Environment and Climate Change Canada
Environnement et Changement climatique Canada

LAND-BASED GREENHOUSE GAS EMISSIONS AND REMOVALS

CANADIAN ENVIRONMENTAL SUSTAINABILITY INDICATORS

Canada

Suggested citation for this document: Environment and Climate Change Canada (2022) Canadian Environmental Sustainability Indicators: Land-based greenhouse gas emissions and removals. Consulted on *Month day, year*.
Available at: www.canada.ca/en/environment-climate-change/services/environmental-indicators/land-based-greenhouse-gas-emissions-removals.html.

Cat. No.: En4-144/93-2022E-PDF
ISBN: 978-0-660-45445-0
Project Code: EC22011

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Aussi disponible en français

CANADIAN ENVIRONMENTAL SUSTAINABILITY INDICATORS

LAND-BASED GREENHOUSE GAS EMISSIONS AND REMOVALS

September 2022

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Land-based greenhouse gas emissions and removals

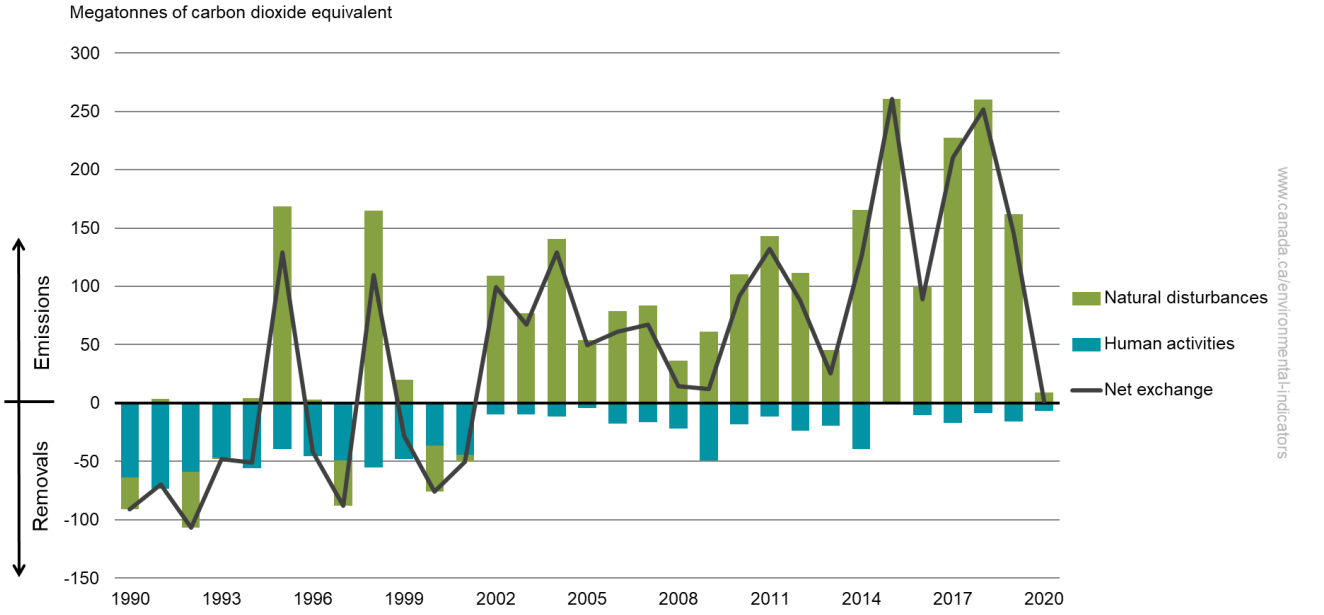
Greenhouse gas (GHG) emissions are the major drivers of climate change. Land use activities (such as timber harvesting and land conversion) as well as natural disturbances (such as forest fires and insect infestations) result in GHG emissions. Land use activities can also result in GHG removals. For example, as forests recover, carbon is removed from the atmosphere and converted into wood by trees. Tracking the trends in Canada's land-based GHG emissions and removals can help us understand how land management decisions could reduce emissions and increase removals over time.

The indicator provides annual estimates of Canada's GHG emissions and removals from managed lands. These are lands influenced by human intervention to perform production, ecological or social functions. Examples include agricultural land, wetlands, settlements, and managed forests.

Key results

- In 2020,
  - natural disturbances (such as wildfires and insect infestations) accounted for emissions of about 8.8 megatonnes of carbon dioxide equivalent (Mt CO_2 eq)
  - human activities (such as timber harvesting and agricultural activities) accounted for removals of 6.3 Mt CO_2 eq
- Between 1990 to 2001, estimates of land-based GHG were net removals in all years with the exception of 1995 (emissions of 130 Mt CO_2 eq) and 1998 (emissions of 110 Mt CO_2 eq)
- Since 2002, the net exchange has consistently resulted in emissions, ranging between 2.5 Mt CO_2 eq (2020) and 260 Mt CO_2 eq (2015)

Figure 1. National land-based greenhouse gas emissions and removals, Canada, 1990 to 2020



Data for Figure 1

Note: Natural disturbances refer to emissions and removals related to wildfires and large forest insect infestations. Human activities refer to emissions and removals from managed lands (such as settlements, forested lands, agricultural land and wetlands) as well as emissions from harvested wood products. For more information, see the section on emissions and removals from human activities.
Source: Environment and Climate Change Canada (2022) National Inventory Report 1990-2020: Greenhouse gas sources and sinks in Canada.

Natural disturbances such as forest fires and large insect infestations have occurred in Canada's forests for thousands of years. These disturbances are part of the natural life cycle of the forest and generally help the forest renew itself. However, there is evidence that climate change is driving an increase in natural disturbances. These disturbances can contribute to the release of large amounts of GHGs into the atmosphere through the burning

and decay of dead trees, as well as significant removals as the forest regenerates over time.[1] For the past 20 years, the total net GHG exchange (that is, the land-based GHG emissions minus removals) has been significantly impacted by these natural disturbances.

There was a shift in the net exchange in 2002 where it shifted from removals in prior years to emissions. This, in part, is due to an increase in emissions from natural disturbances, and a decline in removals from human activities.

In managed forests, emissions and removals due to natural disturbances such as forest fires or insect infestations are associated with human activities under specific circumstances. These circumstances are described in the methods section.

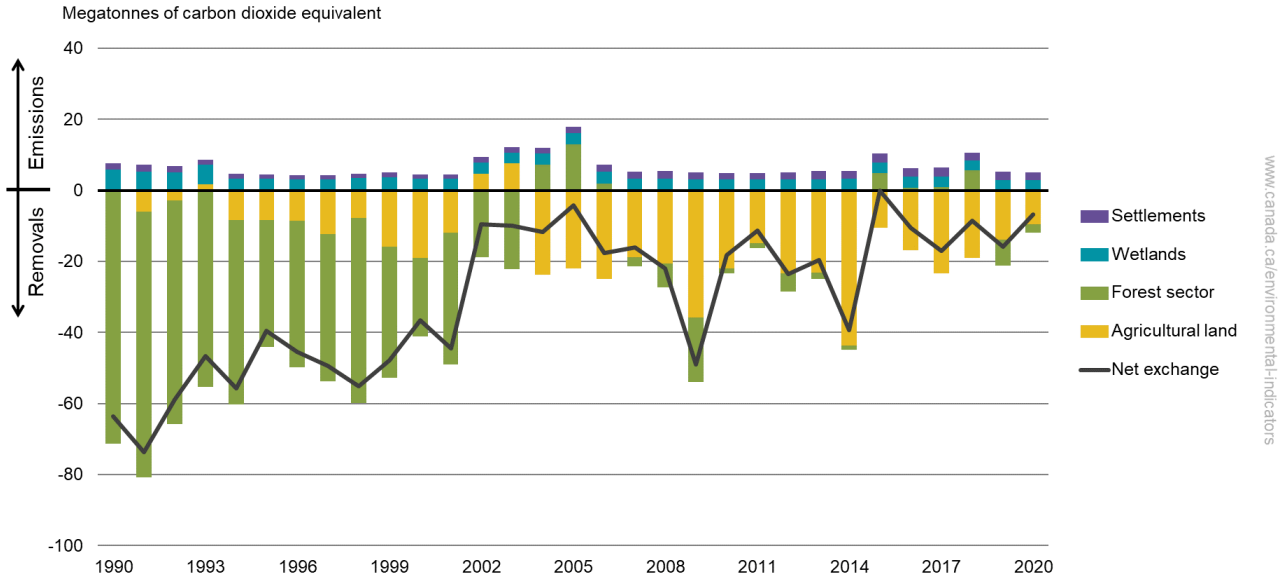
Land-based GHG emissions and removals from human activities

Land-based GHG emissions and removals from human activities are commonly referred to as land use, land-use change and forestry (LULUCF) according to international standards.

Key results

- In 2020,
  - Wetlands and settlements emitted 2.9 and 2.3 megatonnes of carbon dioxide equivalent (Mt CO_2 eq), respectively
  - Agricultural land and forested land removed 9.5 and 2.0 Mt CO_2 eq, respectively
- Between 1990 and 2020, human activities on managed land resulted in net removals. It has declined over time, from 63 Mt CO_2 eq in 1990 to 6.3 Mt CO_2 eq in 2020
- Prior to 2003, the activity sector that contributed the most to GHG removals was the forest sector. After 2003, this shifted to the agricultural sector

Figure 2. Land-based greenhouse gas emissions and removals from human activities by activity sector, Canada, 1990 to 2020



Data for Figure 2

Note: Greenhouse gas exchange from the forest sector considers emissions and removals from managed forests and all harvested wood products. Harvested wood products originate from forest trees, urban trees and agricultural land. As such, the reported forest sector emissions

[1] Warren FJ and Lemmen DS, editors (2014) Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation. Government of Canada, Ottawa, ON, 286p. Retrieved May 13, 2022.

may differ from the National Inventory Report. For more information, see Chapter 6.4 of the National Inventory Report.
Source: Environment and Climate Change Canada (2022) National Inventory Report 1990-2020: Greenhouse gas sources and sinks in Canada.

Forest sector

In 2020, removals from the atmosphere through forests, and emissions to the atmosphere from harvested wood products were close to equal, having an estimated net removal of 2.0 Mt CO_2 eq.

GHG contributions from the forest sector have varied over the period from 1990 to 2020, ranging from removals of 74 Mt CO_2 eq (1991) to emissions of 14 Mt CO_2 eq (2005). This change is related to reduced carbon sequestration in forests due to natural disturbances (such as forest fires and insect infestations) and changes in harvest rates over time, in particular in the Mountain and Boreal regions. Natural disturbances increase GHG emissions through the decomposition of affected trees, and reduce the areas of mature growing trees that are removing carbon. Like harvesting, they can also cause a shift in forest age to younger forests that are either emitting carbon or removing less carbon than the mature forests that were harvested.

The forest sector category refers to emissions and removals from forest management activities such as timber harvesting, thinning and replanting, and ecological processes such as tree growth and decomposition. It also includes emissions from harvested wood products, which are the wood materials removed from the harvested site and turned into consumer products, such as timber for construction, furniture or paper products. Harvested wood products are not limited to wood harvested from forests, and include those harvested from agricultural land and land conversion. The carbon removed from the atmosphere by trees is stored in the harvested wood products and tracked over the lifespan of the consumer products. The carbon is emitted back into the atmosphere at the end of the products' useful life.

Agricultural land

Agricultural land has typically contributed to GHG removals, and has consistently done so since 2004. Removals by agricultural land has ranged between 2.6 Mt CO_2 eq (1992) to 43 Mt CO_2 eq (2014). This is due to changes in agricultural practices, such as the adoption of conservation tillage,[2] increases in crop yield, and the reduced use of summerfallow. However, the removal rate from agricultural land has been decreasing in recent years due to a decline in the adoption rate of conservation tillage and in the area of land used to grow perennial crops, and increases in the conversion of forested land and grassland to agricultural land.

The agricultural land category reports emissions and removals from annual and perennial cropland, as well as from forest lands and grassland converted to cropland. Cropland includes lands in annual crops, summerfallow and perennial crops. Managed agricultural grassland refers to rangeland that is used only for grazing domestic livestock.

Wetlands

Trends in this category are mainly driven by the creation of large reservoirs before 1990, resulting in higher emissions over the 1990 to 1993 period. Emissions from reservoirs have declined from 1990 to 2020, while emissions from drained and excavated wetlands for peat extraction have increased. Overall, total emissions has declined during this time period from 5.5 Mt CO_2 eq (1993) to 2.9 Mt CO_2 eq (2020).

The wetlands category includes activities such as peat extraction for use in horticulture and land flooding to develop reservoirs for hydropower development.

Settlements

Total emissions for settlements fluctuated between 1.2 Mt CO_2 eq (1997) and 2.7 Mt CO_2 eq (2016). Emissions were mainly driven by rates of forested land converted to settlements, and are offset by the storage of carbon in urban trees (annual removals of about 4.3 Mt CO_2 eq).

The settlements category refers to emissions and removals occurring on developed lands (such as urban environments, transport infrastructure, oil and gas infrastructure and mining) and from land conversion of forests and agricultural land to settlements.

[2] The adoption of conservation tillage (examples include no till or minimum till practices) reduces soil disturbance and prevents the release of stable carbon that has built up in soils from past plant growth.

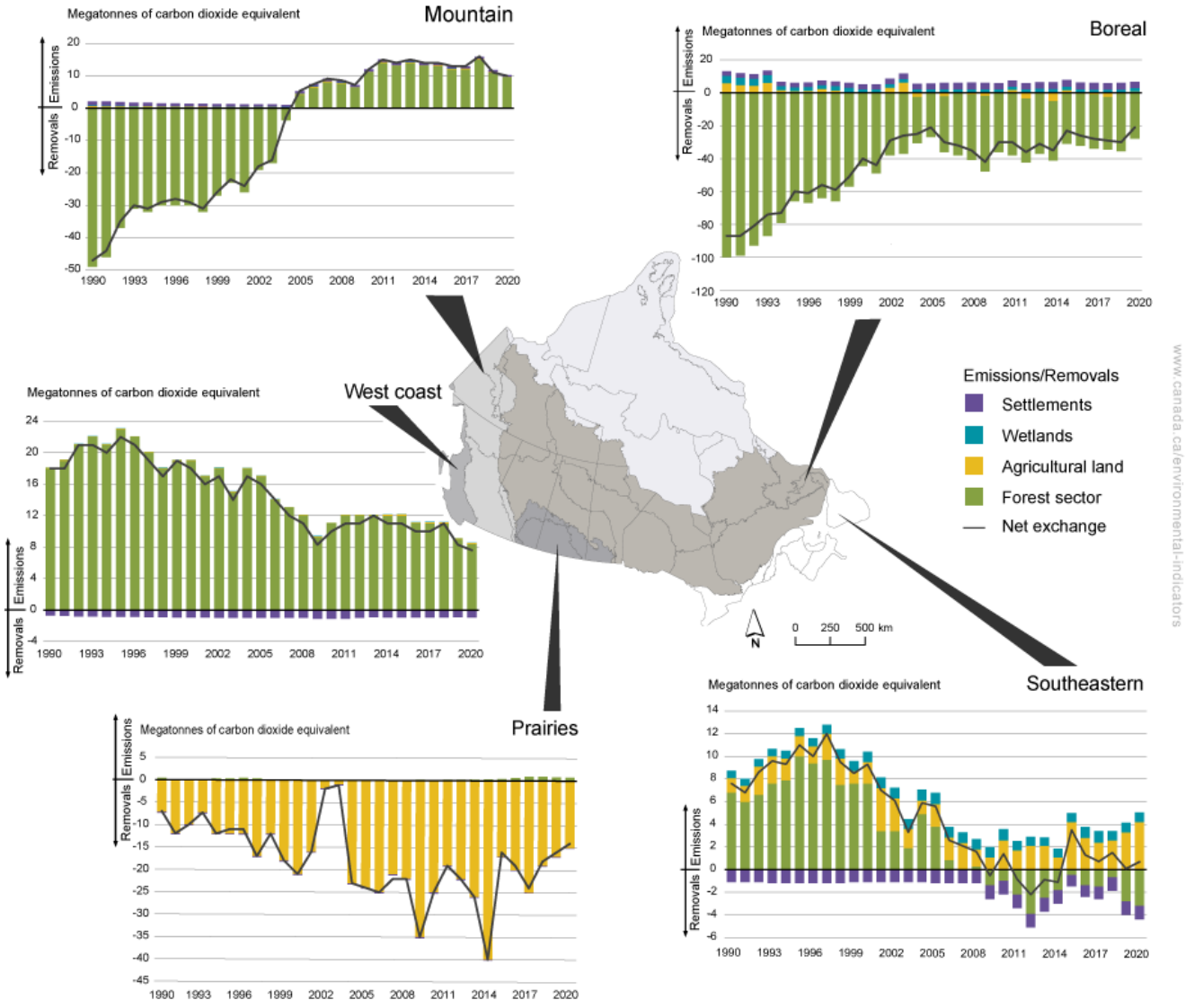
Regional land-based emissions and removals from human activities

Key results

From 1990 to 2020,

- The Boreal region and the Prairies contribute to GHG removals
  - Removals in the Boreal region decreased from 87 megatonnes of carbon dioxide equivalent (Mt CO_2 eq) to 21 Mt CO_2 eq
  - Removals in the Prairies increased from 7.0 Mt CO_2 eq to 14 Mt CO_2 eq
- The West Coast, Mountain and Southeastern regions contribute to GHG emissions
  - Emissions from the West Coast and the Southeastern regions decreased from 18 Mt CO_2 eq to 7.6 Mt CO_2 eq, and from 7.6 Mt CO_2 eq to 0.69 Mt CO_2 eq respectively
  - The Mountain region, which is important for forestry, went from removals of 47 Mt CO_2 eq to emissions of about 10 Mt CO_2 eq. This region has been contributing to emissions since 2005

Figure 3. Regional land-based greenhouse gas emissions and removals from human activities, Canada, 1990 to 2020



Data for Figure 3

Note: Regions are based on the location of the human activities across the country. Forest sector regional estimates provided do not include the long-term impact of emissions from forest harvest or deforestation prior to 1990.
Source: Environment and Climate Change Canada (2022) National Inventory Report 1990-2020: Greenhouse gas sources and sinks in Canada.

The overall increase in removals of GHGs on the Prairies can be attributed to changes in agricultural land management practices, such as the adoption of conservation tillage, the proportion of annual and perennial crops, and the reduced use of summerfallow. These changes in land management decrease soil disturbance and thereby lower releases of carbon from the soil. However, due to a decrease in the proportion of perennial crops in the crop mixture and in the adoption rate of conservation tillage, and an increase in crop residue, there has been a decline in the rate of GHG removals in recent years.

In the West Coast and Southeastern regions, forestry management practices (changes in harvest rates and forest regeneration) contributed to the reduction in emissions. However, in recent years, net GHG emissions have been increasing in the Southeastern region. Similar to the Prairies, this increase is in part due to shifts in agricultural land management practices.

The decrease in GHG removals in the Boreal region and the shift from removals to emissions in the Mountain region are related to increased forest harvesting (in part in an effort to salvage timber from trees killed by the Mountain Pine Beetle) as well as a reduction in net carbon removals from forests. The latter is due to insect infestations and fires in managed forests. The disturbances reduce the area of mature growing trees, and increase decomposition and salvage logging (the harvest of dead or dying standing trees). For more information, see the Forest sector in Land-based emissions and removals from human activities.

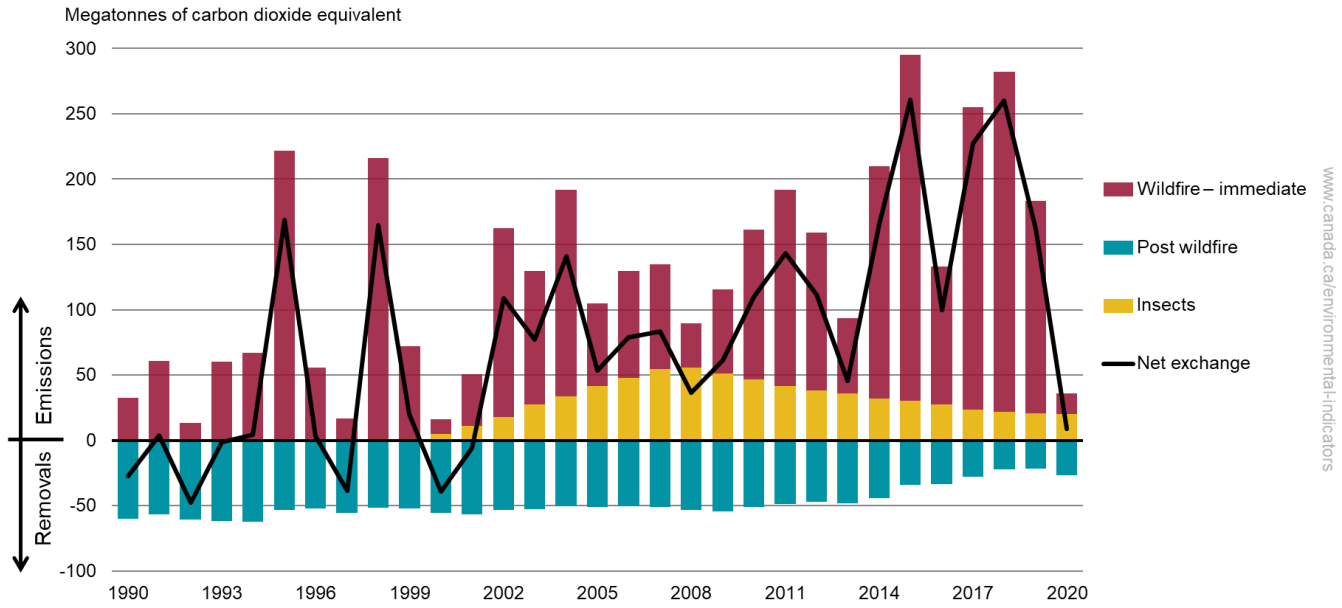
Land-based emissions and removals from natural disturbances

Forests remove carbon from the atmosphere as they grow and release it along with other GHGs when they decay after dying or burn in forest fires.

Key results

- In 2020,
  - Emissions from wildfires contributed 16 megatonnes of carbon dioxide equivalent (Mt CO_2 eq)
  - Emissions caused by insect infestations were 20 Mt CO_2 eq
  - Removals due to forest regrowth post wildfire were 27 Mt CO_2 eq
- Since 2002, wildfires had the largest influence on land-based emissions and removals from natural disturbances

Figure 4. Land-based greenhouse gas emissions and removals from natural disturbances in managed areas, Canada, 1990 to 2020



Data for Figure 4

Note: Wildfire emissions and removals are divided in 2 categories, (1) wildfire – immediate and (2) post wildfire. Wildfire – immediate includes emissions from trees and soils from the burning of wildfires. Post wildfire includes emissions released by the decay of dead trees and soil organic matter and removals related to forest regeneration. Insect disturbances include emissions from the decay of organic matter and removals from natural regeneration.
Source: Environment and Climate Change Canada (2022) National Inventory Report 1990-2020: Greenhouse gas sources and sinks in Canada.

Natural disturbances are an important factor in determining whether forests remove or release GHGs each year. These disturbances contribute to immediate emissions (for example, from the burning of trees), as well as post-disturbance emissions and removals. Post-disturbance emissions are from the gradual decay of dead organic matter. Post-disturbance removals are related to the natural regeneration and regrowth of forests.

The variability in emissions and releases from natural disturbances can vary greatly from year to year. For example, emissions from managed lands were lower in 2016 than in adjacent years because of the smaller area burned.[3] However, since the mid-2000s, emissions from wildfires and insect disturbances have generally been increasing. Severe insect infestations in the early 2000s are having an effect on today's net GHG exchange and are expected to influence GHG emissions over the next few decades.

[3] Natural Resources Canada (2022) The State of Canada's Forests 2021. Retrieved May 13, 2022.

About the indicator

What the indicator measures

The Land-based greenhouse gas emissions and removals indicator tracks exchanges of greenhouse gas (GHG) emissions and removals between the atmosphere and Canada's managed lands. Reported GHG emissions and removals are annual totals from:

- Land use and land-use change activities
    - Forest sector (managed forested land and harvested wood products)
    - Agricultural land (cropland and agricultural grassland)
    - Wetlands (peat extraction and reservoirs for hydropower)
    - Settlements (developed land and land conversion to settlement)
- Natural disturbances (insect infestations and wildfires)

The indicator does not report emissions from Canadian economic sectors: oil and gas, transport, buildings, electricity, heavy industry, agriculture (such as fuel use, and crop and animal production) and waste. For information on anthropogenic (human-made) GHG emissions, refer to the Greenhouse gas emissions indicator.

Why this indicator is important

GHG emissions and their increasing concentrations in the atmosphere are having significant impacts on the environment, human health and the economy. Tracking the trends in Canada’s land-based GHG emissions and removals provides a useful context for understanding how different management activities could reduce emissions and increase removals over time. This indicator could also help identify opportunities for mitigating the impacts of climate change and the potential for enhancing carbon sequestration.

The distinction between emissions and removals from human activities versus natural disturbances allows for a better understanding of emissions that could be directly managed in the near to medium term. The National Inventory Report has made this distinction since 2017 in the 2015 National Inventory Report.

Related indicators

The Greenhouse gas emissions indicators report trends in total anthropogenic (human-made) GHG emissions at the national level, per person and per unit gross domestic product, by province and territory and by economic sector.

The Global greenhouse gas emissions indicator provides a global perspective on Canada's share of global GHG emissions.

The Carbon dioxide emissions from a consumption perspective indicator shows the impact of Canada's consumption of goods and services, regardless of where they are produced, on the levels of carbon dioxide released into the atmosphere.

The Greenhouse gas emissions projections indicator provides an overview of Canada's projected GHG emissions up to 2030.

The Greenhouse gas emissions from large facilities indicator reports GHG emissions from the largest GHG emitters in Canada (industrial and other types of facilities).

The Greenhouse gas concentrations indicators present atmospheric concentrations as measured from sites in Canada and at a global scale for 2 greenhouse gases: carbon dioxide and methane.

Data sources and methods

Data sources

This indicator is developed using data from Canada's National Inventory Report and includes emissions and removals associated with natural disturbances and with land use, land-use change and forestry (LULUCF) activity on managed lands. Managed lands are defined by the Intergovernmental Panel on Climate Change (IPCC) as "land where human interventions and practices have been applied to perform production, ecological or social

functions."[4] Information on the land category definition and representation of managed lands is available in Chapter 6 of the National Inventory Report.

Land-based greenhouse gas (GHG) emissions and removals include emissions and removals of carbon dioxide (CO_2). It also includes emissions of methane (CH_4), nitrous oxide (N_2O), and indirect CO_2 from the atmospheric oxidation of carbon monoxide (CO) due to controlled biomass burning; CH_4 and N_2O emissions from wetland drainage and rewetting due to peat extraction; and N_2O released following land conversion to cropland.

More information

Data used to develop the land-based emission and removal estimates presented in the National Inventory Report are drawn from published and unpublished sources from various government departments, industry sources and scientific papers.

Land-based GHG emission estimates are provided at the national level, by sector and by region. Annual GHG emission estimates are updated each year; the most recent edition of the inventory reported estimates for the period from 1990 to 2020. Complete details of the temporal coverage for each data source used for the indicators can be found in Chapter 6 of the National Inventory Report.

Preparation of the GHG inventory, including the land-based emission and removal estimates, takes almost 16 months from the end of the reporting year because of the time needed to collect, validate, calculate and interpret the data. In keeping with good practice guidance for managing national inventories, methods and data are improved on an on-going basis to reflect new knowledge and improved data or methods. Inventory estimates are prepared by Environment and Climate Change Canada's Pollutant Inventories and Reporting Division with input from numerous experts and scientists across Canada. Preliminary estimates and draft text are reviewed extensively by experts and officials, before they are finalized. The final report is submitted electronically to the United Nations Framework Convention on Climate Change (UNFCCC) no later than mid-April, as required.

Methods

Land-based GHG emissions and removals are quantified using methods that are consistent with an internationally agreed methodological framework set out in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The methodologies used to estimate emissions and removals are reviewed, updated and improved on a periodic basis. Collaborative work with sector experts from within and outside Environment and Climate Change Canada is undertaken to incorporate available expertise and the latest advancements in scientific knowledge. Further information on these methods is available through Environment and Climate Change Canada's National Inventory Report.

More information

Land-based GHG emissions and removals are reported in carbon dioxide equivalents (CO_2 eq), determined by multiplying the amount of emissions of a particular GHG by the global warming potential of that gas. GHGs differ in their ability to absorb heat in the atmosphere due to their differing chemical properties and atmospheric lifetimes. For example, over a period of 100 years, the potential of methane to trap heat in the atmosphere is 25 times greater than that of carbon dioxide. Therefore, methane is considered to have a global warming potential of 25. The UNFCCC Reporting Guidelines (PDF; 258 KB) publish the global warming potentials and atmospheric lifetimes to be used for each GHG reported in national GHG inventories; these can be found in Table 1-1 of the National Inventory Report.

Areas within managed forests are subject to both forest management and natural disturbances. Emissions and removals from these areas are associated with human activities under specific circumstances. All stands harvested or that have been affected by stand-replacing natural disturbances in the past but have reached commercial maturity, or a minimum operable age (for a given region) are recognized to be under human influence. Commercially mature stands subject to natural disturbances causing less than or equal to 20% biomass mortality (for example some insects that cause defoliation but

[4] Intergovernmental Panel on Climate Change (2006) 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Vol. 4: Agriculture, Forestry and Other Land Use. Retrieved May 13, 2022.

low mortality) remain associated with human activities. Large, uncontrollable natural disturbances (for example wildfires or insect outbreaks causing more than 20% biomass mortality) are recognized to result from natural occurrences and the associated emissions and removals are reflected in the natural disturbance category. See Part II Annex 3 of the National Inventory Report for more information on the tracking and reporting of natural disturbances.[5]

Spatial aggregation

Estimates for the land use, land-use change and forestry (LULUCF) sector in the National Inventory Report are provided for 18 reporting zones (Chapter 6, Figure 6-1 Canada's National Inventory Report). These reporting zones are similar to the ecozones of the National Ecological Framework, a hierarchical, spatially consistent national ecosystem classification.

In this indicator, the reporting zones were grouped into regional categories that better reflect trends in management practices. Table 1 shows the indicator regional categories and the corresponding National Inventory Report reporting zones.

Table 1. Indicator regional categories and National Inventory Report reporting zones

Indicator regional categories	National Inventory Report reporting zones
Mountain	Taiga Cordillera
	Boreal Cordillera
	Montane Cordillera
Boreal	Taiga Plains
	Taiga Shield West
	Boreal Plains
	Boreal Shield West
	Hudson Plains
	Boreal Shield East (excluding Newfoundland)
	Taiga Shield East
West Coast	Pacific Maritime
Prairies	Subhumid Prairies
	Semiarid Prairies
Southeastern	Boreal Shield East (Newfoundland)
	Atlantic Maritime
	Mixedwood Plains
Not reported	Arctic Cordillera
	Northern Arctic
	Southern Arctic

Land-based greenhouse gas emissions and removals by land use categories

In this indicator, calculated emissions and removals data from the National Inventory Report are grouped into 4 broad classes. Table 2 shows the categories of Land-based GHG emissions and removals reported in the indicator compared with those reported in the National Inventory Report.

[5] Kurz et al. (2018) Quantifying the impacts of human activities on reported greenhouse gas emissions and removals in Canada's managed forest: conceptual framework and implementation. Canadian Journal of Forest Research 48: 1-14. Retrieved May 13, 2022.

Table 2. Land-based emissions and removals categories

Land-based emissions and removals categories reported in the indicator	Land-based emissions and removals categories reported in the National Inventory Report
Forest sector	Forest land
	Harvested wood products (HWP)
Agricultural land	Cropland
	Agricultural grassland
Wetlands	Peat extraction and flooded lands
Settlements	Settlements

Note: Definitions for land-use change and forest land as reported in the National Inventory Report are consistent with the International Panel on Climate Change land categories. Harvested wood product includes those that originate from forest trees, urban trees or agricultural land.

Recent changes

Improvements were made to the methods used to calculate the emissions and removals from agricultural land and as such, reported emissions this year may vary from past publications. For example, the changes now track carbon inputs from crop residues and the use of manure. Refer to Table 6-3 of the National Inventory Report for more information.

Caveats and limitations

The methodologies for compiling land-based GHG emissions and removals improve over time. As a result, the land-based emissions and removals data reported in the indicator may be different from previously published estimates.

Harvested wood products are not limited to those that originate from forests and include those from urban trees and agricultural land. As such, the reported emissions from the forest sector may differ from the National Inventory Report. For more information, see Chapter 6.4 of the National Inventory Report.

Canada is a vast country with heterogeneous landscapes and climates. Factors such as geographic location, climatic conditions, plant species and age, and management activities all play a role in influencing the net amount of GHG that is removed or released back to the atmosphere from each location in Canada. The land-based emissions and removals data provide a simplified representation of the complex reality and may not account for all relevant ecological processes.

Current reporting of land-based emissions and removals does not account for climate feedback other than what is captured through natural disturbances such as wildfires and insect infestations. Climate feedback mechanisms can either amplify (positive feedback) or diminish (negative feedback) the effects of a changing climate. For example, as rising concentrations of GHGs warm Earth's climate, permafrost begins to melt. This melting releases the organic carbon stored, contributing to GHG releases that cause more warming, which causes more melting, and so on, in a self reinforcing cycle.

For a complete discussion of the caveats and limitations with respect to land-based GHG emissions and removals data, refer to the methodological issues sections in Chapter 6 of Canada's National Inventory Report.

The latest year reported (2020) coincides with the 1st year of the COVID-19 pandemic. As the total impact of the pandemic is difficult to quantity, especially for the forest sector, long-term trends presented in the indicator must be interpreted with caution.

Resources

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Related information

Canada's Action on Climate Change

Climate Change

Greenhouse gas emissions: drivers and impacts

Land-based greenhouse gas emissions and removals infographic

Annex

Annex A. Data tables for the figures presented in this document

Table A.1. Data for Figure 1. National land-based greenhouse gas emissions and removals, Canada, 1990 to 2020

Year	Natural disturbances (megatonnes of carbon dioxide equivalent)	Human activities (megatonnes of carbon dioxide equivalent)	Net exchange (megatonnes of carbon dioxide equivalent)
1990	-27	-63	-90
1991	3.9	-73	-69
1992	-48	-58	-110
1993	-1.5	-45	-47
1994	4.5	-55	-50
1995	170	-38	130
1996	3.2	-44	-41
1997	-39	-48	-87
1998	160	-54	110
1999	20	-47	-27
2000	-39	-36	-75
2001	-5.9	-44	-50
2002	110	-8.6	100
2003	77	-9.1	68
2004	140	-11	130
2005	54	-3.3	50
2006	79	-17	62
2007	83	-15	68
2008	37	-21	15
2009	61	-48	13
2010	110	-18	92
2011	140	-11	130
2012	110	-23	89
2013	45	-19	26
2014	170	-39	130
2015	260	0.69	260
2016	99	-9.9	90
2017	230	-16	210
2018	260	-7.9	250
2019	160	-15	150
2020	8.8	-6.3	2.5

Note: Data are accurate to 2 significant figures in accordance with Part III Annex 8 of the National Inventory Report. Net exchange is calculated by subtracting removals from emissions. Natural disturbances refer to emissions and removals related to wildfires and large forest insect infestations. Human activities refer to emissions and removals from managed lands (such as settlements, forested lands, agricultural

land and wetlands) as well as emissions from harvested wood products. For more information, see the section on emissions and removals from human activities.
Source: Environment and Climate Change Canada (2022) National Inventory Report 1990-2020: Greenhouse gas sources and sinks in Canada.

Table A.2. Data for Figure 2. Land-based greenhouse gas emissions and removals from human activities by activity sector, Canada, 1990 to 2020

Year	Forest sector (megatonnes of carbon dioxide equivalent)	Agricultural land (megatonnes of carbon dioxide equivalent)	Wetlands (megatonnes of carbon dioxide equivalent)	Settlements (megatonnes of carbon dioxide equivalent)	Net exchange (megatonnes of carbon dioxide equivalent)
1990	-71	0.70	5.4	2.0	-63
1991	-74	-5.7	5.3	1.9	-73
1992	-62	-2.6	5.2	1.8	-58
1993	-54	1.9	5.5	1.6	-45
1994	-51	-8.2	3.3	1.4	-55
1995	-35	-8.3	3.2	1.3	-38
1996	-40	-8.4	3.1	1.3	-44
1997	-41	-12	3.2	1.2	-48
1998	-51	-7.6	3.5	1.4	-54
1999	-36	-16	3.7	1.5	-47
2000	-21	-19	3.2	1.4	-36
2001	-37	-12	3.2	1.4	-44
2002	-18	4.8	3.2	1.6	-8.6
2003	-22	7.7	3.1	1.6	-9.1
2004	7.8	-24	3.2	1.7	-11
2005	14	-22	3.1	1.8	-3.3
2006	2.6	-25	3.2	2.2	-17
2007	-2.0	-19	3.3	2.2	-15
2008	-6.3	-21	3.3	2.2	-21
2009	-18	-36	3.2	2.0	-48
2010	-0.7	-22	3.2	1.9	-18
2011	-0.8	-15	3.0	2.0	-11
2012	-4.8	-23	3.1	2.0	-23
2013	-1.2	-23	3.2	2.4	-19
2014	-0.94	-43	3.2	2.5	-39
2015	5.4	-10	3.0	2.7	0.69
2016	1.1	-17	3.1	2.7	-9.9
2017	1.2	-23	3.1	2.5	-16
2018	6.0	-19	2.8	2.3	-7.9
2019	-7.0	-14	2.9	2.4	-15
2020	-2.0	-9.5	2.9	2.3	-6.3

Note: Data are accurate to 2 significant figures in accordance with Part III Annex 8 of the National Inventory Report. Net exchange is calculated by subtracting removals from emissions. Greenhouse gas exchange from the forest sector considers emissions and removals from

forests and all harvested wood products. Harvested wood products originate from forest trees, urban trees and agricultural land. As such, the reported forest sector emissions may differ from the National Inventory Report. For more information, see Chapter 6.4 of the National Inventory Report.
Source: Environment and Climate Change Canada (2022) National Inventory Report 1990-2020: Greenhouse gas sources and sinks in Canada.

Table A.3. Data for Figure 3. Regional land-based greenhouse gas emissions and removals from human activities, Canada, 1990 to

Region	Year	Forest sector (megatonnes of carbon dioxide equivalent)	Agricultural land (megatonnes of carbon dioxide equivalent)	Wetlands (megatonnes of carbon dioxide equivalent)	Settlements (megatonnes of carbon dioxide equivalent)	Net exchange (megatonnes of carbon dioxide equivalent)
Mountain	1990	-49	0.65	0.21	1.2	-47
Mountain	1991	-46	0.61	0.19	1.3	-44
Mountain	1992	-37	0.61	0.18	1.1	-35
Mountain	1993	-31	0.55	0.17	1.0	-30
Mountain	1994	-32	0.58	0.11	0.99	-31
Mountain	1995	-30	0.48	0.11	0.94	-29
Mountain	1996	-30	0.46	0.10	0.88	-28
Mountain	1997	-30	0.46	0.10	0.86	-29
Mountain	1998	-32	0.44	0.091	0.86	-31
Mountain	1999	-27	0.37	0.086	0.83	-26
Mountain	2000	-23	0.39	0.081	0.80	-22
Mountain	2001	-26	0.38	0.077	0.75	-24
Mountain	2002	-19	0.37	0.073	0.72	-18
Mountain	2003	-17	0.40	0.070	0.70	-16
Mountain	2004	-3.8	0.28	0.066	0.67	-2.8
Mountain	2005	4.2	0.30	0.063	0.68	5.3
Mountain	2006	6.3	0.33	0.060	0.74	7.4
Mountain	2007	8.0	0.29	0.058	0.72	9.1
Mountain	2008	7.6	0.25	0.055	0.69	8.6
Mountain	2009	6.2	0.27	0.053	0.65	7.2
Mountain	2010	11	0.23	0.051	0.70	12
Mountain	2011	14	0.26	0.049	0.79	15
Mountain	2012	13	0.21	0.047	0.75	14
Mountain	2013	14	0.21	0.045	0.80	15
Mountain	2014	13	0.18	0.043	0.68	14
Mountain	2015	13	0.25	0.042	0.63	14
Mountain	2016	12	0.22	0.040	0.64	13
Mountain	2017	12	0.24	0.039	0.64	13
Mountain	2018	15	0.22	0.038	0.58	16
Mountain	2019	11	0.17	0.036	0.55	11
Mountain	2020	9.4	0.22	0.035	0.55	10

Region	Year	Forest sector (megatonnes of carbon dioxide equivalent)	Agricultural land (megatonnes of carbon dioxide equivalent)	Wetlands (megatonnes of carbon dioxide equivalent)	Settlements (megatonnes of carbon dioxide equivalent)	Net exchange (megatonnes of carbon dioxide equivalent)
Boreal	1990	-100	5.8	4.6	2.7	-87
Boreal	1991	-99	4.7	4.5	2.7	-87
Boreal	1992	-93	4.3	4.3	2.7	-81
Boreal	1993	-87	6.1	4.7	2.7	-74
Boreal	1994	-79	1.6	2.5	2.6	-73
Boreal	1995	-66	1.0	2.4	2.7	-60
Boreal	1996	-67	1.3	2.3	2.7	-61
Boreal	1997	-64	2.4	2.3	2.7	-56
Boreal	1998	-66	1.5	2.6	2.8	-59
Boreal	1999	-57	0.55	2.7	2.9	-51
Boreal	2000	-44	-0.56	2.2	2.9	-40
Boreal	2001	-49	0.059	2.2	2.9	-44
Boreal	2002	-38	3.1	2.2	3.3	-29
Boreal	2003	-37	6.3	2.1	3.3	-26
Boreal	2004	-28	-2.6	2.2	3.4	-25
Boreal	2005	-27	0.033	2.1	3.5	-21
Boreal	2006	-34	-2.1	2.2	3.8	-30
Boreal	2007	-38	0.0056	2.2	3.9	-32
Boreal	2008	-40	-0.86	2.3	4.0	-35
Boreal	2009	-46	-1.9	2.2	3.8	-42
Boreal	2010	-36	-0.064	2.1	3.7	-30
Boreal	2011	-38	1.7	2.1	3.7	-30
Boreal	2012	-39	-3.4	2.2	3.7	-36
Boreal	2013	-37	0.21	2.4	3.9	-31
Boreal	2014	-36	-5.1	2.4	4.1	-35
Boreal	2015	-31	1.6	2.2	4.1	-23
Boreal	2016	-32	-0.24	2.1	4.1	-26
Boreal	2017	-33	-0.88	2.0	4.1	-28
Boreal	2018	-32	-2.6	1.9	3.9	-29
Boreal	2019	-35	-0.56	2.0	4.0	-30
Boreal	2020	-28	0.89	2.0	3.9	-21
West coast	1990	18	0.11	0.014	-0.69	18
West coast	1991	19	0.12	0.014	-0.75	18
West coast	1992	21	0.11	0.014	-0.81	21
West coast	1993	22	0.094	0.014	-0.82	21
West coast	1994	21	0.11	0.014	-0.86	20
West coast	1995	23	0.10	0.014	-0.89	22

Region	Year	Forest sector (megatonnes of carbon dioxide equivalent)	Agricultural land (megatonnes of carbon dioxide equivalent)	Wetlands (megatonnes of carbon dioxide equivalent)	Settlements (megatonnes of carbon dioxide equivalent)	Net exchange (megatonnes of carbon dioxide equivalent)
West coast	1996	22	0.08	0.014	-0.89	21
West coast	1997	20	0.12	0.014	-0.93	19
West coast	1998	18	0.090	0.014	-0.93	17
West coast	1999	19	0.090	0.014	-0.94	19
West coast	2000	19	0.092	0.014	-0.96	18
West coast	2001	17	0.089	0.014	-0.94	16
West coast	2002	18	0.10	0.014	-1.0	17
West coast	2003	15	0.091	0.014	-1.0	14
West coast	2004	18	0.083	0.014	-1.0	17
West coast	2005	17	0.090	0.014	-1.0	16
West coast	2006	14	0.091	0.014	-1.0	14
West coast	2007	13	0.10	0.014	-1.0	12
West coast	2008	12	0.10	0.014	-1.0	11
West coast	2009	9.3	0.092	0.014	-1.1	8.3
West coast	2010	11	0.086	0.014	-1.1	10
West coast	2011	12	0.10	0.014	-1.1	11
West coast	2012	12	0.10	0.014	-1.0	11
West coast	2013	12	0.12	0.014	-0.91	12
West coast	2014	12	0.15	0.014	-0.96	11
West coast	2015	12	0.19	0.014	-0.96	11
West coast	2016	11	0.15	0.014	-0.97	10
West coast	2017	11	0.18	0.015	-0.94	10
West coast	2018	11	0.17	0.015	-0.97	11
West coast	2019	9.00	0.13	0.014	-0.91	8.3
West coast	2020	8.40	0.16	0.014	-0.94	7.6
Prairies	1990	0.39	-7.2	0.00	-0.18	-7.0
Prairies	1991	0.17	-12	0.00	-0.18	-12
Prairies	1992	0.13	-10	0.00	-0.18	-10
Prairies	1993	0.21	-7.3	0.00	-0.19	-7.3
Prairies	1994	0.30	-12	0.00	-0.19	-12
Prairies	1995	0.34	-12	0.00	-0.19	-11
Prairies	1996	0.46	-12	0.00	-0.19	-11
Prairies	1997	0.35	-17	0.00	-0.19	-17
Prairies	1998	0.12	-12	0.00	-0.20	-12
Prairies	1999	0.15	-18	0.00	-0.20	-18
Prairies	2000	0.18	-21	0.00	-0.20	-21
Prairies	2001	-0.01	-16	0.00	-0.20	-16

Region	Year	Forest sector (megatonnes of carbon dioxide equivalent)	Agricultural land (megatonnes of carbon dioxide equivalent)	Wetlands (megatonnes of carbon dioxide equivalent)	Settlements (megatonnes of carbon dioxide equivalent)	Net exchange (megatonnes of carbon dioxide equivalent)
Prairies	2002	0.018	-1.8	0.00	-0.20	-1.9
Prairies	2003	-0.11	-0.80	0.00	-0.21	-1.1
Prairies	2004	0.03	-23	0.00	-0.21	-23
Prairies	2005	0.10	-24	0.00	-0.21	-24
Prairies	2006	0.10	-25	0.00	-0.21	-25
Prairies	2007	0.087	-21	0.00	-0.21	-22
Prairies	2008	0.15	-22	0.00	-0.22	-22
Prairies	2009	0.18	-35	0.00	-0.22	-35
Prairies	2010	0.15	-25	0.00	-0.22	-25
Prairies	2011	0.23	-19	0.00	-0.21	-19
Prairies	2012	0.22	-22	0.00	-0.20	-22
Prairies	2013	0.28	-26	0.00	-0.18	-26
Prairies	2014	0.35	-40	0.00	-0.15	-40
Prairies	2015	0.40	-17	0.00	-0.12	-16
Prairies	2016	0.61	-20	0.00	-0.12	-19
Prairies	2017	0.93	-25	0.00	-0.11	-24
Prairies	2018	0.97	-19	0.00	-0.10	-18
Prairies	2019	0.83	-17	0.00	-0.091	-16
Prairies	2020	0.80	-15	0.00	-0.084	-14
Southeastern	1990	6.8	1.3	0.64	-1.1	7.6
Southeastern	1991	6.0	1.4	0.64	-1.1	6.8
Southeastern	1992	6.6	2.5	0.65	-1.1	8.6
Southeastern	1993	7.6	2.4	0.66	-1.2	9.6
Southeastern	1994	7.9	1.9	0.69	-1.2	9.3
Southeastern	1995	10	1.8	0.70	-1.2	11
Southeastern	1996	9.4	1.5	0.70	-1.2	10
Southeastern	1997	9.7	2.3	0.79	-1.2	12
Southeastern	1998	7.5	2.3	0.83	-1.2	9.5
Southeastern	1999	7.6	1.1	0.89	-1.1	8.5
Southeastern	2000	7.6	1.9	0.90	-1.1	9.3
Southeastern	2001	3.4	3.8	0.93	-1.1	7.0
Southeastern	2002	3.4	2.9	0.94	-1.1	6.1
Southeastern	2003	1.9	1.7	0.87	-1.1	3.3
Southeastern	2004	4.9	1.2	0.97	-1.1	5.9
Southeastern	2005	3.8	2.0	0.98	-1.2	5.6
Southeastern	2006	0.84	2.0	0.93	-1.2	2.6
Southeastern	2007	0.052	2.3	0.93	-1.2	2.1

Region	Year	Forest sector (megatonnes of carbon dioxide equivalent)	Agricultural land (megatonnes of carbon dioxide equivalent)	Wetlands (megatonnes of carbon dioxide equivalent)	Settlements (megatonnes of carbon dioxide equivalent)	Net exchange (megatonnes of carbon dioxide equivalent)
Southeastern	2008	0.28	1.5	0.92	-1.2	1.6
Southeastern	2009	-1.4	1.1	0.90	-1.2	-0.53
Southeastern	2010	-1.0	2.6	0.98	-1.2	1.4
Southeastern	2011	-2.2	1.7	0.84	-1.2	-0.84
Southeastern	2012	-3.9	2.1	0.79	-1.2	-2.2
Southeastern	2013	-2.5	2.1	0.75	-1.2	-0.88
Southeastern	2014	-1.8	1.1	0.75	-1.2	-1.1
Southeastern	2015	-0.48	4.2	0.80	-1.0	3.5
Southeastern	2016	-1.4	2.8	0.98	-1.0	1.3
Southeastern	2017	-1.5	2.4	1.00	-1.1	0.73
Southeastern	2018	-0.67	2.6	0.82	-1.2	1.5
Southeastern	2019	-2.8	3.3	0.86	-1.2	0.093
Southeastern	2020	-3.2	4.2	0.85	-1.2	0.69

Note: Data are accurate to 2 significant figures in accordance with Part III Annex 8 of the National Inventory Report. Net exchange is calculated by subtracting removals from emissions. Regions are based on the location of the human activities across the country. Forest sector regional estimates provided do not include the long-term impact of emissions from forest harvest or deforestation prior to 1990.
Source: Environment and Climate Change Canada (2022) National Inventory Report 1990-2020: Greenhouse gas sources and sinks in Canada.

Table A.4. Data for Figure 4. Land-based greenhouse gas emissions and removals from natural disturbances in managed areas, Canada, 1990 to 2020

Year	Wildfire – immediate (megatonnes of carbon dioxide equivalent)	Post wildfire (megatonnes of carbon dioxide equivalent)	Insects (megatonnes of carbon dioxide equivalent)	Net exchange (megatonnes of carbon dioxide equivalent)
1990	32	-60	0.31	-27
1991	60	-57	0.41	3.9
1992	13	-61	0.40	-48
1993	60	-62	0.40	-1.5
1994	67	-63	0.44	4.5
1995	220	-53	0.51	170
1996	55	-52	0.52	3.2
1997	16	-56	0.51	-39
1998	220	-52	0.59	160
1999	71	-52	1.0	20
2000	11	-56	5.0	-39
2001	40	-57	11	-5.9
2002	140	-53	18	110
2003	100	-53	27	77
2004	160	-51	34	140

Year	Wildfire – immediate (megatonnes of carbon dioxide equivalent)	Post wildfire (megatonnes of carbon dioxide equivalent)	Insects (megatonnes of carbon dioxide equivalent)	Net exchange (megatonnes of carbon dioxide equivalent)
2005	64	-51	41	54
2006	82	-50	48	79
2007	80	-51	55	83
2008	34	-53	56	37
2009	65	-54	51	61
2010	110	-51	47	110
2011	150	-49	41	140
2012	120	-47	38	110
2013	58	-48	36	45
2014	180	-44	32	170
2015	260	-34	30	260
2016	110	-34	27	99
2017	230	-28	24	230
2018	260	-22	22	260
2019	160	-22	21	160
2020	16	-27	20	8.8

Note: Data are accurate to 2 significant figures in accordance with Part III Annex 8 of the National Inventory Report**.** Net exchange is calculated by subtracting removals from emissions. Wildfire emissions and removals are divided in 2 categories, (1) wildfire – immediate and (2) post wildfire. Wildfire – immediate includes emissions from trees and soils from the burning of wildfires. Post wildfire includes emissions released by the decay of dead trees and soil organic matter and removals related to forest regeneration. Insect disturbances include emissions from the decay of organic matter and removals from natural regeneration.
Source: Environment and Climate Change Canada (2022) National Inventory Report 1990-2020: Greenhouse gas sources and sinks in Canada.

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