Land-Use Change and Forestry: 1990-1999

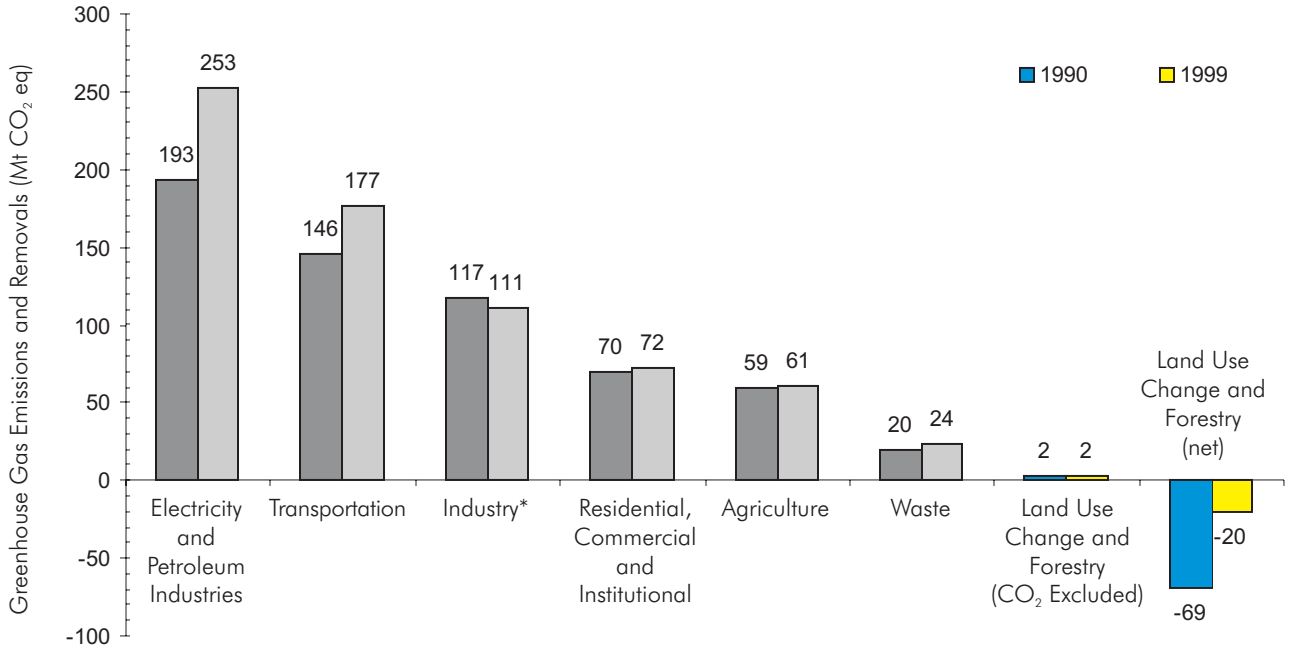
The Land-use Change and Forestry (LUCF) sector of the Canadian Greenhouse Gas Inventory (CGHGI) includes the contribution to greenhouse gas emissions and removals of forest management, human-induced fires, and changes in the way land is used.

In view of Canada's 200 million hectares of managed lands, clearly land-use and land-use practices embody a significant component of the Canadian way of life.

- *In 1999,* Canada's LUCF sector removed from the atmosphere an estimated 18 megatonnes of carbon dioxide equivalent* (Mt CO_2 eq). The dominant greenhouse gas is carbon dioxide (CO_2), with small contributions of methane (CH_4) and nitrous oxide (N_2O). As per current IPCC Guidelines (IPCC 1997), carbon dioxide fluxes in the LUCF sector are excluded from national inventory totals. Methane and nitrous oxide emissions in the LUCF sector, while included in the Canadian totals, represent about 0.3% (2 Mt) of national total emissions (699 Mt) in 1999.
- *Between 1990 and 1999,* the LUCF sector, calculated as the sum of the net carbon dioxide flux and non-carbon dioxide emissions, remained a net sink. The general trend indicates a 70% decline in the net removal, from 59 Mt in 1990 to 18 Mt in 1999. Excluding methane and nitrous oxide emissions, the net carbon dioxide flux alone also amounts to a sink, decreasing by 67% from 61 Mt in 1990 to 20 Mt in 1999. If the LUCF net carbon dioxide removals were included in the national totals, it would result in a reduction of total Canadian emissions of 10% in 1990, and 3% in 1999. If carbon storage in harvested wood products is accounted for, the decline in the net carbon dioxide removal is much smaller, between 55% and 14%, depending on the selected accounting approach. Overall, the trends observed in the LUCF category largely reflect the changing levels of industrial forestry activity during the 1990s.

**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.*

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



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

Canada's LUCF Sector

The LUCF sector, as well as agricultural soils, are distinct from other sectors as they include both emissions and removals of greenhouse gases to and from the atmosphere.

Greenhouse gases are emitted to the atmosphere through the decomposition or burning of living and dead organic matter. They are absorbed by vegetation through photosynthesis and stored in biomass and in soils. Both emissions and removals of greenhouse gases are large fluxes resulting from minute processes dispersed over a vast land area. Changes in land-use practices directly alter the size and rate of these natural exchanges of greenhouse gases between the terrestrial landscape and the atmosphere, both in the present and over long time periods. Understanding and measuring the components of these natural fluxes that are due to human intervention represent unique scientific and accounting challenges.

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

1. Changes in Forest and Other Woody Biomass Stocks
2. Forest and Grassland Conversion
3. Abandonment of Managed Lands
4. Carbon Dioxide Emissions and Removals from Soil
5. Other

For the purpose of describing the trends in LUCF emissions and removals in Canada, the five LUCF categories are grouped into three headings within this fact sheet: Forest Management (corresponding to category 1 of this section), Land-use Changes (categories 2 to 4) and Forest Fires (category 5).

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).

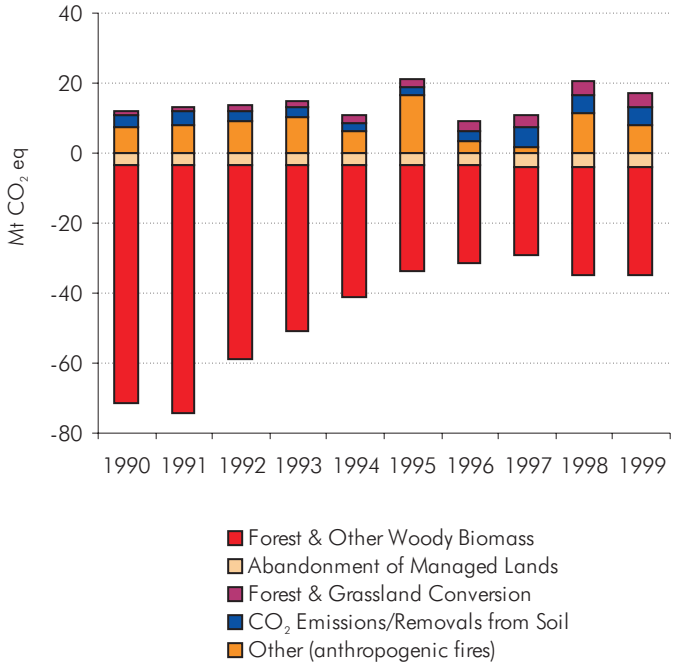
The greenhouse gases that have been estimated in the national inventory are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulphur hexafluoride (SF_6), perfluorocarbons (PFCs), and hydro fluorocarbons (HFCs).

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.

LUCF Sector Emissions and Removals Trends: 1990 to 1999

Of the five LUCF sector categories, the largest and most influential on total greenhouse gas emissions and Removals is the Changes in Forest and Other Woody Biomass category (Figure 2). It generally represents more than 87% of all carbon dioxide removals in the LUCF sector and displays a trend similar to the overall sector trend, with sinks declining by 55% between 1990 and 1999.

Figure 2. LUCF Sector Emissions and Removals by Category, 1990 to 1999



Forest Management

Which forest?

The LUCF inventory estimates carbon dioxide emissions and removals in the "*managed*" part of the forests, thus excluding forests unmanaged for wood production. In the CGHGI, this forest is identified as the "*Wood Production Forest*", and is defined as the non-reserved, stocked, timber-productive forests with access (Canadian Forestry Inventory Publications). The Wood Production Forest extends over 133 million hectares (133 Mha), distributed unevenly throughout Canada.

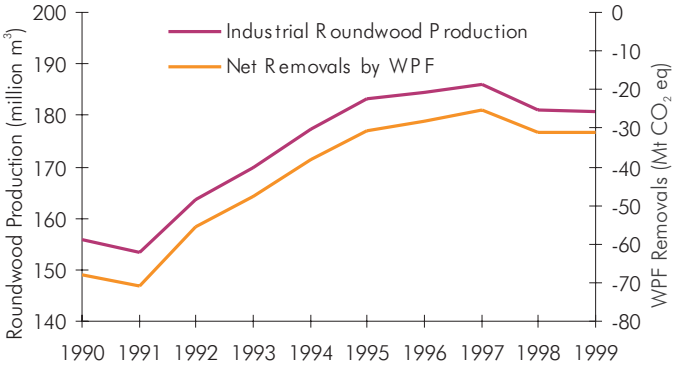
Carbon fluxes in and out of the forest

The LUCF inventory estimates net carbon dioxide fluxes in and out the Wood Production Forest by subtracting the carbon removed in the harvested wood from the net carbon taken up by trees in the "*growing area*" of the Wood Production Forest. This "*growing area*" (123 Mha) consists of the area over which trees are actively sequestering carbon through photosynthesis, and excludes overmature forests. Fluxes of carbon to and from forest soils are also excluded due to a lack of data. It is assumed that carbon dioxide emissions from fires in the Wood Production Forest are implicitly incorporated in the average growth rates. This assumption is reconsidered below, under the heading "*Uncertainty*". The decline in net removals during the 1990s is in large part explained by the 16% increase in the annual volume of harvested wood over the period.


(B. McMullen)

Since it is assumed that the areal extent of the 'growing' forests and their average growth rates are stable over the 1990 to 1999 period, trends in carbon emissions and removals largely result from the levels of harvesting activities. The 67% decline in forest carbon sinks over the period is mirrored by a 16% increase in industrial roundwood production (Figure 3).

Figure 3. Trends in Industrial Roundwood Production and Carbon Dioxide Removals in the Wood Production Forest



Carbon Accounting of Harvested Wood Products

The IPCC default approach currently requires that all the carbon in the wood harvested from forests is emitted to the atmosphere in the year of harvest, unless it can be shown that the wood products pool is increasing; hence, it doesn't account for long-term carbon storage in harvested wood products and landfills. Where these pools do in fact increase, the default method overestimates carbon dioxide emissions from forest management. The IPCC has not yet recommended an alternative approach for the accounting of carbon storage in wood products.

While awaiting further guidance from the IPCC, Canada has produced estimates of the contribution of the wood product sector to net carbon emissions and removals from its managed forest, using two alternative approaches. Both alternative approaches markedly reduce the apparent impact of industrial forestry activity on the carbon balance of the Wood Production Forest. In 1999, harvest emissions vary from 258 Mt CO_2 (current default method) to 244 Mt CO_2 (Stock-change) or 170 Mt CO_2 (Atmospheric Flow). The difference in harvest emissions between the Stock-change and Atmospheric Flow approaches mainly resides in the different treatment of exported wood products.

Very little information is available on the wood waste stream in Canada, specifically on the composition and fate of wood-based material landfilled annually. Landfills are a potentially vast reservoir for long-term carbon storage.

Land-Use Changes

In 1999, the net flux associated with land-use changes in Canada resulted in emissions of over 5 Mt CO_2. These emissions have more than doubled between 1990 and 1999 (Figure 4).

Which Land-use Changes?

In the national inventory, land-use changes in Canada comprise the conversion of forests and grasslands to other land-uses (e.g. agriculture or urban lands), and the abandonment of agricultural lands which then revert to their original vegetation cover.

Dynamics of Carbon Emissions and Removals

In general, forest and grassland conversion causes carbon emissions to the atmosphere. Carbon removals from the atmosphere are associated with vegetation regrowth on abandoned agricultural lands. The dynamics of carbon emissions and removals, however, operate at different time scales: emissions are immediate when large quantities of biomass are oxidized at once, or delayed over longer time periods due to the gradual decomposition of residues or soil organic matter.

Conversely, carbon removals from the atmosphere and storage in living and dead organic matter is a slow process which spans decades, if not centuries. Consequently, for the purpose of greenhouse gas accounting, forest conversion and vegetation growth on abandoned lands cannot be treated as mirror processes.

Forest Fires

In Canada's LUCF inventory, the Other category consists of carbon dioxide emissions from fires caused by humans (also called "*anthropogenic*" fires) outside of the Wood Production Forest. Carbon dioxide emissions associated with fires in the Wood Production Forest were discussed in the section on Forest Management. However, non-carbon dioxide emissions from all human-induced forest fires are included, regardless of location.

The quantity of greenhouse gases released by forest fires varies annually with the extent of the area burned; therefore, it displays the large variability typical of natural disturbances (Figure 5). Over the period 1990 to 1999, annual emissions of greenhouse gases resulting from anthropogenic forest fires fluctuated between 2 and 17Mt. The estimated area burned for 1999 is projected from historical data, and, in view of the inter-annual variability noted above, should be treated with caution. This category is the only one for which non-carbon dioxide greenhouse gases are reported.

Uncertainty

While a reasonable degree of confidence can be placed on the overall trend direction, the flux estimates themselves are characterized by a high degree of uncertainty. To reflect this uncertainty, figures have been rounded (Environment Canada, 2001).

Figure 4. Trends in Carbon Dioxide Emissions and Removals Related to Land-use Changes in Canada

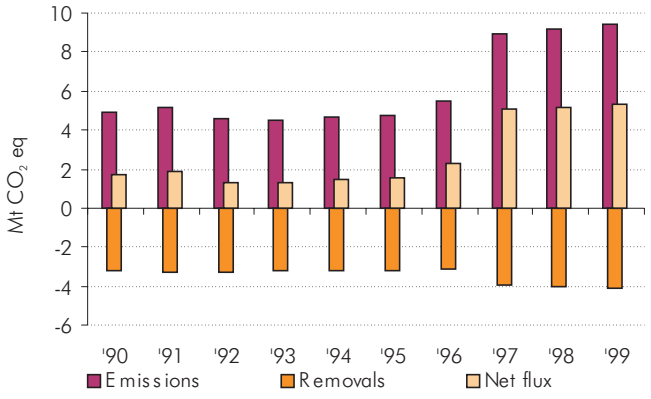
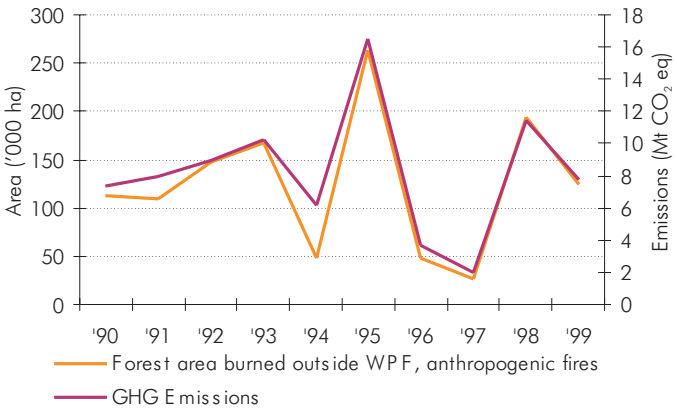


Figure 5. Forest Area Burned and Total Greenhouse Gas Emissions from Fires 1990 - 1999



Forest Management

In view of the dominant influence of forest management on the net carbon flux in the LUCF sector, an analysis was conducted on the sensitivity of results to a selection of key parameters and data inputs.

Parameters that were modified in the course of the analysis were:

- area of the Wood Production Forest and its *"growing"* part;
- average rate of tree growth;
- harvest rates; and
- explicit account of carbon dioxide emissions from fires in the Wood Production Forest.

The three inputs with the largest influence on the total carbon removal by the Wood Production Forest in 1999 are, in decreasing order of importance: carbon dioxide emissions from fires in the Wood Production Forest, tree growth rates, and the harvest rate. It is important to consider that the relative significance of fire emissions in the Wood Production Forest vary annually, as do the location and extent of fires in all Canadian forests.

These results indicate a priority for methodological improvement should be the development of better tools to estimate fire emissions from the Wood Production Forest. Efforts should also concentrate on a better assessment of biomass growth rates. It is believed that the overall improvement in accuracy obtained from better harvest data would be modest, given the relatively high confidence on the data quality.

The analysis omitted those unquantifiable and uncertain sources associated with insufficient knowledge or data. In particular, the magnitude of the net forest sink may be significantly altered by including the carbon content of dead organic matter in forest soils and litter, another large and poorly understood carbon pool. Work is on-going to incorporate this carbon pool in the model.

Land-Use Changes

Two major sources of uncertainty have been identified in carbon accounting of land-use changes: lack of data and information on land-use changes and land-use change practices; and, an incomplete understanding of soil carbon dynamics when land is converted to another use.

Missing data on land-use changes include the extent of the conversion, in each Canadian province, of natural ecosystems to agriculture, urban and industrial lands, rural residential land, as well as mining, petroleum and transportation infrastructure. Moreover, land-use change practices, such as burning, are poorly documented.

The current estimation methods for soil carbon emissions and removals due to land-use changes is based on the long-term average values of soil carbon content under different land uses. It is assumed that all soil carbon losses occur within twenty-five years, and all carbon sequestration on abandoned farmlands within one hundred years.

The Kyoto Protocol: from Agricultural Soils and LUCF to LULUCF

The national greenhouse gas inventory is the ultimate measure against which Canada will be judged when reporting under the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol, or any similar, legally binding agreement.

Canada, if it ratifies the Kyoto Protocol, will see its reporting commitments greatly increased. The seventh Conference of the Parties to the UNFCCC, in November 2001, agreed that the accounting for the 2008-2012 reduction targets would include emissions and removals from afforestation, reforestation and deforestation (ARD) and optionally from forest management, crop management, grazing land management, and revegetation activities. This provision would call for an integrated reporting of all greenhouse gas sources and sinks from land-based resources, from Land Use, Land-use Change and Forestry (LULUCF) activities.

Environment Canada and all its partners in the federal, provincial, industry, non-governmental and academic communities are already organizing their resources to address the scientific and technical challenge of implementing the Kyoto requirements.

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3. Census of Agriculture, compiled by Statistics Canada
http://www.statcan.ca/english/censusag/agri.htm

4. Food and Agriculture Organization of the U.N. (FAO) Forestry Database
http://apps.fao.org/cgi-bin/nph-db.pl?subset=forestry

Methodological Sources:

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

Intergovernmental Panel on Climate Change (IPCC), *Greenhouse Gas Inventory Reporting Instructions*, Vol. 1; and *Greenhouse Gas Inventory Manual*, Vol. 3, Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, 1997.

Glossary

Afforestation: the establishment of forests, through planting, seeding or other management activities, on land that has not been forested for a determined period of time.

Biomass: the mass of living and dead plant material, above-ground and below-ground.

Carbon flux: transfer of carbon from one pool to another.

Carbon pools: carbon reservoirs, with the capacity to accumulate or release carbon (e.g. forest biomass, wood products, soils and the atmosphere).

Carbon sequestration: the process of increasing the carbon content of a pool other than the atmosphere.

CO_2 equivalent: the amount of CO_2 that would cause the same effect as a given amount or mixture of other greenhouse gases.

Emissions: the act of releasing a greenhouse gas to the atmosphere. Emissions come from sources.

Greenhouse gas: a gas that absorbs infrared radiation and in turn emits it in the atmosphere. The net effect is a local trapping of energy and a tendency to warm the earth's surface. Water vapour (H_2O), carbon dioxide (CO_2) methane (CH_4), nitrous oxide (N_2O) and ozone (O_3) are the primary greenhouse gases in the Earth's atmosphere.

IPCC Guidelines: guidelines developed by the Intergovernmental Panel on Climate Change for the preparation of national greenhouse gas inventories. The latest version was published in 1997.

Land Use: all arrangements, activities and inputs (sets of human actions) undertaken in a certain land cover type. The social and economic purpose for which land is managed (timber production, grazing, conservation).

Organic matter: carbon-based material that makes up living tissues and their residues (litter, soil organic matter).

Removal: the act of removing a greenhouse gas from a pool. Removals from the atmosphere are done by sinks.

Sink: any process or mechanism which removes a greenhouse gas from the atmosphere. See also "removal".

Sources: any process or mechanism which release a greenhouse gas in the atmosphere. The opposite of sinks.

Wood products: all products derived from the wood harvested from a forest. Includes fuelwood, logs and commodities derived from them (e.g. sawnwood, paper etc).

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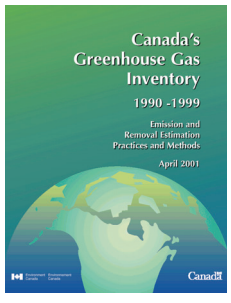

Contact:
Art Jaques, P. Eng
Chief - GHG Division, Environment Canada
351 St. Joseph Boulevard, Hull, QC, K1A 0H3
(819) 994-3098, (819) 953-3006 (fax)
ghg@ec.gc.ca

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