soil carbon sequestration for Canadian situations is not yet recognized under the IPCC methodology, the CENTURY model (see Desjardins et al., Undated) was used to obtain the appropriate ECs.

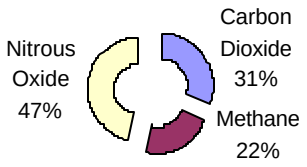
Total emissions from Saskatchewan agriculture were categorized under direct emissions (from crop and livestock production), indirect emissions, and induced emissions. The indirect emissions included those resulting from the application of manure and fertilizer in an indirect manner. The induced emissions refer to those which are on account of economic activities linked to primary agricultural production. The use of fertilizer, for example, would lead to its manufacturing, storage and transportation; crop and livestock products have to be transported to final destinations; and many agricultural products are processed further before they reach consumers.

## Baseline Emissions of Greenhouse Gases

The estimated emissions of GHGs from Saskatchewan agriculture can be aggregated to three levels: (1) Kyoto agriculture; (2) primary production; and (3) the entire agriculture and agri-food sector (AAFS). In order to properly address the impacts of the Kyoto commitment, this distinction is important. The Kyoto agriculture method of aggregation includes all GHG emissions from non-energy sources. In addition, it

includes sources of GHGs from soils, but not if soils have become a net sequester of carbon. Uptake of methane by agricultural soils and wetlands are included as a part of this level of accounting. Primary production agriculture includes all emissions recognized under Kyoto agriculture, plus on-farm energy based emissions and carbon sequestration by soils. The AAFS level of aggregating emissions is all inclusive of direct, indirect and induced emissions. In this study, in addition to the commercial production activities, another source of GHGs was recognized: emissions from the agroecosystem, which included on-farm shelterbelts, and wooded lands. However, on account of poor data, the latter type of land was not included.

FIGURE 2: DISTRIBUTION OF GHG EMISSIONS (CO2 Eq) FROM SASKATCHEWAN PRIMARYAGRICULTURE, BY GAS, 1990




Source : CEEMA

Saskatchewan agriculture is a major producer of nitrous oxide, as shown in Figure 2. This gas contributes 47% of the total emissions at the primary production level, followed by carbon dioxide, and then methane. Methane, being a direct result of livestock production, is smaller because of the predominance of crop production in the province.

In order to aggregate the three GHGs into a single unit, one should take into account their relative contribution to global warming. This procedure is based on the global warming potential (GWP) for each gas, and is in equivalence of carbon dioxide. According to Environment Canada, methane has a 100 year GWP of 21, and that for nitrous oxide is 310. Estimated results for the 1990 and 2010 period for the three levels of accounting are shown in Table 1. The emission levels are in carbon dioxide equivalent ($CO_2$-Eq), based on the above noted conversion factors. It is estimated that Saskatchewan agriculture contributed 11.5

Table 1: Estimated Emissions of GHGs from Saskatchewan Agriculture, 1990 and 2010

| Source | Level of emissions in Kilotonnes in $CO_2$-Eq | | % Change in 2010 |
|---|---|---|---|
| | 1990 | 2010 | |
| Crop Residues | 1,812 | 1,704 | -6 |
| Fertilizer | 691 | 1,926 | 178 |
| Production of Nitrogen Fixing Crops | 540 | 982 | 82 |
| Soil Carbon – Source | 2,060 | 0 | -- |
| Farm Animals | 2,838 | 3,725 | 31 |
| Animal Excretions | 1,913 | 2,475 | 29 |
| Indirect Emissions | 1,658 | 3,418 | 106 |
| Wetlands and Agric. Soils | 25 | 2 | -- |
| **Kyoto Agriculture** | **11,537** | **14,234** | **23** |
| Farm Machinery Energy | 1,831 | 1,510 | -18 |
| Transportation and other Energy | 585 | 632 | 8 |
| Soil Carbon – Sink | 0 | -4,230 | -- |
| **Primary Production** | **13,954** | **12,147** | **-13** |
| Farm Input Production | 3,036 | 3,099 | 2 |
| Off-Farm Transportation and Storage | 779 | 1,139 | 46 |

megatonnes (Mt, which is equal to one million tonnes) of $CO_2$-Eq. GHGs during 1990, using the Kyoto agriculture definition. If all direct primary production activities are included, this increases to almost 14 Mt. At the entire agriculture and agri-food sector level, the emissions increase to 18 Mt per annum. Using a similar methodology, 2010 emissions under business-as-usual were also estimated. Current estimates suggest that Saskatchewan soils would become a net carbon sink by 2010. Thus, emissions from soils as a source of carbon dioxide would be zero and carbon sequestration would be 4.2 Mt, thereby reducing the primary agriculture emissions to 11.55 Mt – some 87% of the 1990 base. However, if one looks at the Kyoto agriculture level, emissions from Saskatchewan are expected to increase to 14 Mt – some 23% higher than the 1990 level.

**Reduction Target for Saskatchewan Agriculture**

Although the Federal Government has not specified any set target for the agriculture industry, or for regions within Canada, let us assume that Saskatchewan agriculture must reduce its 2010 GHG emissions to 6% below 1990 levels. This raises the question as to at what level emissions are to be reduced. First let us assume that the industry would only be credited for the mitigation activities that are under its direct control, i.e. primary production. The next question is whether the sector would have to comply in terms of the present Kyoto definition of agriculture. Let us assume that both the levels are relevant and estimate the reductions needed. These are shown in Table 2. For Kyoto agriculture, this would translate into a needed reduction of 3.38 Mt, whereas for the primary agriculture (which includes soils as carbon sinks) there would be no need for any further reduction measures. Agriculture under this definition would have a surplus of 0.96 Mt, which could be credited to other sectors, if necessary.

Table 2. Reduction Target in Mt $CO_2$ -Eq for Saskatchewan Agriculture under the Kyoto Protocol

| Particulars | Kyoto Agriculture | Primary Agriculture |
|---|---|---|
| 1990 Emission | 11.54 | 13.95 |
| 94% of Above | 10.85 | 13.11 |
| 2010 Emissions | 14.23 | 12.15 |
| Target | 3.38 | -0.96 |

Source: Estimated from Table 1

**Efficacy and Economics of Mitigation Strategies**

The Agriculture and Agri-Food Climate Change Table identified several areas for reducing GHG emissions from agriculture (see Options Report, 2000). The major focus of concentration was on primary agricultural production, and within that on nitrous oxide. The food processing sector and other industries related through induced linkages were not considered in this analysis.

Two aspects of mitigation strategies are important: (1) are they effective in reducing GHG emissions from Saskatchewan agriculture? and (2) would their adoption impose a cost burden on producers? Both of these aspects were analysed using the CEEMA. However, the costs included here were only operating

costs. In other words, fixed (capital) costs were not included. The cost aspect presented here, therefore, is partial. This should be kept in mind in interpreting the results that are shown in Table 3. Both definitions of agriculture are used for estimating the reduction efficacy of selected strategies, and economic (partial) costs to producers.

Table 3. Results for Selected Mitigation Strategies for Saskatchewan Agriculture

| Mitigation Strategy | Change in GHG Emissions (Kt of $CO_2$-Eq) Relative to 2010 BAU | | Short-Run Cost to Producer ($/t) of Reducing GHG Emission | |
|---|---|---|---|---|
| | Kyoto Agric. | Primary Agric. | Kyoto Agric. | Primary Agric. |
| **Soil Nutrient Management** | | | | |
| *SNM:* Improved Management of Soil Nutrients | -253 | -241 | ($112) | ($118) |
| **Soil Management** | | | | |
| *SM1:* Increased use of conservation tillage | 306 | -1,124 | NA | $49 |
| *SM2:* Decreased frequency of summerfallow | 1,074 | 844 | NA | NA |
| *SM3:* Permanent Cover Program with no cattle increase | -103 | -384 | ($12) | ($3) |
| *SM4:* Permanent Cover Program with cattle increase | 475 | 210 | NA | NA |
| **Grazing Management** | | | | |
| *GRZ:* Decreased stocking density plus complementary grazing plus rotational grazing | 34 | -353 | NA | ($7) |
| **Feeding Management** | | | | |
| *FDG5:* Changed diets for pigs, poultry, and dairy cattle | -17 | -23 | $153 | $113 |
| *FDG6:* Decreased Period of Backgrounding | -153 | -74 | $140 | $289 |
| *FDG7:* Improve forage quality | -108 | -65 | $83 | $138 |
| **Manure Management** | | | | |
| *MNR1:* Eliminate fall application | -28 | -29 | $378 | $365 |
| *MNR2:* Cover liquid manure tanks | -71 | -72 | $3 | $3 |
| **Agro-Forestry** | | | | |
| *AFRST:* Convert 1% of area under shelterbelts | -102 | -1,098 | $7 | $1 |

Figures in parentheses are negative costs, or benefits through adoption of the proposed strategy

Source: CEEMA Output

Six categories of strategies were selected by the Table, which included a total of 12 mitigation practices that could be undertaken on Saskatchewan farms to reduce GHG emissions from agriculture. These measures included changes in land use (such as agro-forestry and permanent cover programs), better

management practices (such as soil nutrient management, feeding strategies, and manure application), as well as adoption of new technologies (reduced summerfallow, increased conservation tillage). Results vary from strategy to strategy. These are summarized in Table 4.

Table 4. Ranking of GHG Emission Reduction Strategies based on Efficacy and Cost to Farmers, 2010

| Kyoto Agriculture | Primary Agriculture |
|---|---|
| **Rejected Strategies** | |
| SM1<br>SM2<br>SM4<br>GRZ | SM2<br>SM4 |
| **Win-Win Strategies** | |
| SNM<br>SM3 | SNM<br>SM3<br>GRZ |
| **Strategies with Cost Implications** | |
| MNR2<br>AFRST<br>FDG7<br>FDG6<br>FDG5<br>MNR1 | AFRST<br>MNR2<br>SM1<br>FDG5<br>FDG7<br>FDG6<br>MNR1 |
| **Total Reduction in GHG (kt) including Win-Win Strategies** | |
| -860 | -3,484 |
| **% of Kyoto Reduction Target** | |
| 25 | NA |
| **Short Run Cost to Producer (000$)** | |
| -14,610 | -67,338 |

Source: Based on Table 3

For the Kyoto aggregation of agriculture, some strategies led to increased emissions, and therefore were rejected. Four such strategies included – increased use of conservation tillage, decreased summerfallow, a permanent cover program with increased cattle, and proper grazing management. However, there were also two "win-win" strategies – those that lead to an improvement in producers economic returns, and reduce GHG emissions at the same time. These included soil nutrient management, and a permanent cover program with no increase in cattle. However, the rest of the mitigation strategies led to some cost to the producer, ranging from $3 - $378 per tonne. Total cost (short run) to producers would be in the neighbourhood of $15 million, which in tough times such as those being faced currently, would not be favoured.

One item of interest is that using this definition of agriculture, based on the strategies discussed here, it is estimated that Saskatchewan could only reduce it agricultural emissions by 25% of what is required under the Kyoto Protocol. Thus, if soils as sinks are not recognized, Saskatchewan agriculture could face a tough challenge to find alternative ways to reduce GHG emissions from agricultural sources.

If the definition of primary agriculture is used (which includes soils as sinks), the model estimates that Saskatchewan agriculture would not have to reduce emissions any further from the 2010 business-as-usual case. However, if agriculture can reduce emissions cheaper than other sectors, such reductions would be in the best interest of the country as a whole.

## Areas for Future Research

This study has presented an aggregate view of GHG emissions from Saskatchewan agriculture and the mitigation strategies that could be implemented to secure the desired reduction in emissions. A number of areas remain for future studies.

One, The total cost to the producer in this study excluded the fixed cost of investment in the new technology. It is conceivable that if other costs are included, the ranking of these strategies could change.

Two, Success in reducing the GHG emissions from agriculture using the above set of mitigation measures assumes that farmers would adopt them. However, very little attention is paid on the factor that affect their adoption? What impediments are present for their adoption? And, What measures could the federal and provincial governments implement to facilitate their adoption, particularly for those strategies that are not in the "win-win" category.

Three, Analysis is based on a single farm with various enterprises. Thus, differences in the impact of the mitigation strategies on various size farms located in different regions of the province are excluded. Knowledge of such impacts is necessary for the development of a successful provincial implementation strategy for Saskatchewan agriculture.

Four, Much of then scientific knowledge used in the development of the emissions coefficients is based on the IPCC recommendations, and therefore, not Saskatchewan based. Knowledge of emissions and economic costs for Saskatchewan conditions would be helpful in determining both the economic cost to provincial economy and emissions reduction efficacy of various strategies.

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