

# CANADA'S GREENHOUSE GAS INVENTORY

GHG Trends Information from Environment Canada's Greenhouse Gas Division

## Land-Use Change and Forestry: 1990-2000

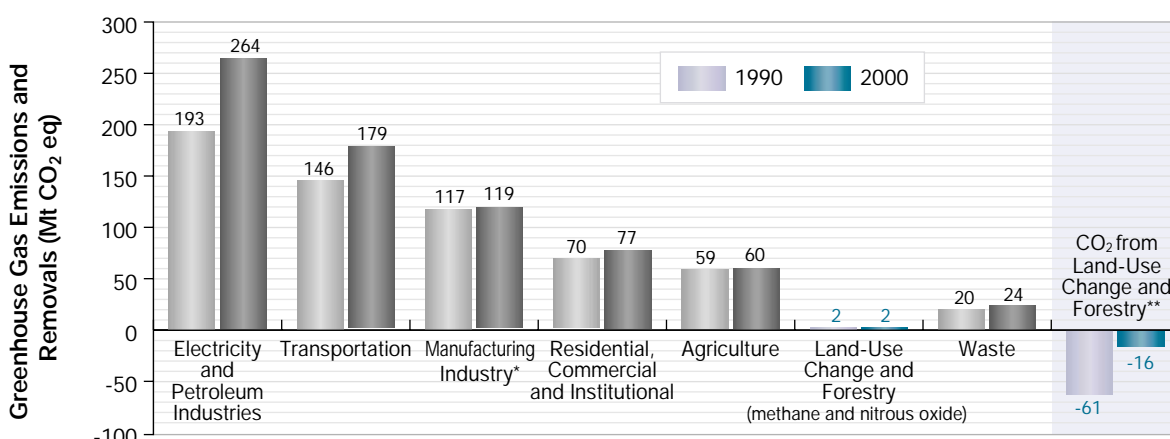
The Land-use Change and Forestry (LUCF) sector of the Canadian Greenhouse Gas Inventory (CGHI) includes the contribution to greenhouse gas emissions and removals of forest management, human-induced fires, and changes in the way land is used.

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 2000*, Canada's LUCF sector removed from the atmosphere an estimated 14 megatonnes of carbon dioxide equivalent\* (Mt CO<sub>2</sub> eq). The dominant greenhouse gas is carbon dioxide (CO<sub>2</sub>), with small contributions of methane (CH<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O). 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 from the LUCF sector are included in the Canadian totals and represent about 0.3% (2 Mt) of national total emissions (726 Mt) in 2000.
- *Between 1990 and 2000*, 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 decline in the net removal, from 59 Mt in 1990 to 14 Mt in 2000. This trend results from an 18% increase in harvest emissions during the period, and reflects the high variability in emissions from forest fires. 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 2% in 2000. If carbon storage in harvested wood products was accounted for, the decline in the net carbon dioxide removal would be much smaller over the period, by up to 60%, depending on the selected accounting approach.

\*Unless otherwise indicated, all emissions are reported in Mt CO<sub>2</sub> eq. For brevity, this has been shortened to Mt. This concept provides a measure of the impacts of different gases on global warming, with the effect of carbon dioxide being equal to one.

**Figure 1 Canadian Greenhouse Gas Emissions and Removals, 1990 and 2000**



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

\*\*Carbon dioxide emissions from the Land-Use Change and Forestry sector are not included in the national inventory totals.



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**Table 1** 2000 Greenhouse Gas Emissions and Removals Summary for the LUCF Sector

LUCF Category	Carbon Dioxide Mt	Methane and Nitrous Oxide Mt CO <sub>2</sub> eq	LUCF Category Total Mt CO <sub>2</sub> eq
Forest Management	-28	not estimated	-28
Land-Use Changes	5	not estimated	5
Anthropogenic Forest Fires			
inside Wood Production Forest	included in		
	Forest Management	2	2
outside Wood Production Forest	6	0.5	6.5
<b>Total</b>	<b>-16</b>	<b>2.5</b>	<b>-14</b>

Notes: Shaded areas indicate values that are not included in the national inventory totals.  
Due to rounding, individual values may not add up to the sector total.  
Removals are shown as negative values.

## Canada's LUCF Sector

The LUCF sector shares, with agricultural soils, two distinctive characteristics: they include both emissions and removals of greenhouse gases to and from the atmosphere, and they involve close interactions of human activities and natural processes.

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 periods of time. Understanding and measuring the components of these natural fluxes that are due to human intervention represent unique scientific and accounting challenges.

For the purpose of describing the trends in LUCF emissions and removals in Canada, the LUCF sector is divided into the following three categories: Forest Management; Land-use Changes; and Anthropogenic Forest Fires (Table 1).

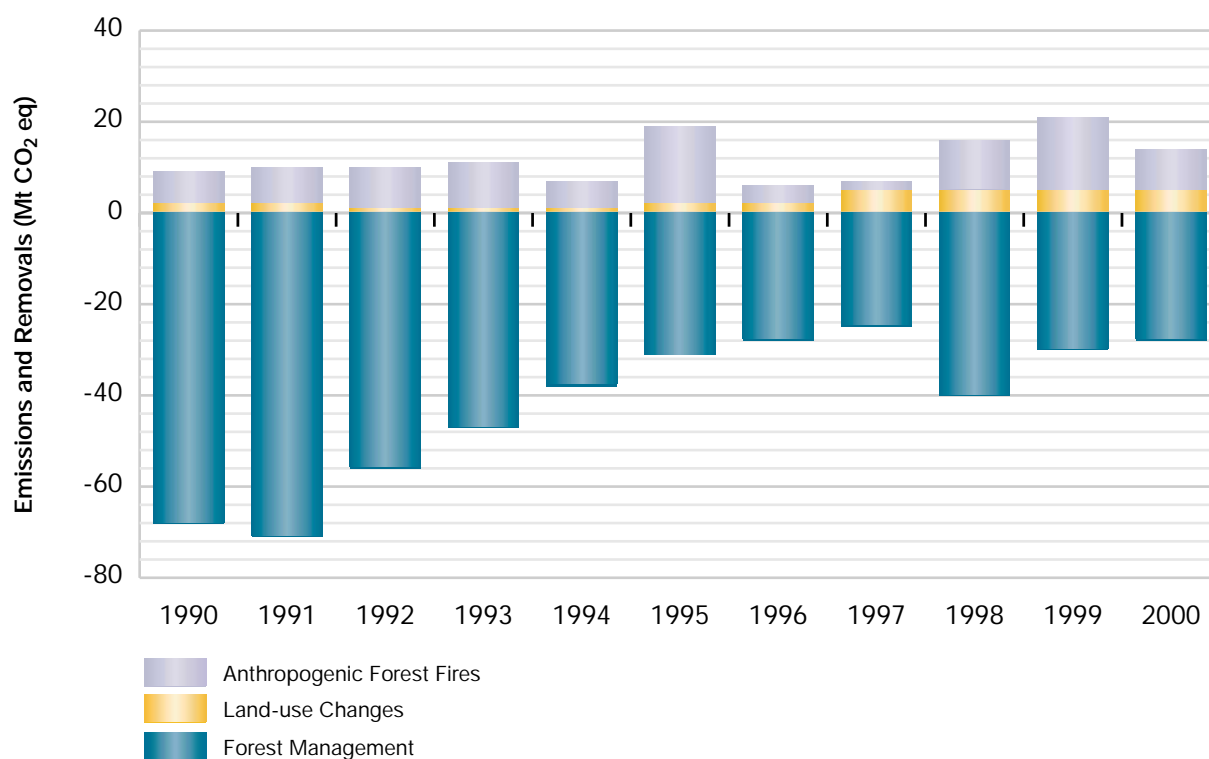
In 2000, the LUCF sector accounted for a net removal of 14 Mt CO<sub>2</sub> eq. The largest and most influential category on total greenhouse gas emissions and removals is Forest Management, with a net removal of nearly 30 Mt CO<sub>2</sub> (Table 1). However, carbon dioxide from the LUCF sector is not included in the national inventory totals; hence, the only contribution by the LUCF sector to these totals are emissions of approximately 2 Mt CO<sub>2</sub> eq arising from anthropogenic forest fires.

### 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<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O), sulphur hexafluoride (SF<sub>6</sub>), perfluorocarbons (PFCs), and hydrofluorocarbons (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 2000 Trends Fact Sheet Series, while presenting the latest information on Canadian greenhouse gas emissions and removals derived from the latest national inventory, uses a modified sector approach to facilitate the use of information by the public.

**Figure 2** LUCF Sector Emissions and Removals by Category, 1990 to 2000

## LUCF Sector Emissions and Removals Trends: 1990 to 2000

Over the decade, Forest Management has remained the dominant LUCF category. It generally represents at least 87% of all carbon dioxide removals in the LUCF sector and displays a trend similar to the overall sector trend, with sinks declining by 59% between 1990 and 2000.

### Forest Management

#### Which forest?

The LUCF inventory estimates carbon dioxide emissions and removals in the "managed" part of the forests, thus excluding forests not managed 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 Forest Inventory Publications). The Wood Production

Forest extends over 133 million hectares (133 Mha), distributed unevenly throughout Canada.

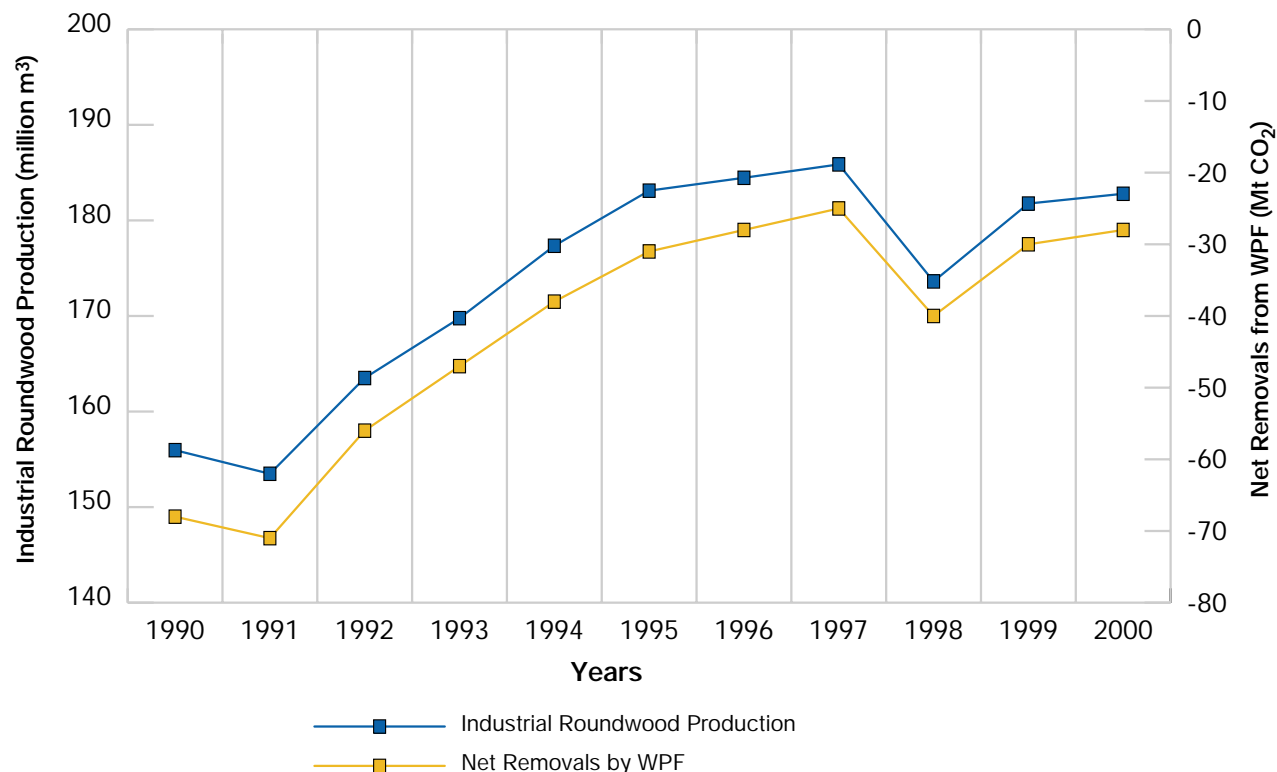
#### Carbon fluxes in and out of the forest

The LUCF inventory estimates net carbon dioxide fluxes in and out of 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"*.

Since it is assumed that the areal extent of the 'growing' forests and their average growth rates are stable over the 1990 to 2000 period, trends in carbon emissions and removals largely result

Figure 3

Trends in Industrial Roundwood Production and Carbon Dioxide Removals by the Wood Production Forest, 1990 to 2000



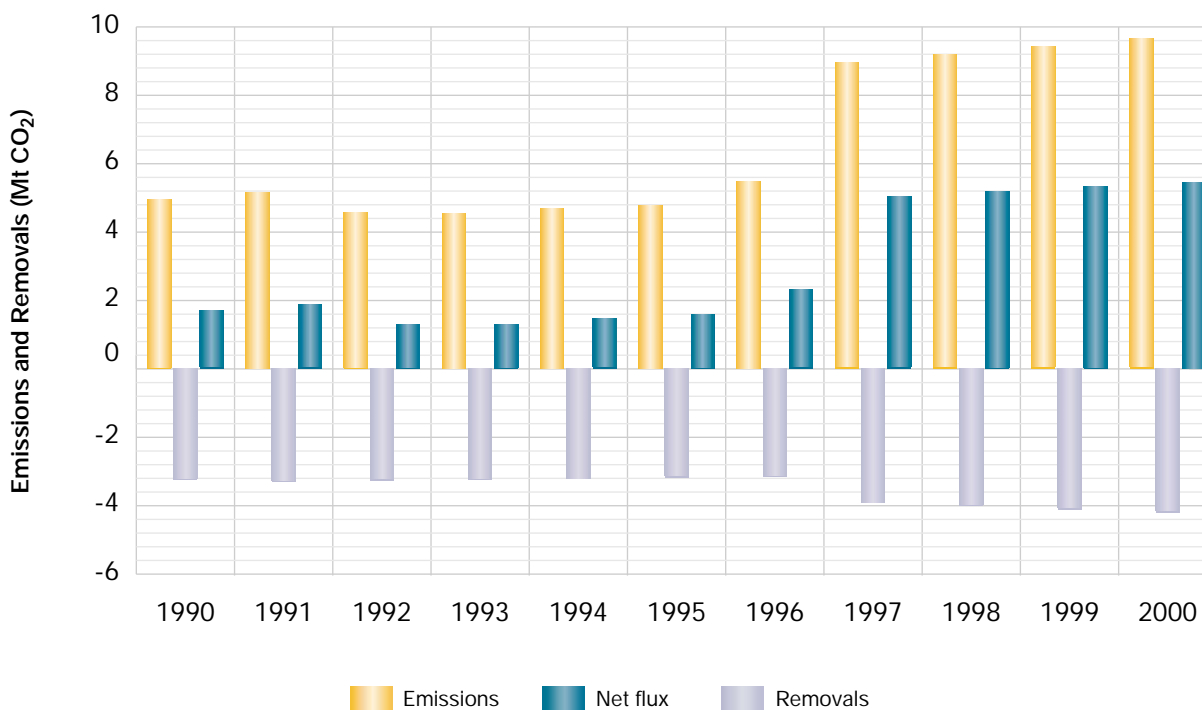
### Carbon Accounting of Harvested Wood Products

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). The IPCC default approach currently requires that all the carbon in the wood harvested from forests is considered to be emitted to the atmosphere in the year of harvest; hence, it does not 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 2000, depending on the approach selected, harvest emissions vary from 261 Mt CO<sub>2</sub> (current default method) to as low as 169 Mt CO<sub>2</sub>. Different accounting for carbon in exported wood products explains a large part of the variability in harvest emissions.

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 poorly known, yet potentially vast carbon depository.

**Figure 4** Trends in Carbon Dioxide Emissions and Removals Related to Land-use Changes in Canada, 1990 to 2000



from the levels of harvesting activities. In 1990, the net CO<sub>2</sub> removal in the LUCF sector totalled 61 Mt, while in 2000, the removal was only 16 Mt. Overall, the large decline in greenhouse gas removals in this sector over the decade is mirrored by a 18% increase in industrial roundwood production (Figure 3).

In 2000, the net flux associated with land-use changes in Canada resulted in emissions of over 5 Mt CO<sub>2</sub>. These emissions have more than doubled between 1990 and 2000 (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 are assumed to revert back 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 they can last longer when residues or soil organic matter decompose gradually. 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

Canada's LUCF inventory only reports greenhouse gas emissions from fires caused by humans (also called "*anthropogenic*" fires). These emissions consist of carbon dioxide released from fires outside of the Wood Production Forest, as well as non-carbon dioxide emissions from all human-induced fires, regardless of location. Carbon dioxide emissions associated with fires inside the Wood Production Forest were discussed in the section on Forest Management. The non-carbon dioxide gases are methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O), nitrogen oxides (NO<sub>x</sub>), and carbon monoxide (CO).

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 2000, annual emissions of greenhouse gases resulting from anthropogenic forest fires fluctuated between 2 and 17 Mt. The estimated area burned for 2000 is the average of the ten previous years, 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).

## 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 1999 estimates to a selection of key parameters and data inputs.

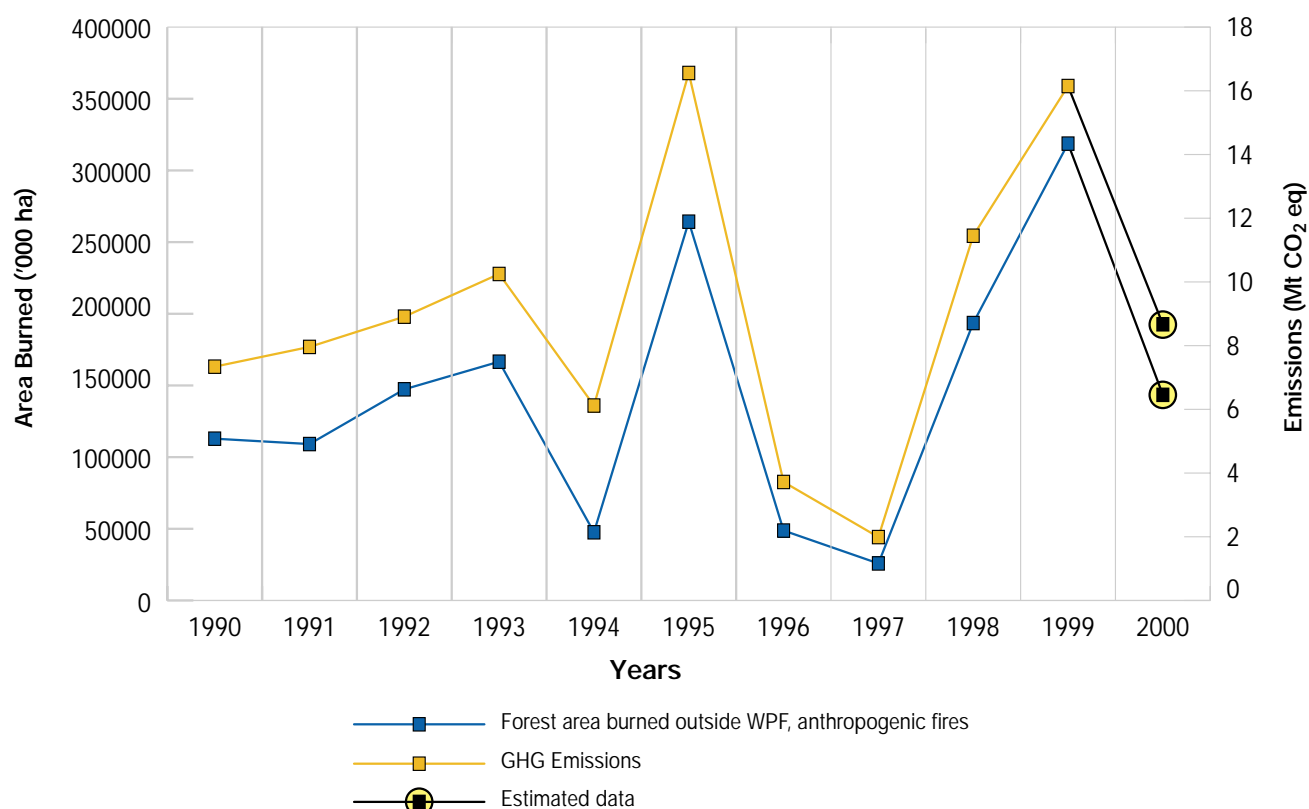
Parameters that were modified in the course of the analysis were:

- 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 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

Figure 5

Forest Area Burned and Total Greenhouse Gas Emissions from Anthropogenic Forest Fires, 1990 to 2000





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 that 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 occurs within one hundred years.

Greenhouse gas accounting in Canada's LUCF sector is a complex and challenging task, due to the large land area, the myriad of human activities involved, and the intricate ways in which human activities and natural processes interact with each other. The inventory of greenhouse gas emissions and removals is an evolving process; in the coming years it will continue to strive for improved accuracy, completeness and transparency.

### The Kyoto Protocol: Integrated LULUCF Reporting

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, cropland 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 under the collective heading of 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 reporting requirements.

## Data Sources:

1. Canadian Forest Inventory Publications  
[http://www.pfc.cfs.nrcan.gc.ca/monitoring/inventory/canfi/pubs\\_e.html](http://www.pfc.cfs.nrcan.gc.ca/monitoring/inventory/canfi/pubs_e.html)
2. National Forestry Database maintained by the Canadian Council of Forest Ministers  
[http://nfdp.ccfm.org/frames2\\_e.htm](http://nfdp.ccfm.org/frames2_e.htm)
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 1990-2000*, June 2002.

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.

**Anthropogenic Forest Fires:** forest fires caused by human activities, both intentional and accidental (also includes prescribed burning).

**Biomass:** the mass of living 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<sub>2</sub> equivalent:** the amount of CO<sub>2</sub> that would cause the same atmospheric 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<sub>2</sub>O), carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O) and ozone (O<sub>3</sub>) 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 the living tissues of plants and animals 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".

**Source:** 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, woodchips, etc).

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