Agriculture: 1990 - 1999

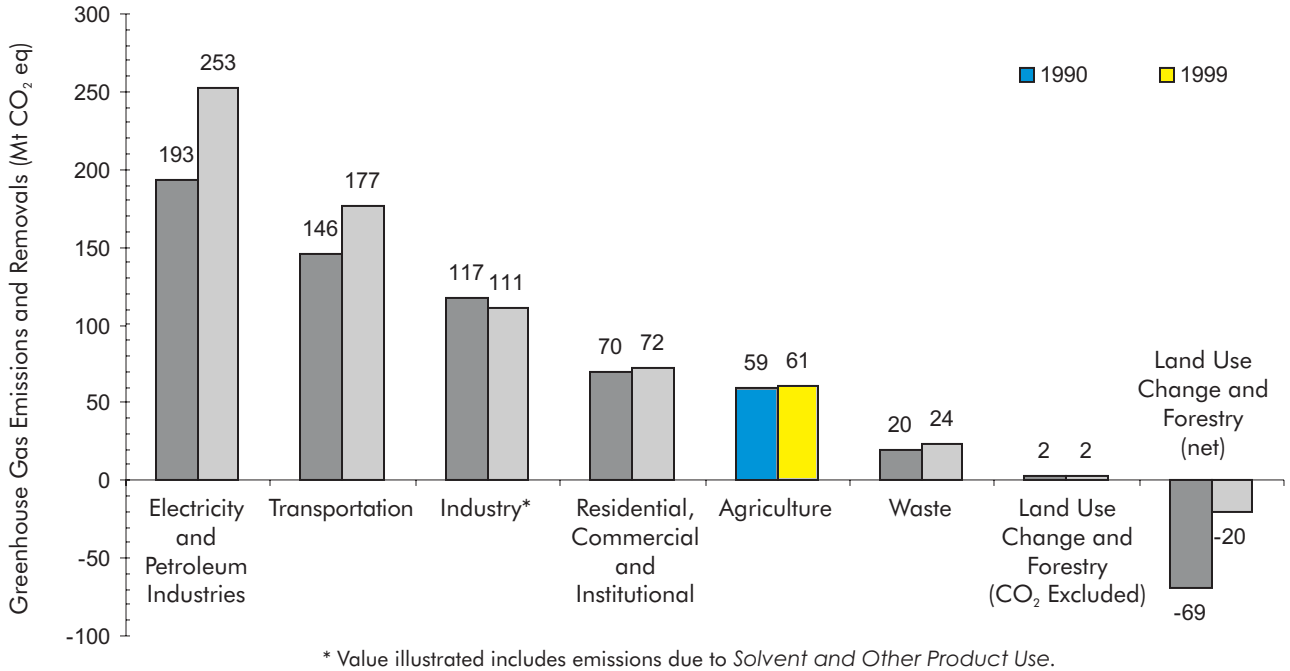
The Agriculture sector of the Canadian Greenhouse Gas Inventory (CGHGI) includes the contribution to greenhouse gas emissions from livestock, manure management, and agricultural soils.

- *In 1999*, greenhouse gas emissions from the Agriculture sector totaled 60.7 megatonnes of carbon dioxide equivalent* (Mt CO_2 eq) and contributed 9% towards total national emissions of 699 Mt. Agriculture accounted for 69% of Canada's total emissions of nitrous oxide, 25% of methane, and less than 1% of carbon dioxide. Agricultural soils contributed 56% of sectoral emissions in 1999 (33.6 Mt). Enteric fermentation emissions from domestic animals totaled 17.8 Mt and accounted for 29% of Agriculture emissions, while manure management contributed 15%, at 9.3 Mt.

- *Between 1990 and 1999*, total agricultural emissions rose 3%. If the carbon dioxide flux from agricultural soils is excluded**, total emissions from this sector would have increased 18% since 1990 (from 51.3 Mt to 60.6 Mt). On a category basis, emissions from manure management rose 13% and enteric fermentation emissions increased 11%. Net carbon dioxide emissions from agricultural soils decreased from 7.3 Mt in 1990 to 0.2 Mt in 1999 as a result of conservation tillage and reduced frequency of summer-fallow on the prairies. Nitrous oxide emissions from agricultural soils increased 23%, from 27.2 Mt in 1990 to 33.4 Mt in 1999.

**Unless otherwise indicated, all emissions are reported in Mt CO_2 eq. For brevity, this has been shortened to Mt. This concept provides a relative measure of the impacts of different greenhouse gases on global warming, with the effect of carbon dioxide being equal to one.*
*** The net flux of carbon dioxide is a combination of both the source and sink from agricultural soils.*

Figure 1. Canadian Greenhouse Gas Emissions and Removals 1990 and 1999



* Value illustrated includes emissions due to *Solvent and Other Product Use*.

Canada's Agriculture Sector

Many agricultural activities result in emissions of greenhouse gases. The processes that produce emissions are enteric fermentation in domestic animals, manure management systems, and cropping practices. While large quantities of methane are produced through the enteric fermentation process, manure management systems generate both methane and nitrous oxide. Cropping practices can result in a release of carbon dioxide and nitrous oxide from soils.

The preparation of the Canadian Greenhouse Gas Inventory for the Agriculture sector closely follows the Guidelines published by the Intergovernmental Panel on Climate Change (IPCC, 1997). Accordingly, the inventory allocates greenhouse gas emissions by sources in the Agriculture sector within the following three categories:

1. Enteric Fermentation
2. Manure Management
3. Agricultural Soils

The Canadian Greenhouse Gas Inventory (CGHGI)

The Canadian Greenhouse Gas Inventory is developed, compiled, and reported annually by the Greenhouse Gas Division of Environment Canada, and utilizes methods and models developed in-house by engineering and scientific staff, as well as published data, data developed by industry, or methods developed by the Intergovernmental Panel on Climate Change (IPCC, 1997).

The greenhouse gases that have been estimated in the national inventory are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulphur hexafluoride (SF_6), perfluorocarbons (PFCs), and hydro fluorocarbons (HFCs).

The inventory uses an internationally agreed to reporting format that groups emissions and removals into the following six sectors: Energy, Industrial Processes, Solvent and Other Product Use, Agriculture, Land-Use Change and Forestry, and Waste. The 1999 Trends Fact Sheet Series, while presenting the latest information on Canadian greenhouse gas emissions and removals derived from the latest national inventory, use a modified sector approach to facilitate the use of information by the public.

The remainder of this fact sheet will outline and discuss the major trends and underlying factors in greenhouse gas emissions for the Agriculture sector.

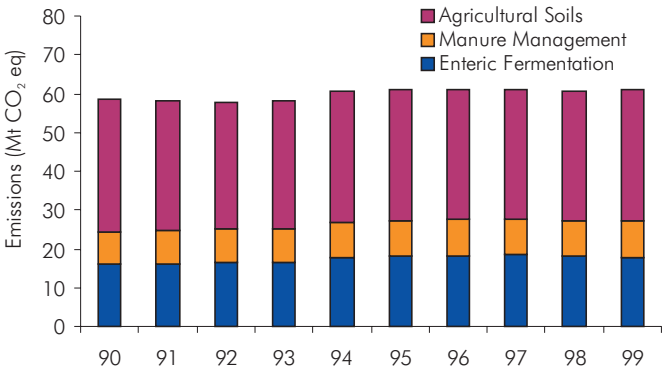
Agriculture Sector Emission Trends : 1990 to 1999

Greenhouse gas emissions in the Agriculture sector rose 3% between 1990 and 1999, from 58.9 to 60.7 Mt.

Of the three greenhouse gas source categories within the Agriculture sector, the largest contribution of emissions is from Agricultural Soils. This category represents approximately half of the sector's emissions in 1999, as well as throughout the 1990's (Figure 2).

Excluding the carbon dioxide flux from agricultural soils, total non-carbon dioxide emissions from the Agriculture sector increased 17% since 1990 (from 51.3 Mt in 1990 to 60.6 Mt in 1999).

Figure 2. Agriculture Emissions by Category, 1990 -1999



Enteric Fermentation

Emissions associated with enteric fermentation of animals accounted for 17.8 Mt in 1999, or nearly 30% of the total emissions within the Agriculture sector. Since 1990, emissions have increased 11%, mainly due to increased beef production.

The rising trend in greenhouse gas emissions from enteric fermentation is due to increases in cattle production. Non-dairy cattle production, which accounts for the highest emissions among the various types of cattle, has increased 21% since 1990 with a similar increase in emissions (Table 1).

What is enteric fermentation?

During the digestive process of herbivores, carbohydrates are broken down by micro-organisms into simple molecules for absorption into the bloodstream, where methane is produced as a by-product. This process results in methane in the rumen, which is released by eructation and exhalation. Some methane is released later in the digestive process by flatulation. The animals that generate the most methane are ruminant animals such as cattle.

The increase in emissions from non-dairy cattle was partly offset by a reduction in emissions from dairy cattle, resulting from a decline in the number of dairy cows. Dairy cattle population decreased from 196,400 in 1990 to 165,700 in 1999 resulting in a decline in emissions of 15% (Statistics Canada, #23-603).

Table 1. Enteric Fermentation Emissions by Category, 1990 and 1999

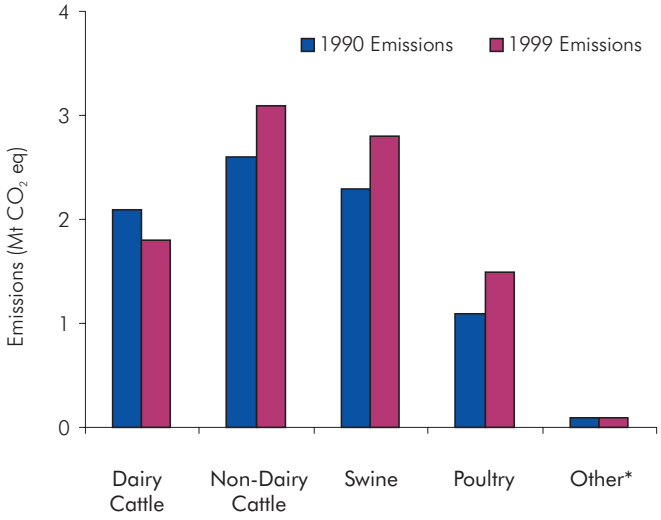
	1990	1999	% Change
Animal Type	Mt CO_2 eq		since 1990
Dairy Cattle	4.1	3.5	-15%
Non-Dairy Cattle	11.3	13.6	20%
Swine	0.3	0.4	33%
Other	0.3	0.3	0%
Total	16.0	17.8	11%

Manure Management

During the handling and storage of livestock manure, both methane and nitrous oxide are emitted. The magnitude of the emissions is dependent upon the manure properties, quantities of manure, as well as the type of handling system. As for manure handling systems, poorly aerated ones generate more methane but little nitrous oxide, while well-aerated systems generate little methane but more nitrous oxide.

Nitrous oxide and methane emissions within this category have increased steadily since 1990 (Figure 3). Combined, these emissions increased 13% between 1990 and 1999, from 8.2 Mt to 9.3 Mt. The rising trend in emissions from manure management is mainly due to the expansion in the beef, swine and poultry industry.

Figure 3. Combined Nitrous Oxide and Methane Emissions from Manure Management, 1990 and 1999



* The category entitled "Other"includes emissions from goats, horses and sheep.

Agricultural Soils

Greenhouse gas emissions from agricultural soils in Canada totaled 33.6 Mt in 1999. This represents a 2% reduction in emissions over the 1990 estimate of 34.5 Mt. If the carbon dioxide flux from agricultural soils is excluded, total emissions from this category increased 23%, from 27.2 Mt in 1990 to 33.4 Mt in 1999.

Soil management and cropping practices affect both the carbon and nitrogen cycles in soils. These management practices can lead to emissions and removals of carbon dioxide, as well as emissions of nitrous oxide. For example, both conservation tillage and reducing the frequency of summer-fallowed fields can lead to increased carbon storage in soils. Conversely, uses of nitrogen fertilizer and manure on agricultural soils lead to emissions of nitrous oxide. Table 2 outlines the trends in both nitrous oxide and carbon dioxide emissions from agricultural soils for the period 1990 to 1999.

Carbon Dioxide

Net carbon dioxide emissions from agricultural soils have decreased significantly from 7.3 Mt in 1990 to 0.2 Mt in 1999. The primary reason for the reduced net emissions from soils is due to the increasingly common practice of conservation tillage and reduced frequency of summer-fallow on the prairies. In particular, no-till farming was practiced on over 16% of Canada's annual croplands in 1996 (Statistics Canada, #93-356), as opposed to 7% in 1991 (Statistics Canada, #93-350).

Nitrous Oxide

Nitrous oxide emissions have increased 23% between 1990 and 1999 (from 27.2 Mt to 33.4 Mt). Emissions of nitrous oxide can be subdivided into direct and indirect sources. Direct emissions are those that are emitted directly from agricultural fields, while indirect emissions are those that are emitted off site by either volatilization and subsequent redeposition or by leaching and runoff.

Direct Sources

The direct sources of nitrous oxide emissions from agricultural soils are:

- *synthetic nitrogen fertilizers*: nitrous oxide emissions from the application of synthetic nitrogen fertilizers have increased steadily from 6.5 Mt in 1990 to 8.9 Mt in 1999, representing an increase of approximately 37%.

- *animal wastes applied as fertilizer*: emissions due to animal manure used as fertilizers on agricultural soils have increased from 3.2 to 3.7 Mt per year, resulting from an expansion of the national livestock industry.

- *grazing animals*: emissions associated with the application of manure to soils through grazing animals increased from 2.3 to 2.7 Mt between 1990 and 1999 due to the increased livestock population.

- *plant biological nitrogen fixation*: leguminous crops such as alfalfa, soybean and lentil can fix atmospheric nitrogen, but the ribozobia in plant nodules of these crops can emit nitrous oxide as they fix nitrogen. Nitrous oxide emissions from the production of leguminous crops remained relatively unchanged during the last decade at about 4 Mt per year.

- *crop residue decomposition*: after a crop is harvested, a portion of the crop is left on the field to decompose. The remaining plant matter is a source of nitrogen. Nitrous oxide emissions through crop residue decomposition increased over the period 1990 to 1999 from 6.0 to 6.8 Mt per year.

- *cultivation of histosols*: nitrous oxide is emitted as a result of cultivating organic soils, also known as histosols, for annual crop production. There is no detailed agricultural census data available on the area of cultivated histosols in Canada. In light of this, through consultation with soils and crops specialists, the area of cultivated histosols is estimated to be approximately 30,000 hectares. Emissions from this source are small and remain unchanged at 0.01 Mt per year.

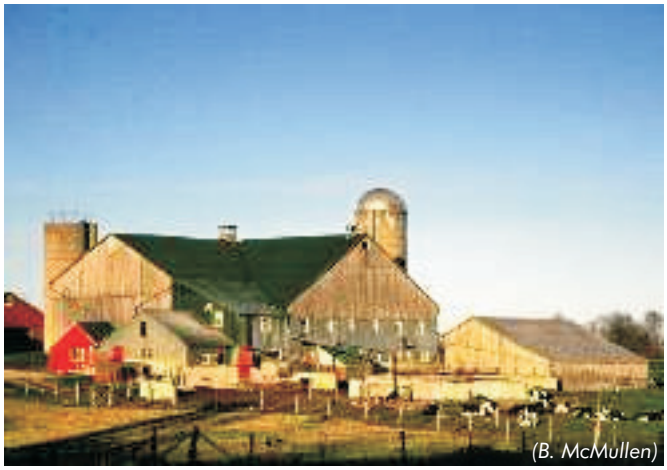

(B. McMullen)

Table 2. Agricultural Soil Emissions by Category, 1990 to 1999

Greenhouse Gas Emissions	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	Mt CO_2 equivalent									
Carbon Dioxide Total	7.3	6.7	5.8	4.7	4.2	3.2	1.8	1.2	0.7	0.4
Nitrous Oxide										
Synthetic Fertilizer Nitrogen	6.5	6.4	6.9	7.2	7.7	7.9	8.6	9.1	9.1	8.9
Manure as Fertilizer	3.2	3.2	3.3	3.3	3.5	3.6	3.6	3.6	3.7	3.7
Grazing Animals	2.3	2.4	2.4	2.4	2.6	2.7	2.7	2.8	2.7	2.7
Biological Nitrogen Fixation	3.8	3.6	3.4	3.8	4.3	3.9	3.8	3.6	3.8	4.4
Crop Residue Decomposition	6.0	5.7	5.4	5.6	5.4	5.9	6.5	6.0	6.4	6.8
Cultivation of Histosols	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Indirect Nitrous Oxide	5.4	5.4	5.7	5.8	6.2	6.4	6.7	7.0	6.9	6.9
Nitrous Oxide Total	27.2	26.7	27.1	28.1	29.7	30.4	31.9	32.1	32.6	33.4
Greenhouse Gas Emissions Total	34.5	33.4	32.9	32.8	33.9	33.6	33.7	33.3	33.3	33.8

Indirect Sources

A fraction of the nitrogen fertilizer that is applied to agricultural fields will be transported off site by both volatilization and subsequent redeposition or by leaching and runoff. The nitrogen that is transported from the agricultural field will provide an additional source of nitrogen for nitrous oxide emissions.

Indirect emissions of nitrous oxide increased substantially from 5.4 Mt in 1990 to 6.9 Mt in 1999. This increase is attributed to both the expansion of the livestock industry, as well as to an increased consumption of synthetic nitrogen fertilizers.

Summary of Non-Carbon Dioxide Trends in Agricultural Emissions

In this section, greenhouse gas emissions within the Agriculture sector are alternatively classified as either animal or crop production-related. Emissions associated with animal production include enteric fermentation, manure management and manure disposal. Crop production emissions include greenhouse gases from both direct Sourcesdirect and indirect sources as described in the previous section.

Excluding the carbon dioxide flux from agricultural soils, animal production contributed between 60 to 65% of the total sectoral emissions, while crop production accounted for 35 to 40% of emissions (Table 3).

Animal Production

Approximately one half of emissions related to animal production in Canada result from enteric fermentation, while the other half is equally split between manure management and on-land use of manure as fertilizers.

Major contributors of greenhouse gases among domestic animals in Canada are non-dairy cattle, dairy, swine, and poultry. Since 1990, emissions associated with non-dairy cattle increased 18%, swine by 19% and poultry by 31%, while dairy production-related emissions decreased 15%. Contributions of emissions from other domestic animals remain unchanged for the period.

Table 3. Summary of Major Non-Carbon Dioxide Emissions Resulting from Animal and Crop Production in Canada

Greenhouse Gas Source		1990	1993	1996	1999
Animal Production[a]					
(percent of annual Total)		Mt CO_2 equivalent			
	Non-Dairy[b]	20.2	21.7	24.0	23.8
		(39%)	*(41%)*	*(40%)*	*(39%)*
	Dairy	6.2	5.7	5.8	5.3
		(12%)	*(10%)*	*(10%)*	*(9%)*
	Swine	3.7	3.9	4.4	4.4
		(7%)	*(7%)*	*(7%)*	*(7%)*
	Poultry	2.6	2.7	3.1	3.4
		(5%)	*(5%)*	*(5%)*	*(5%)*
Crop Production					
(percent of annual Total)		Mt CO_2 equivalent			
	Synthetic Nitrogen Fertilizers[c]	9.2	10.1	12.5	12.7
		(18%)	*(19%)*	*(21%)*	*(21%)*
	Crop[d]	9.8	9.4	10.3	11.2
		(19%)	*(18%)*	*(17%)*	*(18%)*

[a] Also includes manure used as fertilizer

[b] Percent of total Agriculture Sector non-carbon dioxide emissions

[c] Includes both direct and indirect sources

[d] Includes Biological Nitrogen Fixation and Crop Residue Decomposition

Crop Production

While non-carbon dioxide emissions have increased during the 1990 to 1999 period, the contributions of the major emission sources remained relatively unchanged.

While the contribution of nitrous oxide emissions, resulting from the consumption of synthetic nitrogen fertilizers, only increased from 18 to 21% of the total nitrous oxide emissions, the consumption of synthetic nitrogen fertilizer increased by nearly 35% between 1990 and 1999. Emissions associated with legume and non-leguminous crops, as well as crop residue decomposition, collectively contributed between 17and 19% of Canada's Agriculture sector emissions.

Provincial Non-Carbon Dioxide Agricultural Emissions

Since 1990 there has been very little change in non-carbon dioxide emissions in British Columbia, Ontario, Quebec, and Atlantic regions of Canada. From 1990 to 1999, however, non-carbon dioxide emissions increased steadily from 5.6 to 7.1 Mt in Manitoba, from 8.9 to 12.9 Mt in Saskatchewan, and from 14.2 to 17.5 Mt in Alberta. Table 4 highlights the provincial trends in non-carbon dioxide emissions between 1990 and 1999.

The increased emissions from the prairies provinces resulted from livestock expansion and synthetic nitrogen fertilizer consumption, and contributed to nearly all increases in Canada's greenhouse gas emissions from the Agriculture sector since 1990.

References

Environment Canada, *Canada's Greenhouse Gas Inventory 1990 - 1999: Emission and Removal Estimation Practices and Methods*, April 2001.

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Statistics Canada, *Agricultural Profile of Canada in* 1991, Census of Agriculture, 1992, Catalogue #93-350.

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Statistics Canada, *Livestock Statistics*, Agriculture Division, 1991-1999, Catalogue #23-603.

Table 4. Summary of Provincial Non-Carbon Dioxide Greenhouse Gas Emissions in the Agriculture Sector (Mt CO_2 eq)

Province	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Newfoundland	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Prince Edward Island	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Nova Scotia	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
New Brunswick	0.5	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Quebec	7.8	7.3	7.3	7.5	7.6	7.8	7.9	7.8	7.8	7.7
Ontario	11.2	11.0	10.8	10.8	11.1	11.2	10.8	11.1	11.2	11.2
Manitoba	5.6	5.8	6.1	6.1	6.5	6.7	7.2	7.0	7.3	7.1
Saskatchewan	8.9	9.0	9.7	10.0	10.9	11.5	12.7	13.1	12.9	12.9
Alberta	14.2	14.3	14.4	15.1	15.9	16.4	16.7	16.5	16.8	17.5
British Columbia	2.4	2.3	2.4	2.5	2.6	2.6	2.7	2.7	2.5	2.6
CANADA	51.6	51.1	52.1	53.4	56.2	57.6	59.6	59.8	60.0	60.5

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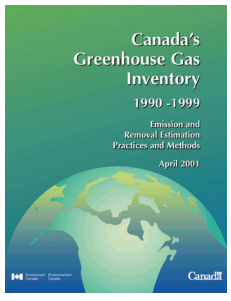

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