



STUDY GUIDE 2025

**Roots and Resiliency:
Fostering Forest
Stewardship**



STUDY GUIDE 2025

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Acknowledgments

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MAPLE LEAVES FOREVER



2025 Ontario Envirothon

Roots and Resiliency: Fostering Forest Stewardship

Key Ideas and Learning Objectives

Key Ideas

1. Climate change projections
2. Forest health in a changing climate
3. Rights of indigenous people to land stewardship
4. Adaptation strategies for forest sustainability (assisted species migration, selective breeding, etc)
5. Legislation and regulations pertaining to forest management

Learning Objectives

After reading this guide, students should be able to...

1. Define and understand key terms such as sustainable forest management, climate change, natural disturbance, adaptation, mitigation, two-eyed seeing, succession, assisted migration, selective breeding, afforestation, and biodiversity.
2. Explain the impacts of climate change on forests
3. Explain how the climate might change in response to different levels of human activity, and how models are used to represent the potential future scenarios.
4. Describe how wildfire impacts the hydrology, wildlife, and soils of forest communities
5. Describe the conditions of drought as it relate to forest ecosystems, and identify how increasing drought severity and frequency impacts forests
6. Describe the impacts of native and non-native forest pests and how their prevalence and spread are expected to shift with climate change
7. Describe how land-based learning and traditional knowledge systems can contribute to improved land use, forest management, and mitigation strategies
8. Analyse the benefits and drawbacks of various climate change adaptation strategies for forests, including assisted species migration and selective breeding.
9. Distinguish how various ecozones face differing levels of vulnerability and explain which ecological factors drive this vulnerability
10. Describe how governments determine if forest harvesting levels will be sustainable in the future with climate change
11. Describe how forest certification can be used as a tool to manage forests sustainably in a changing climate.

What is Climate Change?

NOTE: Text is from the 2024 Current Issue Guide: Biodiversity in a Changing Climate

Climate change describes the long-term shifts in Earth's average weather conditions that is reflected by changes in temperature, humidity, wind, cloud cover, and precipitation (Environment and Climate Change Canada, 2019). While variability is a natural part of Earth's climate cycle (e.g. ice ages), the planet is currently experiencing an unprecedented, rapid increase in global temperature (Fig 1). The last eight years have been the eight hottest years ever recorded, with global average temperatures in 2022 being 1.15°C warmer than pre-industrial levels (World Meteorological Organization, 2023). According to Canada's Climate Change Report from 2019, Canada is warming at almost twice the global rate. From 1948-2019, average temperatures across Canada have increased by 1.7°C.

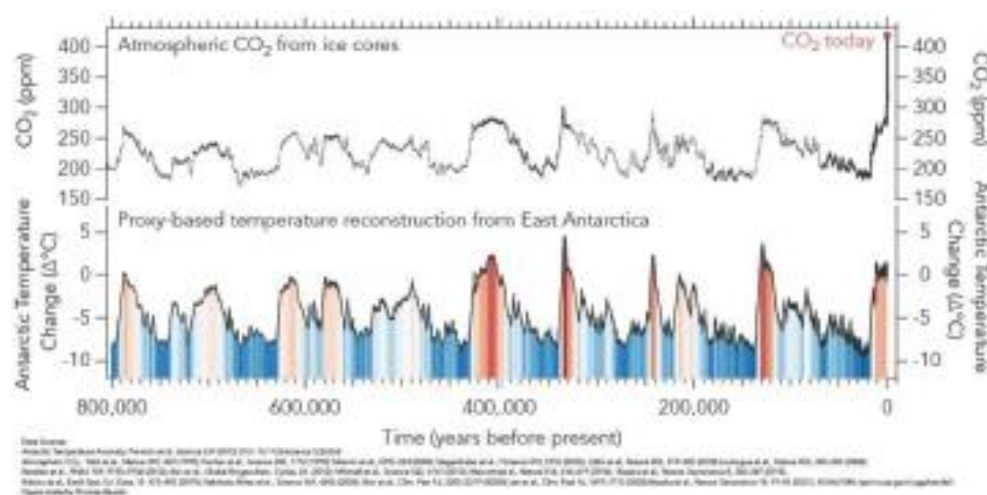


Figure 1 The earth's historic climate trends determined from ice core analysis. This graph shows the relationship between atmospheric CO₂ levels and average temperatures. It also depicts the rapid increase in CO₂ following the Industrial Revolution. Source: <https://www.bas.ac.uk/data/our-data/publication/ice-cores-and-climate-change/>

The vast majority of scientists agree that modern climate change is not a part of the natural climate cycle; it is being caused by human activity increasing the amount of greenhouse gases (GHGs) in our atmosphere. GHGs are long-lived molecules in the Earth's atmosphere that trap solar radiation from the sun and thus warmth. While the greenhouse effect is a natural and crucial part of Earth's atmosphere and climate system, humans have emitted significantly more GHGs than any natural system. More GHGs in the atmosphere means more solar radiation is being trapped close to Earth's surface, warming the planet (Fig 2; NASA, 2023b).

The main source of GHG emissions is the burning of fossil fuels, as a main byproduct of their combustion is CO₂. Carbon dioxide (CO₂) is the most abundant GHG. Deforestation and filling in wetlands to clear land for agriculture or development is diminishing the amount of carbon sinks able to store excess CO₂. Land conversion continues to increase as the human population grows and there is more demand for food and space to live (Environment and Climate Change Canada, 2019). In May 2013, atmospheric CO₂ levels reached the historic record high of 400ppm, a record that surpassed measurements from millions of years ago (Blunden, 2014). As of February 2023, the concentration of CO₂ in earth's atmosphere has risen to 419ppm (NASA, 2023a).



Figure 2. The natural greenhouse gas effect and how human activity is enhancing it. Source: <https://climatechange.lta.org/get-started/learn/co2-methane-greenhouse-effect/>

DID YOU KNOW? Researchers have pieced together ancient climate conditions from ice cores taken in Antarctica and Greenland (some can be 3km deep!). Air bubbles get trapped as snow accumulates to form ice sheets, and researchers analyze the bubbles in core samples to determine what the earth's atmosphere looked like as far back as 800,000 years ago (Bauska, 2022). This provides a baseline of the earth's climate to compare to current data.

Modelling Climate Change

The representative concentration pathways (RCPs) are a set of four scenarios developed by the International Panel on Climate Change to describe future climate conditions under different projections of GHG emissions and land use. Climate forcing scenarios are a method used by climate researchers to develop strategies for mitigation and adaptation. The current RCPs model climate conditions from 2013 to 2100. Having an industry standard tool like RCPs is useful because it makes research more comparable. The four RCP scenarios are:

- RCP2.6: high degree of greenhouse gas emission mitigation where radiative forcing peaks at 2.6W/m^2 (watts per square metre) before 2100 and then declines. This is the scenario with the least amount of climate forcing. Under this scenario, the amount of global warming is projected to be below 2°C . To meet this goal, humans will need to drastically reduce GHG emissions by about two gigatons of CO_2 per year before 2100.
- RCP4.5: intermediate levels of mitigation where radiative forcing stabilizes at 4.5W/m^2 after 2100.
- RCP6.0: intermediate levels of mitigation where radiative forcing stabilizes at 6.0W/m^2 after 2100.
- RCP8.5: “worst case scenario” with little to no mitigation efforts, where radiative forcing exceeds 8.5W/m^2 by 2100 and continues to rise. This is the scenario with the greatest amount of climate forcing.

For the purposes of this guide, most studies will refer to RCP 8.5, the “worst case scenario” with limited mitigation enacted in projections.

DISCUSSION QUESTIONS:

1. How do human activities like the burning of fossil fuels and deforestation contribute to climate change?
2. How does modern climate change differ from past variability in the Earth's climate cycle?
3. If greenhouse gas emissions continue to rise, how might your life be affected?
4. How can industry do more to reduce their contributions to climate change?

2.0 Forests and their health in a changing climate



Our forests are incredibly diverse, with many species living across a wide variety of ecosystems, across the three broad ecozones found in Ontario. While these ecosystems are dynamic and always changing, the risks of drought, floods, and warm weather as a consequence of a changing climate can lead to further impacts, such as a boom in insect population, both native and invasive, and a change in the fire regime.

In this section, we will look at Ontario and Canada's forests, the impacts of climate change on temperate forests, with a dive into insects.

Key terms: resiliency, invasive species, native species, diversity, natural disturbance, ecozones

Discussion Questions:

1. Compare and contrast how high and low intensity fires impact forests and wildlife.
 - a. What are the benefits of fire?
 - b. What are the negative impacts of fire?
 - c. Which type for fire is likely to cause the most damage? Why?
 - d. Why are fires becoming more difficult to control?
2. What roles do insects play in our forests?
3. What defines a forest pest?
4. Native insects such as the spruce budworm and eastern tent caterpillar are generally not a concern to our forests unless their population grows beyond an acceptable threshold.
 - a. What can cause an increase in insect populations?
 - b. What are the impacts of increased populations of these native insects? What species do they threaten?
 - c. Brainstorm: How can these impacts be monitored and managed?
5. Invasive alien species such as emerald ash borers and Asian longhorned beetles have been introduced to Ontario.
 - a. How were they introduced?
 - b. What species do they threaten? How?
 - c. How can their spread be limited so that they do not spread further?
6. List two (2) potential sources of stress for a forest ecosystem. What can those impacts lead to, and how? (Ex. Warmer weather patterns can lead to increased insect populations)
7. List three (3) factors that need to be considered when predicting forest fires
8. What are prescribed burns, and what is their importance?

Canada's many forest values are enhanced by a rich diversity of relationships

Key facts and figures about Canada's forests and forest sector

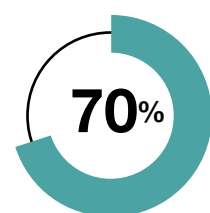
Canada's forests are sustainably managed for a diversity of benefits

Canada has **367 million hectares (ha) of forest**, or **9% of the world's forest** and **25% of the world's boreal forest**.

72% of Crown forest land managed in Canada is certified to third-party standards for sustainable forest management (2022).

Nearly **10% of Canada's forests are protected (2022).**

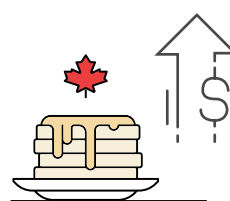
Canada's maple syrup industry is thriving!



Canada produces approximately 70% of the world's maple syrup.



Production increased from 33 to 79 million litres between 2010 and 2022.



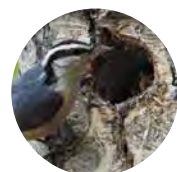
Maple product exports in 2022 totalled \$616 million.

Canada's forests are dynamic and ever-changing systems

Natural disturbances are a part of healthy forest ecosystems.

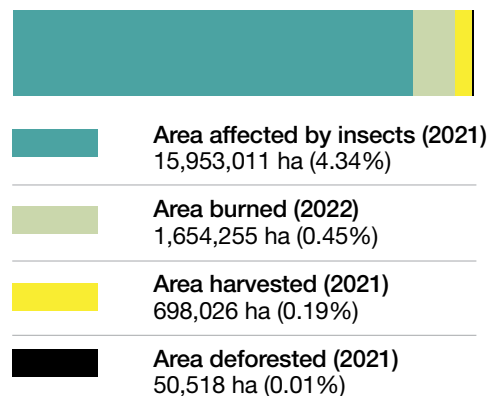


In the boreal forest, the **specially adapted cones** of lodgepole pine and jack pine need the heat of fire to open and release their seeds.



Dead or dying trees (as a result of age, disease, insects, wildfire, or drought) are important habitats for **cavity-nesting birds**; these birds in turn help to control forest insect populations.

Percentage of total forest area affected by disturbances



By modifying their environment, some wildlife species create a diversity of habitats for other species. They are ecosystem engineers.



For nesting, **woodpeckers** dig cavities in snags (standing dead trees) or living trees. These cavities are reused by several other species, such as ducks, owls, bluebirds and flying squirrels.



By building dams, **beavers** create habitats for several species of fish, birds, frogs and mammals. Dams also help create wetlands that improve water quality and reduce the risk of flooding.

Canada's forests are a source of health and well-being

Over 1/3 of Canada's population lives in or near forests, including 55% of Indigenous people (2021).



Canada's forests provide a diversity of employment and revenue



Canada's forest sector contributed **\$33.4 billion (1.2%)** to Canada's **nominal GDP** in 2022.

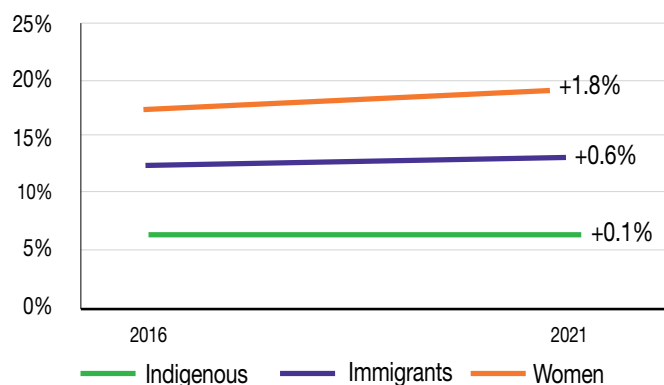


In 2022, Canada's forest sector **employed 212,660 people.**



Average earnings were approximately **\$51,900 annually** (2022).

Change in percentage of total people employed in the forest sector between 2016 and 2021



Canada's forests contribute to a low-carbon economy



Sustainable forest management **sequesters and stores significant amounts of atmospheric carbon** through forest regeneration, growth and harvesting to produce **long-lived wood products.**

Residues left over from traditional forest activities can be used to make **biofuels, which can replace fossil fuels to reduce net carbon emissions.**

The use of bioenergy has **reduced forest product facilities' GHG emissions from fossil fuels by 53%** between 2005 and 2020.

Understanding Climate Change Impacts in Temperate Forests

Written by Ronald Mahoney

May 16, 2019, Climate Woodlands – Extension Foundation and Cooperative Extension

Forest ecosystems are complicated and ever changing. Forest landowners and managers must consider a vast array of information to meet either specific stand objectives and/or broader goals of landscape level management. In many situations, land management objectives integrate measurable products, such as timber and forage, and less tangible assets, often collectively described as aesthetics. On other lands, production of timber or other products may be primary, but a broad consideration of ecosystem functions and processes is still required for sustainable success.

To conceive how climate change can and is affecting temperate and boreal forests, it is necessary to first understand how different species in these ecosystems relate to each other (synecology) and how individual species relate to their environment (autecology). Many of the fundamental ecological principles were developed from research and experience in more tropical ecosystems, which have had little climate change or large-scale disturbances. As a result, tropical species have co-evolved to extreme specialization with highly developed adaptations to specific ecological niches and a finely tuned interdependence.

As you move north, more regular and dramatic disturbances occur. For example, the plants and animals of the Inland Northwest have been associated for less than 10,000 years, and in boreal and arctic regions for far less time. Consequently, the synecology of these plant and animal communities is much less developed. Most species are linked more by competition and adaptation to disturbance than by the refined interdependence we see in tropical ecosystems. Many of the pathogen/host interactions in this temperate region would seem to be a result of co-evolution, although many pathogens show the ability to infest diverse hosts. As examples, the white pine weevil (*Pissodes strobi*) infects mostly spruce (*Picea* spp.) and lodgepole pine (*Pinus contorta*), mountain pine beetles (*Dendroctonus ponderosae*) have success in several pine species, and the spruce budworm (*Choristoneura* spp.) can shift from grand fir (*Abies grandis*) to Douglas-fir (*Pseudotsuga menziesii*) to hemlock (*Tsuga* spp.) depending on availability and host condition. There may be more selection pressure for “generalist” pathogens and other opportunistic adaptations of many plants and animals because of more frequent and dramatic disturbances.

Moving from temperate to boreal to arctic forest ecosystems uncovers an increasing ability of organisms to adapt to change. These forests also experience more dramatic disturbances and their effects on species survival are often evident in epidemic

pathogen outbreaks with some species being reduced or eliminated. Other species in these changing situations may greatly increase their range, vigor, and percent of the population.



Forest pest management

Native insects and diseases play an essential ecological role in Canada's forests.

By consuming trees and other plant material, forest insects and micro-organisms contribute to healthy change and regeneration in forest ecosystems. They help renew forests by removing old or otherwise susceptible trees, recycling nutrients and providing new habitat and food for wildlife.

However, it's not for their ecological benefits that forest insects and diseases sometimes make national news. When infestations are so severe they destroy or damage large areas of commercially valuable forest, or infest Canadian forest products bound for export, then insects and diseases—whether native or alien—become “pests.”

Mountain pine beetle, spruce budworm, and Dutch elm disease are all examples of well-known forest pests that have led to significant losses in value of Canadian forests.

What's what: native, alien, invasive

Forest insects and diseases in Canada are typically classified into three broad categories:

- **Native:** Indigenous species that have existed in Canada for thousands of years. Outbreaks occur periodically. Examples are spruce budworms and mountain pine beetle.
- **Alien:** Species introduced into Canada's forests within recent history. They are also referred to as “exotic,” “non-native” and “foreign.” Examples include emerald ash borer, brown spruce longhorn beetle and Dutch elm disease.
- **Invasive:** Insects and diseases that spread beyond their known usual range.

Both terms, “alien” and “invasive,” refer to shifts from one ecosystem to another, not to shifts across national borders. So, even organisms that move into new ecosystems within the same country can be considered alien and invasive if they extend beyond their usual geographic range. The spread of mountain pine beetle from British Columbia's lodgepole pine forests to Alberta's jack pine forests is an example of a native forest insect behaving invasively.

From friend to foe

Native forest insects and diseases are generally of little concern when they exist at non-damaging population levels.

It is when populations of these native species increase beyond an acceptable threshold, or when alien or native species behave invasively that concerns arise. If ecological or economic damage results in measurable impacts—such as a decline in ecosystem health or large reduction in the available wood fibre—then the insect or disease outbreak is seen as being a disturbance and active management intervention may be considered.

The challenge for forest resource managers is therefore two-fold. First is to assess the risks posed by potential and actual outbreaks and spread. Second is to apply risk-based decision-making to manage forest ecosystems in a way that minimizes the negative impacts of outbreaks and maximizes the positive impacts.

Table 5.1: Common insects that affect coniferous and hardwood plantations in southern Ontario.

Insects that affect conifers	Pines				Spruces				Larches		Eastern white cedar	Hemlock
	Jack	Red	White	Scots	Black	White	Norway	Red	Tamarack	European		
Pine shoot beetle	X	X	X	X								
White pine weevil	X		X				X					
European pine shoot moth		X	X	X			X					
Redheaded pine sawfly	X	X		X								
European pine sawfly	X	X	X	X			X					
Yellow-headed spruce sawfly					X	X	X	X				
European spruce sawfly					X	X	X	X				
Hemlock looper						X						X
Hemlock woolly adelgid ¹												X
Larch casebearer									X	X		
Cedar leafminer											X	
Pine engraver	X	X	X	X	X	X	X	X				

Insects that affect hardwoods	Maples			Oaks			Black walnut		Sycamore	Black cherry	Hybrid poplar	Hickories	
	Sugar	Silver	Red	Red	White	Bur						Shagbark	Bitternut
Sugar maple borer	X												
Asian long-horned beetle ¹	X	X	X						X		X		
Gypsy moth	X	X	X	X	X	X	X		X	X	X	X	X
Forest tent caterpillar	X	X	X	X	X	X	X		X	X	X	X	X
Hickory bark beetle												X	X
Two-lined chestnut borer				X	X	X							

¹These insects are not yet common, but can cause serious damage if not detected and controlled early

Spruce budworm

Choristoneura fumiferana (Clemens)



Distribution

Canada

Micro-habitat(s)

Needle, Bud, Male flower, Cone

Damage, symptoms and biology

Spruce budworm damage appears in May. Evidence of a spruce budworm infestation includes the destruction of buds, abnormal spreading of new twigs, defoliation of current-year shoots and, if an affected branch is disturbed, the presence of large numbers of larvae suspended from strands of silk.

Defoliation begins at the top of the tree and quickly progresses to the periphery of the crown from the top downwards. Current-year needles are partially or completely consumed and, if large numbers of larvae are present, previous-year needles may also be affected. Spruce budworm larvae also feed on staminate (male) flowers and cones. During epidemics, the larvae may destroy all of the cones.

Severely affected stands turn a rust colour due to the presence of dried out needles held by strands of silk spun by the larvae. In the fall, most dead needles are dispersed by the wind and defoliated stands take on a greyish appearance.

A single year of defoliation generally has little impact on the tree. However, it does cause weakening of the tree, making it more susceptible to attacks by other insects. Defoliation over a few consecutive years causes tree growth loss. However, if defoliation of current- and previous-year shoots continues uninterrupted over several years, some trees will die, while others will continue to gradually decline for several years, even after the end of the infestation. This is the case with fir, the species most vulnerable to spruce budworm attacks, which dies after four consecutive years of severe defoliation.

In July and August, the female deposits her eggs in clusters of 10 to 30 under the needles of shoots, preferring those exposed to sunlight. The newly hatched larvae move

towards the interior of the crown in search of a suitable overwintering site and construct a silken shelter, called a hibernaculum.

Life cycle (East of the Rockies)

Life cycle (East of the Rockies)

Stage/Month	J	F	M	A	M	J	J	A	S	O	N	D
Egg												
Larva												
Pupa												
Adult												

Other information

A native species, the spruce budworm is considered the most serious pest of fir and spruce forests in North America. Its range coincides with that of fir, white spruce, and more and more with the range of the black spruce.

Radial growth analyses of trees have shown that cyclical invasions likely occurred between the 18th and 20th centuries. Spruce budworm populations are believed to have fluctuated during this period at intervals of 30 to 40 years. Since the beginning of the 20th century, three invasions have occurred in eastern North America.

The spruce budworm is generally found in large fir stands. Much research has been conducted on this insect by the Canadian Forest Service and it is being monitored by the provincial forest departments. Most control methods mentioned in the recent literature involve the use of biological insecticides, primarily *Bacillus thuringiensis* var. *kurstaki* (B.t.k.).

Through a combination of annual surveys, prediction models, targeted control strategies and proper forestry practices, it is now possible to reduce economic losses caused by spruce budworm outbreaks.

On isolated or ornamental trees, vigorously shaking the tree or spraying with a powerful water jet will cause the larvae to drop to the ground. On small trees, the larvae can be removed by hand.

Diet and feeding behaviour

Heteroconophagous: Feeds occasionally on seeds and cones, but usually lives and feeds on stems and needles.

Phyllophagous: Feeds on the leaves of plants.

Webworm: Spins a silk shelter in which to hide or feed.

Pollinivorous: Feeds on pollen.

Forest tent caterpillar

Malacosoma disstria Hubner



Distribution
Canada

Micro-habitat(s)
Leaf

Damage, symptoms and biology

Defoliation is caused by the caterpillar, which begin to feed on the new leaves as soon as they appear in May. Given this insect's voracious appetite and gregarious behaviour throughout most of its development, its presence can be quickly detected. Older larvae devour entire leaves and, when the tree is completely defoliated, migrate in search of other sources of food. Larvae can also be observed in colonies on tree trunks sheltered from the sun's rays.

During massive invasions, trees can be completely defoliated over large areas. Even when severely defoliated, trees withstand infestations relatively well. Infestations generally last no more than three consecutive years. However, on trembling aspen, radial growth loss and twig dieback occur. Denuded trees will produce another crop of leaves during the season.

In the fall, the presence of egg bands, which resemble spongy, brownish masses, can be easily detected on small branches and twigs. In late June, the female deposits between 150 and 350 eggs in masses that encircle the twigs. The embryo develops over the course of the season and overwintering takes place as a fully developed embryo within the eggshell.

Life cycle (East of the Rockies)

Life cycle (East of the Rockies)

Stage/Month	J	F	M	A	M	J	J	A	S	O	N	D
Egg												
Larva												
Pupa												
Adult												

Other information

A species native to North America, the forest tent caterpillar is the most widespread defoliator of deciduous trees. Its range extends from coast to coast.

The insect has been known for many years and the first outbreak was recorded in 1791. Since then, the forest tent caterpillar has been reported at regular intervals in Canada.

Infestations are generally short and parasitoids are very important in the natural control of populations. The most important parasitoid is the large flesh fly, *Sarcophaga aldrichi* Parker, which acts quickly after the start of an infestation, and can destroy up to 80% of the pupal population.

In recreational parks or on ornamental trees, it is recommended that egg bands be removed in the fall. At that time of year, they are more visible because the leaves have dropped. In the spring, colonies of young larvae at rest can be removed by hand. On small trees, a water jet can be used to dislodge larvae from the foliage.

Diet and feeding behaviour

Phyllophagous : Feeds on the leaves of plants.

Free-living defoliator: Feeds on and moves about freely on foliage.

Emerald ash borer

Agrilus planipennis



Distribution

Quebec, Ontario

Micro-habitat(s)

Leaf, Branch, Trunk

Damage, symptoms and biology

Tree decline, including:

- yellowing of the foliage
- thinning crown
- evidence of adult beetle feeding on leaves
- long shoots growing from the trunk or roots
- vertical cracks in the trunk
- deformed bark (3-4 mm)
- small D-shaped emergence holes
- S-shaped larval tunnels under the bark filled with fine sawdust
- presence of woodpeckers in winter and woodpecker holes

The EAB has killed millions of ash trees in Southwestern Ontario, Michigan and surrounding states, and poses a major economic and

environmental threat to urban and forested areas in both countries. The EAB attacks and kills all species of ash (except Mountain ash which is not a true ash).

The emerald ash borer has only one generation per year in the south of its distribution area in Michigan. Adult emergence starts with the month of June and ends with the end of July. A few days after mating, female lay eggs, one at the time, in bark crevices. One female lays between 60 and 90 eggs during its lifespan. Larvae dig S shaped galleries in the phloem in order to feed themselves. They hibernate in the bark and pupate in April or May. The lifecycle of the emerald ash borer, north of its distribution area, is not known for the moment, but it could last two years.

Other information

Native to eastern Asia, this pest was first discovered in Canada and the U.S. in 2002.

While the EAB can fly up to several kilometres, another significant factor contributing to its spread is the movement of firewood, nursery stock, trees, logs, lumber, wood with bark attached and wood or bark chips.

Regulated materials can be freely moved within a regulated area, but cannot be moved outside of a regulated area without prior written permission from the CFIA. Anyone violating this requirement may be subject to a fine and/or be liable for prosecution.

Regulated materials for EAB include nursery stock, trees, logs, wood, rough lumber including pallets and other wood packaging materials, bark, wood chips or bark chips from ash (*Fraxinus* species), and firewood of all tree species.

Diet and feeding behaviour

Phyllophagous : Feeds on the leaves of plants.

Xylophagous : Feeds on woody tissues (wood).

Asian longhorned beetle

Anoplophora glabripennis



UGA2159038

Distribution

Ontario, United States

Micro-habitat(s)

Twig, Bark

Damage, symptoms and biology

In China, this species may have a one or two year life cycle, depending on the geographical region. The egg, larva, or pupa can overwinter. Young adults emerge from infested trees in May and may fly several hundred meters to search for a host. However, they tend to attack the same tree from which they emerged. Adults are active from early-summer to mid-fall. They feed on the bark of twigs periodically throughout the mating and egg-laying period. On sunny days the adult beetles are most active from mid-morning to early-afternoon. They usually rest in the canopy on cloudy days.

In preparation for egg-laying, females chew oval grooves in the bark in which they lay one egg about 5-7 mm in length. On average, each female will live 40 days and during that period will lay about 25-40 eggs. The wounds may occur anywhere on the tree, including

branches, trunk, and exposed roots. Eggs hatch in one to two weeks. Young larvae begin feeding in the phloem tissue and as they mature they migrate into the wood, creating tunnels as they feed. These galleries cause tree dieback and death. Larvae become pupae, then adults, in the tunnels in summer. The new adults exit the tree through large round holes about 10-15 mm in diameter created by the newly emerging adults. Dripping sap is often seen to be flowing from the egg-laying wounds.

Piles of coarse sawdust around the base of the tree and in branch axils can be seen as well. The adults are large bluish-black beetles (2.5 to 3.5 cm in length) with white spots and very long antennae. The larvae and pupae are normally inside the tree within the larval tunnels. Full grown larvae can reach 50 mm in length.

Other information

In China, *Anoplophora glabripennis* is known as the "starry sky beetle" and is considered a major pest of hardwood trees in many parts of the country. Based on the Chinese distribution and the current infestations in the United States and Canada, it has been shown that the beetle can survive well in the hardwood forests of southern Canada.

The first report of this beetle being established outside of its native range was from the cities of Brooklyn and Amityville, New York in 1996. Many trees were found to be heavily attacked, particularly maples. Quarantine and eradication procedures were quickly implemented to prevent further spread and to eliminate the population. In July-August, 1998, three separate infestations were discovered around Chicago, Illinois. In October 2002 an infestation was discovered in Jersey City, New Jersey. In September 2003 an infestation was discovered in an industrial park located on the boundary line between the Cities of Vaughan and Toronto in the province of Ontario. All of these infestations are under strict quarantine control and are undergoing eradication.

Diet and feeding behaviour

Phloeophagous : Feeds on phloem.

Borer: Bores into and feeds on the woody and non-woody portions of plants.



Shape-shifting forests: a tale of climate, wildfires and surprising outcomes

The story of North American forests is one of resilience, adaptation, renewal and hope.

January 2024

If you hike or stroll through one of Canada's northern forests, you might experience a world of towering trees, cool shade filled with the scent of pines and spruces — home to many different plants and animals of all shapes and sizes. But Ellen Whitman, a wildfire research scientist at the Canadian Forest Service, sees things through a different lens. What she notices is a landscape quietly and gradually transforming.

A very different place

Ellen sheds some light on this phenomenon. “Globally, we’re noticing a change in forest biomes as they shift away from mature forests toward shrub and herb-dominated ecosystems,” she notes. “Head up to the Northwest Territories and you’ll find parts of forests that have been utterly transformed. The towering jack pines have surrendered their reign to grasses and stunted aspens, armed with light seeds that can be carried on the wind,” she says. The small, forested area that caught her eye back then is “a very different place now.”

She first became interested in Wood Buffalo National Park and the southern Northwest Territories in 2014, after a major wildfire season. She worked with two other NRCan scientists, Marc-André Parisien and Dan Thompson, along with wildfire expert Mike Flannigan of Thompson Rivers University. The goal? To compare several paired forested areas with similar climate, pre-fire vegetation and soil conditions. One of each pair had experienced two fires in a short time, also known as short interval reburns. The other had a longer period of regrowth between fires. The differences were significant. The scientists [published their findings](#) in the international science journal *Nature*, noting that, in places with short interval reburns, open stands of aspens dominated in place of dense conifer forests, and the understorey vegetation beneath the trees consisted of sparse shrubs and grasses.

More recently, Ellen and a team of researchers studied wildfire and climate trends in northwestern boreal forests. Looking mainly at Alberta, using historical data from 1970 to 2019 [their research findings](#) were notable: the annual number of large wildfires and the number of extreme short interval reburns both increased as the climate grew warmer and drier. This research supports the growing body of evidence that increasing fire activity affects not just the local environment, but the overall ability of the forest to regenerate.

This transformation is most evident in western and northern parts of Canada and in the southwestern United States. In some reburned areas, you can still spot trees, but they’re less dominant than in neighboring forests, creating a more open, almost savanna-like appearance. Savannas, which are common in Africa and Australia, have a drier climate characterized by rolling grasslands scattered with shrubs, trees and occasional patches of forest.

Key players: wildfires and climate

So, what exactly is happening? Ellen breaks it down: “Climate change and increasingly severe wildfires are key players in this transformation. While they might not be the sole driver, they’re certainly capable of leading to this shift.”

Climate stresses come in the form of droughts, floods and warmer than usual weather patterns. When it’s drier than usual, wildfires tend to happen more often and become more severe.

What’s more, areas recently burned by fires lack nearby sources of seeds for trees to regrow. Sometimes it’s because the burned patch is so vast that the seeds would have a long way to travel. In other cases, it’s because the seed bank, which refers to the dormant seeds that normally exist in the soil, was destroyed in the fire. And even if a tree seedling manages to take root, it might struggle with unusually hot and dry weather. Simply put, they may not survive in today’s climate, which is different than it was when forests first took root decades and centuries ago.

Long term shifts

“There are ongoing long-term shifts away from old-growth tree species like spruce, toward shorter-lived ones like pine or aspen,” Ellen points out.

However, none of this is new, exactly. The balance of tree species in North American boreal forests have shifted many times since the last major ice age 11,700 years ago, as temperatures and wildfire patterns change. Wildfires are a natural phenomenon and can help forests thrive. “Fires can spark overdue regeneration, particularly where they’ve been artificially suppressed,” she points out. “Forests aren’t inherently superior to other ecosystems, and sometimes a bit of rebalancing is needed where they have invaded, such as in some former grasslands.”

Resilience: a race to keep up?

Forests and wildlife can be resilient. Trees have long been adapted to wildfires and changing conditions, while animals can find safer havens. Mature trees have great inertia, which means even if the climate changes fast, they will most likely persist. But Ellen notices a crucial shift. The speed of change is picking up and ecosystems have less time to recover between wildfires. She explains: “there’s some evidence they’re starting to lose the ‘safe operating space’ they need to be resilient to disturbances.”

The story gets more complex when the wider ecological impact is considered. Wildfires create a ripple effect. “In North America, the loss of large, old-growth trees could have consequences for creatures uniquely developed to thrive in mature forests,” notes Ellen. These include specialist species like martens and fishers, members of the weasel family that make their dens inside tree hollows, for example. Beyond that, wildfires impact human social and economic values by reducing carbon storage, altering water dynamics and even affecting how much sunlight the planet can absorb.

Hope, renewal, adaptation

The story of forests is not just a tale of loss, but one of renewal and adaptation. “We can expect most of our burned area to recover fine,” says Ellen. The reality is forests evolve. They may not always resemble the forests we’re used to seeing or respond how we expected. But different combinations of native and non-native plants are sure to fill the voids.

Ellen’s research serves as a reminder that our own actions have far-reaching impacts on the ecosystems we share. There are ways to adapt and mitigate these changes. Land managers can use strategies like fuel treatments and prescribed burning to lessen the severity and spread of wildfires. On a personal level, we can contribute by reducing energy use and cutting down on greenhouse gas emissions. The key is to find a balance that lets nature thrive, while providing the essential ecosystem services we rely on. There is still much work to be done as Ellen and other wildfire scientists continue their quest to understand the drivers and consequences of changes unfolding in our forests.

Disturbances such as windstorms, drought, wildfires, flooding and insect outbreaks are natural features of forest ecology, but they are increasing in frequency and strength due in part to climate change. Research to improve our ability to understand and predict changing climate regimes, species distributions and ecological dynamics will help us adapt to and mitigate the effects of forest disturbance.

Climate change is affecting forest disturbance in Canada

Climate change refers to long-term changes in global weather patterns such as average temperature or precipitation. Although these changes are gradual, they also feature extreme weather events such as a heat dome that produced record high temperatures in British Columbia in 2021, or an unusually severe ice storm that hit eastern Canada in 1998. Forest disturbances such as insect or disease outbreaks can be triggered by species range shifts or novel species interactions that occur in response to climate change. Drought, wildfire, or flooding often result from extreme weather events.

Individual forest disturbances build on one another due to their compounding negative effects on tree health or soil quality. Several prominent examples illustrate these complex interactions:

- Trembling aspen (*Populus tremuloides*) has declined along the southern edge of its boreal range in the Prairies since the 1980s as a result of both drought and defoliation by insects. Increased mortality generates higher levels of potential fuel for wildfires. It also alters local forest canopy structure, microcosms for other species and decomposition.
- A mountain pine beetle (*Dendroctonus ponderosae*) outbreak peaked across British Columbia in the early 2000s, facilitated by mild winter temperature. The beetle spread across the Rocky Mountains into the prairies, decimating pine forests in these regions. It has also

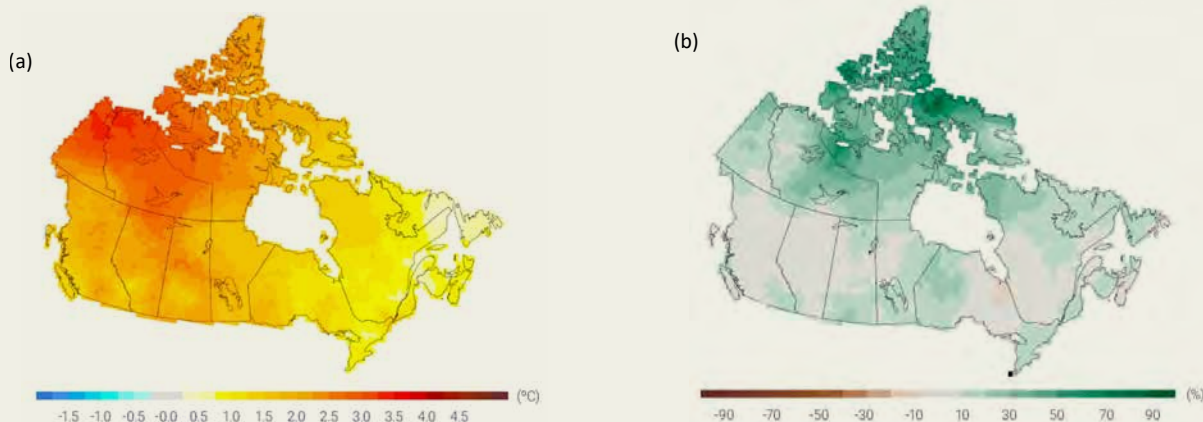
changed the likelihood of other disturbances through the production of increased wood fuel. Furthermore, it has altered the hydrology, affecting soil stability in mountainous terrain. Tree mortality has transformed lodgepole pine forests in this region from a net carbon sink to a source, further contributing to climate change.

- Forest fires have, on average, increased in size and frequency over the past 50 years, burning approximately 2.3 million ha per year since 1990. Projected temperature increases suggest that this trend will continue. However, predicting fire risk at specific locations is complicated by factors such as ground vegetation, precipitation patterns and fuel moisture content.

Forest management can mitigate the impacts of climate change

To address the impact of climate change on forests, responsive forest management is necessary. This involves several important practices, including:

- monitoring changes in forest distribution and composition
- projecting future climate and forest change via computational models that consider climatic inputs, timescales and ecological interactions
- promoting reforestation and afforestation using climate-informed seed selection and considering assisted migration of tree species to future favourable habitats
- sharing knowledge and resources with all parties involved in managing and responding to disturbances



Canadian change in annual average (a) temperature from 1948 to 2016 [$\sim 1.7^\circ\text{C}$ nationwide] (b) precipitation from 1948 to 2012 [$\sim 20\%$ nationwide]. Temperature is projected to increase from one to several degrees (depending on carbon emission levels), and precipitation from 5% to over 20%, before the year 2100. Images are from Canada's Changing Climate Report 2019.

The government supports progress toward a resilient future

- The WildFireSat satellite mission, a \$169.9 million collaboration between Natural Resources Canada, the Canadian Space Agency and Environment and Climate Change Canada, will be the world's first purpose-built, public satellite system for monitoring fires that responds directly to the needs of fire managers in Canada. It will provide unprecedented, daily, near-real-time intelligence on all active wildfires, when the fire management agencies in the provinces and territories need to make critical decisions. Additionally, the mission will support smoke and air quality monitoring and forecasting, and downstream carbon emission monitoring. WildFireSat will also improve our ability to defend Canadian communities, especially the more vulnerable remote northern communities located in forested areas and enable more effective decisions about evacuations.
- The Forest Systems Information and Technology Enhancement (ForSITE) program, part of Budget 2023, "Investing in Canada's Forest Economy," will improve information related to forest carbon and forest integrity, to support decisions about strengthening and sustaining Canada's forest resources.
- The 2 Billion Trees program's research stream will inform reforestation and afforestation efforts through improved seed selection and innovative practices for maximizing carbon sequestration and optimizing the benefits for biodiversity and human well-being.
- Budget 2021 earmarked \$28.7 million over five years, with \$0.6 million in remaining amortization, to Natural Resources Canada to support increased mapping of areas in northern Canada at risk of wildfires.
- Canada regularly works with international partners to prevent the incursion of non indigenous (invasive) forest pests which may become problematic under climate change scenarios.

Source: Gauthier, S., Bernier, P., et al. 2014; Government of Canada; Kurz, W.A., Dymond, C.C., et al. 2008. See *Sources and information* for more detail and visit us online at [cfs.nrcan.gc.ca/stateoftheforests](https://nrcan.gc.ca/stateoftheforests).



Indicator: Forest insects

In 2021, 16.0 million ha of Canada's forests were affected by insects, a 10% decrease from 2020.

- The areas of moderate-to-severe defoliation by spruce budworm decreased over the entire country. This reduction was seen most strongly in Québec; however, in Ontario and the Northwest Territories, populations increased significantly. Jack pine budworm populations also fell, driven mostly by decreases in Ontario. Populations remained steady in Manitoba.
- The area affected by the spruce beetle decreased slightly, with almost all activity centred in British Columbia and Alberta.
- The unprecedented outbreak of spongy moth continued in Ontario in 2021, with defoliation increasing threefold to 1.8 million ha, primarily in southern Ontario. Additional defoliation occurred in parts of southern Québec.
- Almost 6 million ha of forest were affected by other insect species. The most significant impacts were seen in the west, with regional outbreaks of species such as large aspen tortrix and two-year cycle spruce budworm.

Insects are the most diverse group of organisms in Canada, with forests playing home to thousands of species. Many of these co-exist closely with trees. Only a small number kill trees or damage forests, but when they do, the impacts are often long-lasting and widespread.



Why is this indicator important?

- Insects are a normal and natural part of all forest ecosystems and all trees are fed upon by one or more species. Some species of insects, however, may increase their populations to enormous numbers and affect vast areas. These outbreaks are often a normal part of the functioning of forest ecosystems, triggering renewal and change in forest structure. Outbreaks may also reduce Canada's timber supply, affect carbon stocks, increase the risk of wildfires and reduce the recreational and non-timber uses of forests. Severe insect outbreaks can disrupt the forestry sector, leading to regional or national economic impacts. Therefore, it is important to monitor insect populations to ensure proper management of the effects of outbreaks.
- Invasive insects are an increasing threat to forests in Canada. These species and their negative impacts are most frequently experienced in the southern regions of the country with the highest population density. The effects of invasive insects may be significant but are often difficult to predict because they lack a co-evolved relationship with the trees and ecosystems they infest in Canada. This uncertainty sometimes results in unpredicted events, like the large outbreak of spongy moth seen in southern Ontario in 2020 and 2021. Regulatory controls to limit the establishment or spread of invasive species within Canada, or imposed on Canada by trading partners, can increase production costs, impact timber supply and restrict market access. Understanding the impact of these species and preventing their introduction to Canada will enable Canada to minimize the impacts on fragile ecosystems.

What is the outlook?

- Spongy moth populations are expected to decrease substantially across Ontario and Québec. Outbreaks of this insect are regulated by fungal and viral diseases that could reduce outbreak populations to low levels within one to three years. Virus activity increases as spongy moth populations rise. After several years of an increasing spongy moth population, widespread viral infections of caterpillars were expected to cause this insect's population collapse by 2022. The fungal disease may also wipe out spongy moth populations, but it depends more on cool, wet weather. A return to hot or dry conditions could cause these outbreaks to reemerge sooner than the typical 10-year cycle.
- The location and magnitude of spruce budworm outbreaks will change over time. In Québec, outbreaks appear to be diminishing, but populations are trending upward in Ontario and the Northwest Territories. The pattern in the east reflects the typical pattern of budworm outbreaks as they move through the eastern boreal and temperate forest region. Defoliation remains low to nil in New Brunswick and on the island of Newfoundland, where there are aggressive experimental programs to suppress emerging populations. Spruce budworm populations also increased in the Northwest Territories to levels not seen since the late 1990s and early 2000s.
 - Mountain pine beetle populations have stabilized at low levels over much of western Canada but will continue to affect significant areas of forests in Alberta. The insect does not show signs of spreading into northern Saskatchewan from eastern Alberta, where the province has been conducting an aggressive control program. Spruce beetle will likely continue to impact large areas in British Columbia, significantly impacting both the timber supply and forest ecosystems.
 - The Spruce Budworm Early Intervention Strategy initiative, led by Natural Resources Canada, works with partners to help keep spruce budworm populations below outbreak threshold and minimize tree damage and timber losses in Atlantic Canada's spruce and fir forests.
 - Federal support for mountain beetle management in Alberta continued until March 2023. Investments in beetle control and research supported employment and general safety and security of communities in Alberta, and the general safety and security of communities in Alberta and other provinces to the east whose economic well-being and safety depend on healthy forest ecosystems.
 - The provinces will continue to conduct insect pest management programs, such as foliage protection programs against spruce budworm in Québec and Ontario, and mountain pine beetle management in Alberta and Saskatchewan.

Source: National Forestry Database. See *Sources and information* for more detail and visit us online at cfs.nrcan.gc.ca/stateoftheforests.



Indicator: Forest fires

Though the total area burned by forest fires in 2022 was below average, two areas of the country experienced unusually active fire seasons: the Maritimes and the western territories.

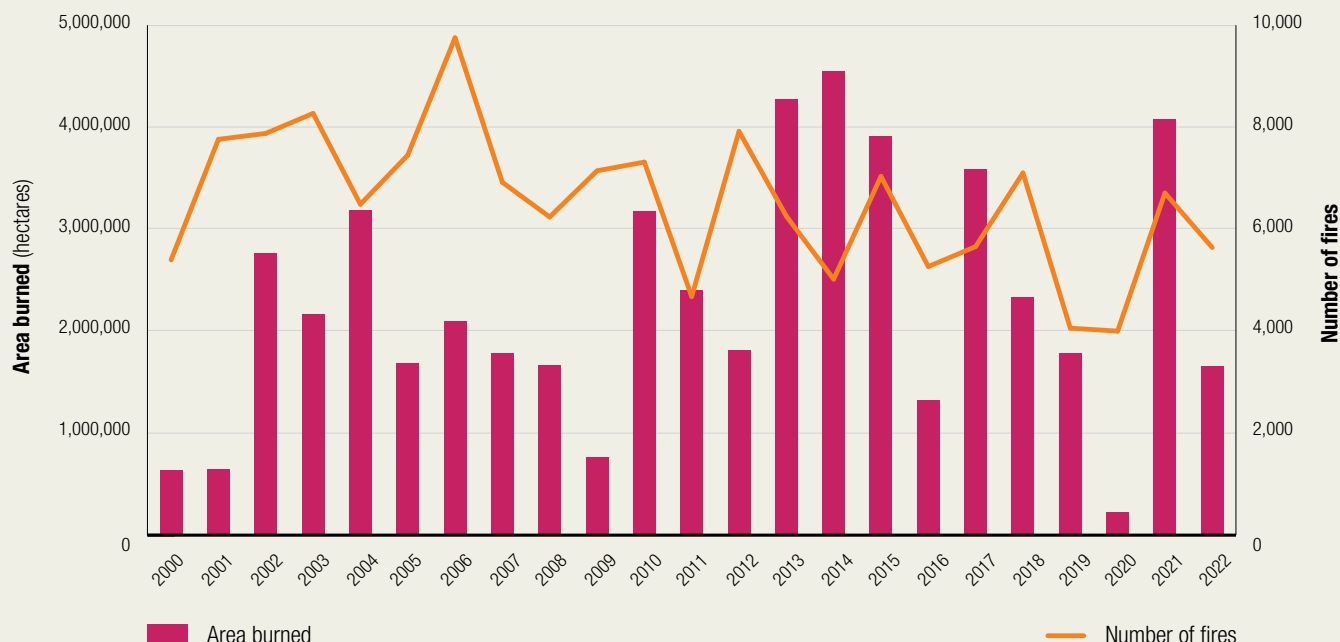
- A spring fire in Yarmouth County grew to become Nova Scotia's largest fire on record.
- In Newfoundland, three lightning-caused fires collectively called the Central Fire Complex started in late July near the town of Grand Falls-Windsor. Firefighting crews from five provinces worked into September to bring the fires under control. These were the largest fires in Newfoundland since 1961.
- As was the case in much of the country, spring was cool and wet in the Yukon. But the end of June was hot and dry, and in the first week of July, more than 20,000 lightning strikes ignited 136 fires, keeping crews and fire managers busy with fire suppression, structure protection and highway closures.
- In contrast, the total area burned in Ontario in 2022 was less than 2% of the long-term average.
- The threat of fire to infrastructure was highlighted in July when a wildfire burned the power line to the community of Pukatawagan in northern Manitoba. The entire population of the community, over 2000 people, was evacuated because the fire was burning nearby. Though the threat of the fire receded, they were unable to return home for more than a month because of the power outage. Power was restored with the installation of two 1500-kW diesel generators while Manitoba Hydro worked to replace 77 burned power poles. Repairs to the line were completed in early October.
- Despite extensive protection efforts including high-volume sprinklers and fire-resistant wrapping around power poles, a September fire near Jasper damaged transmission lines and cut off power to the town for two weeks. Everything from campgrounds to gas stations were closed. Tourism Jasper estimated that the town lost \$10 million in revenue.
- The fire season continued well into the fall in much of the country. In the western provinces, warm, dry conditions caused significant fire activity to continue into late October. In Québec, there were 33 fires in November, which is normally outside the fire season.
- The total area burned in Canada in 2022 was 1.7 million ha, an area more than twice the size of greater Toronto, or more than five times the size of greater Vancouver.



Over the last decade, fire management agencies have increasingly recognized the value of prescribed burning to promote forest health and biodiversity. It can also be used to protect communities from wildfire. Catastrophic wildfire events like the 2016 Fort McMurray fire put forest communities on notice that fire poses a serious threat. In recent years many communities have taken action to protect their communities in a variety of ways, including prescribed burning. A notable example is the Whitehorse South Fire Risk Reduction project, which included thinning or burning 400 ha of forest that could provide a corridor for fire to enter the city of Whitehorse.



Forest area burned and number of forest fires in Canada, 2000–2022



Why is this indicator important?

- Forest fires can damage or destroy homes and businesses in forested areas, trigger evacuations and disrupt people's lives and livelihoods.
- Fires produce large amounts of smoke, reducing air quality and visibility.
- An average of \$1 billion is spent annually on fire management.
- However, fire plays an important and beneficial role in forest health, succession and nutrient cycling.

What is the outlook?

- Forest fire occurrence and spread vary significantly from year to year, but there are reasons why fires are becoming more damaging, not to mention more costly and difficult to control:
 - There are more homes, businesses and infrastructure in the wildland-urban interface.
 - There are more people living and working in forested areas and visiting forested areas for recreation.
 - There is a buildup of flammable forest fuel from insect-caused mortality and decades of successful fire suppression.

- Increasing variability in the climate results in more incidents of drought and high winds, which are ideal conditions for fire spread.
- Recent investments will improve emergency management in Canada, including expanded funding in support of wildland fire prevention and mitigation, and result in modernized national wildfire information and decision-support systems in support of emergency management and wildfire management.
- Our ability to detect and monitor wildfires throughout Canada will be significantly enhanced, especially in Northern Canada, through the development of the first wildland fire-dedicated Satellite System, [WildFireSat](#) (targeted to be used operationally in 2029).
- Investments targeted toward wildfire preparation and response capacity include working with Canada's wildland fire management agencies to increase Canada's capacity to prepare for and respond to wildland fires. This includes investments to train community-based wildland firefighters, and support for provinces and territories to procure specialized firefighting equipment.

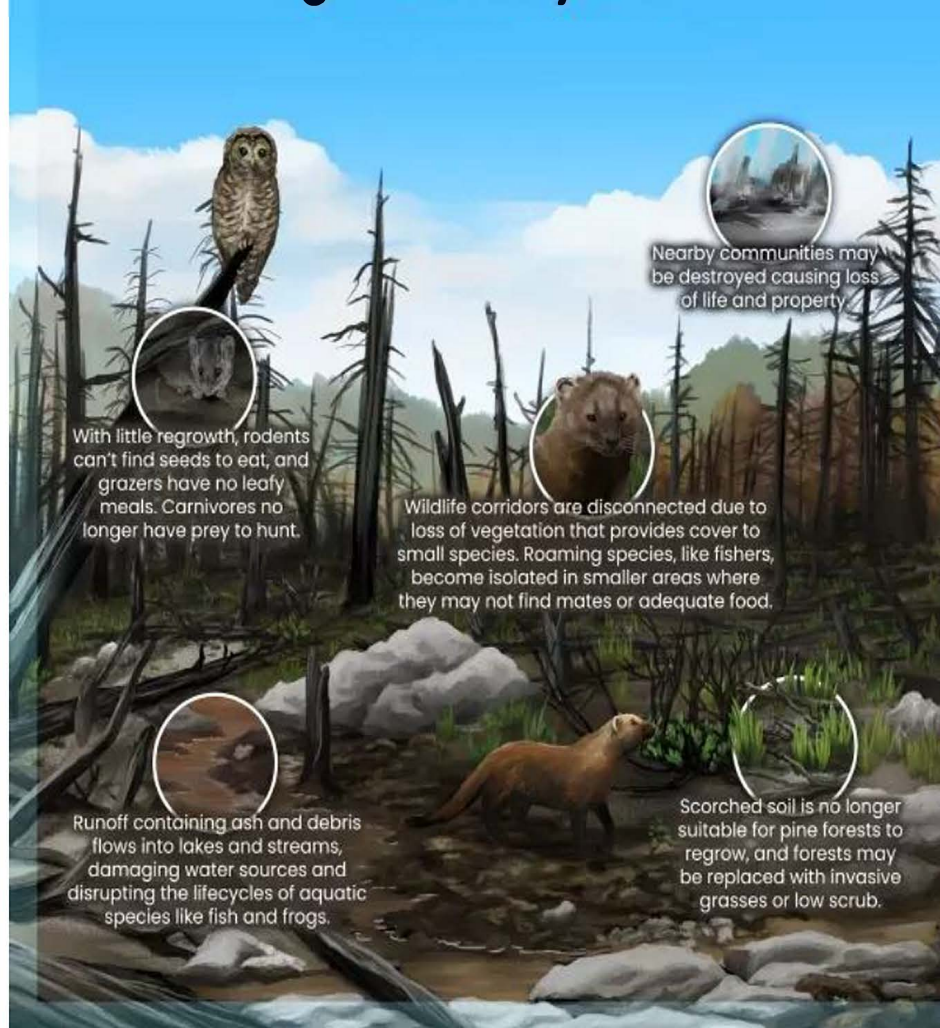
Source: Canadian Interagency Forest Fire Centre; National Forestry Database; Natural Resources Canada. See *Sources and information* for more detail and visit us online at cfs.nrcan.gc.ca/stateoftheforests.

How does fire impact forests and wildlife?

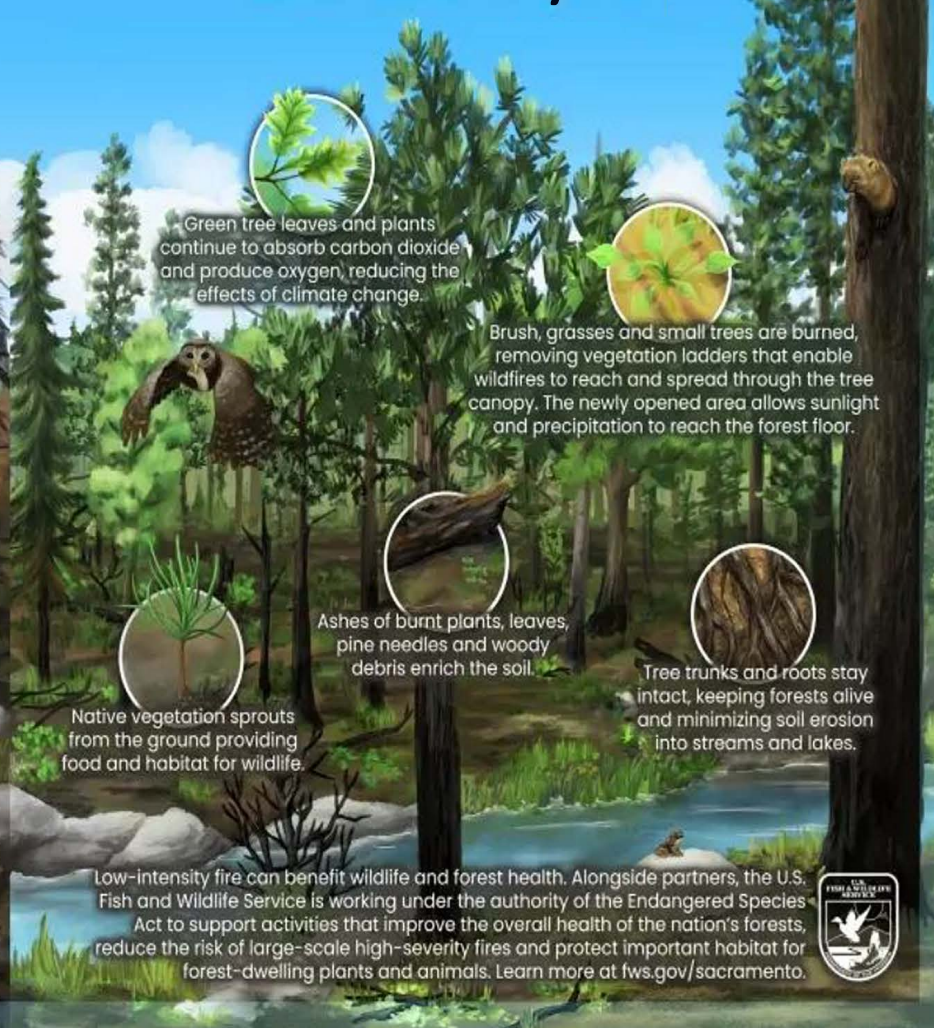
Wildfires are inevitable, but not all fire is harmful to forests. Low-intensity fires can naturally “clean” and thin the forest by removing flammable and thick vegetation on the forest floor. The result is improved habitat for wildlife, healthier soil and new growth of native plants.

It also helps reduce the risk of large-scale high-severity fires that burn through the forest—from the floor to the canopy—with intense heat. High-severity fires across large landscapes can be devastating for wildlife, habitat and surrounding communities.

High-Severity Fire



Low-Intensity Fire



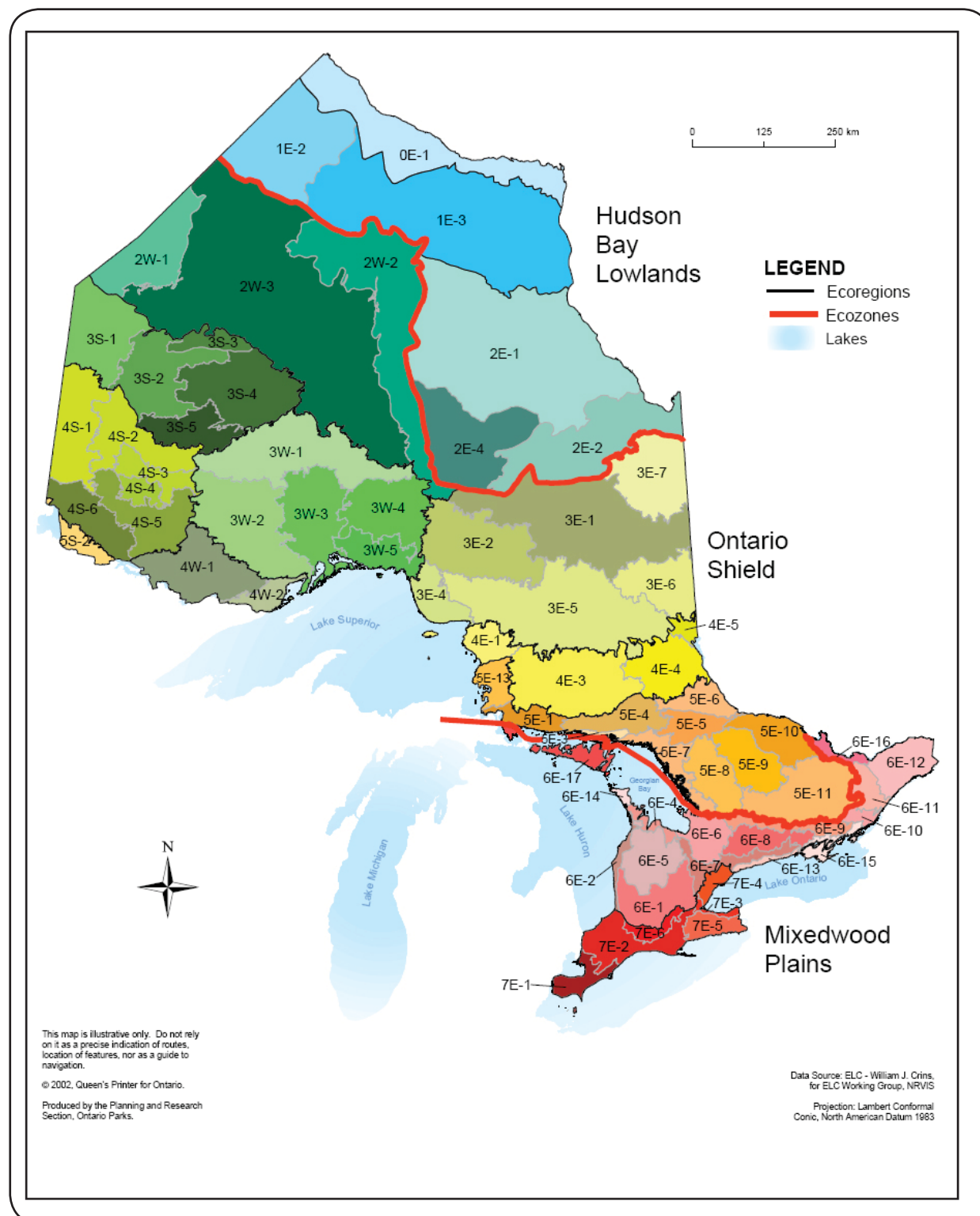


Figure 2: The ecozones, ecoregions, and ecodistricts of Ontario.

Section 2

Hudson Bay Lowlands Ecozone



Northwest James Bay Coast. Photo courtesy: Ken Abraham, OMNR.

This northernmost ecozone constitutes Ontario's portion of the Hudson Plains Ecozone described in the national ELC system (Wiken, 1986). It forms the core of the third largest wetland in the world (Abraham and Keddy, 2005), encompassing about 25% (24,804,611 ha) of Ontario and its boundary (slightly refined from that in the national system), conforms to the contact zone between the Phanerozoic (Ordovician to Cretaceous) limestones and the Precambrian Shield, and includes the limestone bedrock along the coasts and inland from Hudson Bay and James Bay, but excluding

the Precambrian Shield (Shilts, 1982). Moosonee, Moose Factory, Attawapiskat, Peawanuck, and Fort Severn are located in this ecozone. It also contains Ontario's largest protected area, Polar Bear Provincial Park. Furthermore, it is the only ecozone in the province that is adjacent to, and influenced by, salt water and tides, through Hudson and James Bays (Stewart and Lockhart, 2005). At the national level, this ecozone extends north and west into Manitoba, and eastward a short distance into Quebec.

The climate is relatively cold and semi-arid, the winters are long and cold, with mean daily January air temperatures between -20 and -27.5°C , and the summers are short and cool, with mean daily July air temperatures from 12 to 16°C . Average annual precipitation ranges between 240 and 525 mm (Stewart and Lockhart, 2005). The percentage of incoming solar radiation that is reflected from the surface by snow, ice, wet surfaces, fog, and cloud over Hudson and James Bays is high (Stewart and Lockhart, 2005). The presence of permafrost (continuous permafrost in Ecoregion 0E, discontinuous permafrost in Ecoregions 1E and 2E) affects summer climate, since it prevents moisture penetration into the substrate, and energy is expended evaporating that moisture, rather than increasing air temperatures (Stewart and Lockhart, 2005). Clear evidence of climate change exists in the form of decreasing duration of sea ice cover in portions of Hudson and James Bays over the past few decades (Stewart and Lockhart, 2005).

The ecozone constitutes that portion of the province north of the Precambrian Shield where the underlying bedrock is limestone derived from ancient marine seabed deposits. This area coincides fairly closely with the Hudson Bay Lowlands Section of the Boreal Forest Region (Rowe, 1972). The topography throughout the ecozone is extremely flat. In local areas, such as the Sutton Ridges, local exposures of sandstone, shale, and Precambrian rocks rise above the predominantly limestone bedrock landscape. Minor morainal ridges and long eskers provide local relief in the otherwise subdued topography. Marine deposits of clay and beach materials continue to accumulate along the coastal margins of Hudson and James Bay. The near-coastal saline substrates are unique within the province. Over much of the landscape variable depths of glacially deposited lacustrine (fine silts, clays) and morainal materials blanket the surface. The very subdued topography has encouraged the development of vast wetlands with their associated organic substrate accumulations – often many metres deep. Large rivers (e.g., Albany and Winisk) have cut channels and gorges across the broad landscape.

This ecozone emerged from the Laurentide Ice Sheet approximately 8,500 - 6,500 years before present, with the sea flooding in to cover it almost completely. The modern landscape has slowly emerged from the sea as a result of isostatic rebound, evolving from coastal lowland to elevated interior. Along the coasts, the rates of land emergence remain the highest in North America, though far lower than in the period immediately

after deglaciation. After emergence, the initial mineral weathering and accumulation of surface organics begins within about 200 years (Protz, 1982a, Stewart and Lockhart, 2005), with an initial upland vegetation of sparse tundra northward, and ridge thickets southward. These succeed generally to shrub birch, Canada buffalo-berry, heaths and willows, then after a millenium or so, to spruces, tamarack, alders, and *Sphagnum* spp., a pattern that has been consistent since the lowland first emerged (McAndrews *et al.*, 1982). Substrates (soils) are only weakly matured due to cold and saturated conditions. Most common are Orthic Regosols, Cryosols, Orthic and Humic Gleysols, and Orthic Humo-ferric Podzols (Ecoregions Working Group, 1989; Protz, 1982a, b). Discontinuous permafrost occurs in the southern portion of the ecozone. Well expressed frozen (cryosolic) substrates become increasingly common in more northerly areas (Riley, 2003).

Drainage in this ecozone is poor, with much standing or slowly moving water. Riley (2003) estimates 90% of the landscape is dominated by saturated peatland plains in the Hudson Bay Lowlands. Major river systems include the Severn, Winisk, Ekwan, Attawapiskat, Albany, Moose, Abitibi, and Harricanaw Rivers and their tributaries. There are few large lakes, except in the vicinity of bedrock outcrops (e.g., Sutton and Aquatuk Lakes).

The origin of much of the boreal forest throughout the Hudson Bay Lowland Ecoregion is through fire. Stand structure is also affected by wind, insect infestations, and beaver activity.

There are globally significant wetlands comprised of open and treed fens, bogs, and palsas in this ecozone. Marshes develop in supratidal areas. Sedge fens, sometimes with



Coastal marsh, Shegogau Creek, Southern James Bay. Photo courtesy: Ken Abraham, OMNR.



Snow geese. Photo courtesy: Ken Abraham, OMNR.

Coastal Marshes and Mudflats in the Hudson Bay Lowlands Ecozone

The coastal marshes in the Ontario portion of this ecozone support up to 50% of the eastern brant population during their northward migration, and they also serve as breeding, molting, and staging grounds for at least 2.5 million snow geese and hundreds of thousands of Canada geese (Thomas and Prevett, 1982).

The coastal mudflats are important staging areas for hundreds of thousands of shorebirds. The wetlands throughout this ecozone provide ideal habitat for various invertebrates, including biting flies such as mosquitoes, black flies, and bulldogs (tabanids). Many of the invertebrates in adjacent Hudson Bay have Arctic affinities (Stewart and Lockhart, 2005).

a low woody component of dwarf birch and various willow species, are evident near the coast and among the coniferous forests (dominated by tamarack and/or black spruce) inland. On drier areas, herb-moss-lichen tundra develop near the Hudson Bay coast, and open upland coniferous forests (taiga) develop along river levees and old beach ridges throughout (Riley, 2003; Rowe, 1972; Wiken *et al.*, 1996). Predominant fauna include woodland caribou, moose, American black bear, American marten, sandhill crane, greater yellowlegs, lesser yellowlegs, solitary sandpiper, and blackpoll warbler. Arctic fox, snow goose, Smith's longspur, and polar bear inhabit coastal areas during the ice-free period from late spring to early fall. Representative amphibians include American toad, boreal chorus frog, wood frog, and northern leopard frog. Inland streams and lakes contain brook trout, northern pike, and walleye. Marine mammals, such as beluga whales and walrus, occur in the waters adjacent to the ecozone, and utilize the mouths of the major rivers or islands just off the coast (Stewart and Lockhart, 2005). The ichthyofauna of the fresh waters in the ecozone is limited compared to other parts of the province, probably due to the relatively short period during which these waters have been free from glaciers. The lower reaches of the major rivers support populations of sea-run brook trout and arctic char is also known from a few locations (Scott and Crossman, 1973). Threespine stickleback is found only in this ecozone and in the Mixedwood Plains Ecozone, being absent from the Ontario Shield. Other fish species found throughout the ecozone include widespread species such as lake sturgeon, fathead minnow, white sucker, burbot, and mottled sculpin.

The human population in this ecozone is small. Major occupational and economic activities include hunting, trapping, fishing, and resource-based tourism, although mineral exploration and mining, particularly for diamonds, is increasing. Some of the major river systems have been altered for hydro-electric development.

Climate change is affecting the distribution and abundance of species in this ecozone. For example, the impacts of climate warming on polar bear populations may occur first near the southern edge of the range in James Bay and Hudson Bay. Obbard *et al.* (2006) have already detected a decline in body condition, which in part, has been linked to changing sea ice dynamics and access to prey.



Ontario shield landscape. Photo courtesy: Sam Brinker, OMNR.

Ontario Shield Ecozone

The Ontario Shield Ecozone comprises Ontario's portion of the national Boreal Shield Ecozone (Wiken 1986). In Ontario, we use the term "Ontario Shield" because the ecozone includes true boreal forest as well as substantial portions of the non-boreal Great Lakes–St. Lawrence Forest Region (Rowe, 1972). This ecozone occupies more than half of Ontario (65,336,847 ha, 66.2%), and extends from the contact zone with the Hudson Bay Lowlands and its Paleozoic limestone in the north to the limestones and related younger rocks of the Mixedwood Plains Ecozone in the south. Nationally, the ecozone extends well into Manitoba and Quebec.

In a continental context, the climate in this ecozone is relatively cold and moist, with long, cold winters and short, warm summers. However, there is a wide range of temperature, precipitation, and humidity patterns. Precipitation ranges from about 500 mm per year in the west to 850 mm per year in the east (Ecoregions Working Group, 1989). The mean daily temperature in January is about -15°C , and the mean daily temperature in July is around 17°C (but conditions are more moderate in the southern part of the ecozone and adjacent to the Great Lakes).

With the exception of local outliers, this ecozone contains all of the Precambrian bedrock in the province. These rocks tend to be gneisses and granites, but basalts, greenstones, and many other mineral types also occur. The surficial geology is diverse, and includes morainal, organic, and glaciolacustrine deposits, as well as numerous eskers and drumlins. Substrates are also diverse. In deeper mineral material Podzols and Brunisols dominate, but it is important to note that a significant percentage of the Ontario Shield Ecozone is comprised of exposed bedrock. The topography is varied, depending on both local bedrock and surficial deposits. Lakes and rivers are frequent in many parts of the ecozone. Drainage patterns are complex and dependant on local topography and landforms. Some of the numerous river systems found in this ecozone, in whole or in part, include the Severn, Pipestone, English, Rainy, Winisk, Attawapiskat, Pigeon, Nipigon, Albany, Missinaibi, Moose, Abitibi, Montreal, St. Mary's, Batchawana, Goulais, Mississagi, Spanish, French, Ottawa, Mattawa, Petawawa, Madawaska, and Muskoka Rivers. Many of these river systems have their sources within the ecozone, which contains the divide between the Hudson Bay and Great Lakes Watersheds.

In the conifer-dominated boreal forests in the central and northern parts of the ecozone, as well as in pine and oak forests in the southern part, fire is a dominant force of natural change. Frequency, intensity, and size of burns vary, depending on climate, predominant forest type, and local landscape features (Thompson, 2000). Wind and insects also are important forces of change. In the tolerant hardwood forests growing in the southern part of the ecozone natural succession is facilitated through the creation of small gaps as older trees die and fall. These gaps are important in determining the composition, structure, and dynamics of the ecosystems. In aquatic ecosystems the beaver is an important ecological engineer.

Vegetation in the ecozone is diverse. Coniferous forests composed of spruce species, balsam fir, jack pine, tamarack, and intolerant hardwoods including white birch and poplars predominate in the northern part of the ecozone. In the south, mixed and deciduous forests of tolerant hardwoods (e.g., sugar maple, American beech) are more frequent. Wetlands, including peatlands, are abundant. Faunistic and floristic diversity are high, and are comprised of northern and southern elements. Woodland caribou,

white-tailed deer, moose, American black bear, gray wolf, eastern wolf, Canada lynx, American marten, red squirrel, barred owl, boreal owl, white-throated sparrow, pileated woodpecker, wood warblers, blue jay, and gray jay are among the characteristic terrestrial fauna inhabiting the ecozone. Amphibians and reptiles include boreal chorus frog, American toad, spring peeper, northern leopard frog, blue-spotted salamander, western painted turtle, and northern red-bellied snake. In aquatic environments, lake trout, ninespine stickleback, northern pike, northern redbelly dace, yellow perch, and walleye are found.

Many towns and villages are located in this ecozone, but few have populations greater than 50,000 people. Thunder Bay, Sault Ste. Marie, Sudbury, Timmins, and North Bay are the largest communities. The major occupational and recreational activities in the ecozone include forestry, mining, resource-based tourism, hunting, trapping, and fishing. In terms of the spatial extent of resource management influence, forestry is by far the most extensive. Hardrock mining is a principle economic activity throughout the central and northern part of the ecozone. Hydro-electric facilities have been constructed on a number of the river systems.

It is anticipated that the range limits for southern species will expand northward in response to warmer temperatures. For example, warmer lake temperatures will reduce thermal habitat for cool and cold water fish species like walleye and lake trout in some areas and increase thermal habitat for warm water fish species like smallmouth bass (Kling *et al.*; 2003; Minns *et al.*, 2009). In terrestrial ecosystems, increased risk of higher fire severity and a longer fire season will change the natural disturbance regime in many types of forest (Wotton *et al.*; 2005). Changing disturbance patterns in conjunction with warmer temperatures and different precipitation patterns likely will result in the invasion and establishment of new, more southerly plant and animal species in northern ecosystems (Chiotti *et al.*, 2007).

Forest Fires and Spruce Budworm

Forest fires are a major natural disturbance throughout the Ontario Shield Ecozone. Fire intensity is affected by the distribution of available fuel, substrate and fuel moisture, and variation in regional climate. Stand-replacing fires occur over longer intervals in the Great Lakes-St. Lawrence forest portion of this ecozone.

Spruce budworm is one of the most damaging forest insects in North America. Prolonged outbreaks of spruce budworm feeding primarily on balsam fir, white, red, and black spruce can cause tree mortality and increase the susceptibility of forests to fire through fuel loading.



The 'Gunflint' fire, Northwestern Ontario. Photo courtesy: Denis Benoit, OMNR.



Spruce budworm larva. Photo courtesy: North Bay District OMNR Staff.



Mixedwood plains landscape.

Photo courtesy: Wasyl Bakowsky, OMNR.

Mixedwood Plains Ecozone

This southern ecozone is situated on limestone and dolostone formations south of the Precambrian Shield. It encompasses 8,497,803 ha or 8.6% of the province. Ontario's portion of the ecozone is bounded along its southern and western edges by Lakes Huron, Erie, and Ontario, and the St. Lawrence River. This ecozone extends into southern portions of Quebec along the St. Lawrence lowlands.

The climate of this ecozone is cool to mild in a continental context, with cool winters and relatively warm summers. It has one of the mildest climates in Canada. The mean daily temperatures in January range between -3 and -12°C and the mean daily temperatures in July range between 18 and 22°C. The Great Lakes provide a moderating influence. It is also a relatively moist ecozone, receiving between 720 and 1,000 mm of precipitation per year.

The bedrocks in this ecozone are primarily limestone, sandstone, and shale of Ordovician, Silurian, and Devonian ages, with outcrops of sandstone and shale. Surficial materials and landforms are varied, with moraines, lacustrine deposits, and glaciofluvial deposits predominating. Marine silt and clay deposits associated with the post-glacial Champlain Sea occur in the Ottawa and St. Lawrence River valleys. Topographic variation is significant ranging from extremely flat terrain in the southwest and southeast to the rugged terrain of the Niagara Escarpment and numerous terminal and interlobate moraines. Substrates generally are well developed and fertile, and include Luvisols and Gleysols. Hydrology varies in relation to the surficial and bedrock features of the area, with rapid, high-gradient rivers flowing off the Escarpment,



Prairie, Walpole Island. Photo courtesy: Gary Allen, OMNR.

Ojibway Prairie Complex, Windsor. Photo courtesy: Friends of Ojibway Prairie.



Prairies and Savannahs

Ontario's prairies and savannahs are remnants of extensive systems which historically were present throughout southern Ontario.

Prairies are dominated by grasses, sedges, and wildflowers. Savannahs are similar to prairies with scattered trees.

The Ojibway Prairie Complex in Windsor supports one of the largest remnants of tall-grass prairie and related savannah in North America.

meandering slow rivers and streams in areas of low relief, and wetlands in depressions and in areas underlain by clay. Major river systems include the Grand, Humber, Credit and Thames Rivers.

The predominant type of natural disturbance in forest ecosystems is the creation of small gaps through individual trees falling down (known as gap-phase dynamics). However, major weather events (i.e., wind and ice storms) and insect outbreaks can cause more extensive forest disturbance. In wetland systems, beavers are a major force of change. In some of the more localized habitats, such as tall-grass prairies, oak savannahs, and perhaps alvars, fire is more important for habitat renewal.

Vegetation is diverse, despite the conversion of most forested land and wetlands to urban and suburban areas, road networks, and agriculture. Mixed deciduous-evergreen forests and tolerant hardwood forests (including those forests known as Carolinian forests) grow in this ecozone. Alvars and tall-grass prairies also occur here. Although many wetlands were drained during the 19th and 20th centuries, some wetland ecosystems remain. The fauna and flora are among the most diverse in Canada, and the number of species at risk is also high. Among the characteristic species in the ecozone are white-tailed deer, red fox, coyote, northern raccoon, striped skunk, beaver, eastern gray squirrel, great blue heron, red-tailed hawk, black-capped chickadee, blue jay, American robin, wood thrush, yellow warbler, Midland painted turtle, eastern red-backed salamander, smallmouth bass, walleye, yellow perch, pearl dace, and spottail shiner. Alien biota is increasingly problematic in this ecozone, because these species displace native species and alter structural and functional aspects of natural ecosystems.

This ecozone is the most densely populated area in Canada, and many of its natural ecosystems have been converted to human uses, for agriculture and infrastructure. Some of the major cities in this ecozone include Windsor, London, Hamilton, Toronto, Barrie, Oshawa, Kitchener-Waterloo, Peterborough, Kingston, and Ottawa.

Climate change will combine with other types of impacts such as habitat fragmentation and smog to affect ecosystem composition, structure, and function in southern Ontario (Chiotti *et al.*, 2008). For example, climate model projections suggest that this ecozone will be more susceptible to drought in the 21st century, which will favour the establishment and survival of xeric (drought-loving) species (Chiotti *et al.*, 2007).

3.0 Indigenous land stewardship and forest communities



Within our forests are more than just plants and wildlife, but many people who call them home. Many communities in Ontario are reliant on forests for a host of reasons, from being a source of local jobs to being their traditional lands. When discussing forests, it is important to address those who live within them as valuable stakeholders. This includes many indigenous peoples, who have their own worldview and perspective on forests.

Traditional ecological knowledge, or indigenous knowledge, is a valuable component to understand our forests and their health. However, it cannot be separated from its original context and worldview. This is the value of two-eyed seeing, the practice of looking through both the lens of “western” science and traditional ecological knowledge at the same time, considering both with the same weight.

In this section, we will take a look at indigenous communities and perspectives on ecosystem management, two-eyed seeing, and forests communities as a whole.

Key terms: two eyed seeing, traditional ecological knowledge

Discussion questions:

1. In your own words, describe two-eyed seeing. What is the value of this perspective?
2. What are some possible contrasting and complimentary knowledge objectives between Indigenous sciences and western sciences? How can you see these two perspectives working together to study and understand our forests and their current issues?
3. What does UNDRIP stand for?
4. What are the merits of supporting Indigenous-led forestry projects?
5. What is the IFI, and why is it important?
6. How can communities be reliant on forests?

Medicine Wheel for the Planet: A Journey Toward Personal and Ecological Healing

Excerpt From Chapter 2 - The Missing Puzzle Piece: The Indigenous Worldview

“Western science has been the cornerstone of my own work; it has served all of us well, and will continue to do so. What I have come to realize is that it is not providing us with the whole picture. Or rather, it may not be providing us with what we need for “big picture” problem solving. Ecology is an incredibly complicated field of study that, like many areas of science, has a myriad of focuses, all locked in dogmatic encamped positions. The stakes are too high for us to continue placing our eggs all in one basket. The presence of Indigenous Peoples on Turtle Island (North America) for thousands of years, surviving through changes in climate and speciation, and through the attempted termination of our Peoples by colonial governments, is a testament to our qualifications to lead this important work. Adaptation is who we are as a people. We are the adaptation experts. So why not turn to us at this time of ecological crisis?

Many are starting to.

Those who previously dismissed Indigenous Knowledges are now actively seeking them. Many settler scientists and policy-makers are staring at the puzzle of planetary health and realizing that their lack of progress could be attributed to missing pieces vital to understanding the whole picture. I wish I could find myself freely and fully embracing these new-found relationships. At first, I did. This is what I had been longing for – scientists valuing the knowledges of the Peoples of the land. What I didn’t anticipate, perhaps foolishly so, was that just as I experienced with my own land-based knowledges as a practitioner, settler researchers only want to take what we have to offer without understanding exactly what it is they are taking and who they may be leaving behind. Our Indigenous Knowledges are being sought with the detachment of a consumer coveting the latest fad. Our Indigenous Knowledges are not fads. And there is absolutely nothing detached about them as they are inherently a part of us. We are our knowledges. We are the land.

It is our worldview that makes us different, and this truth often goes unacknowledged. Or perhaps the problem is a complete lack of recognition that we see the world differently at all. This awareness goes far deeper than simply learning some Indigenous knowledge. The trend to incorporate our traditional knowledges into ecology often limits our contributions by treating us as historians and colonizes our knowledges through power imbalances and/or attempts to simply add them on to colonial ways of knowing. It is not okay, and it’s plain to see, it is not effective. Traditional ecological knowledge is knowledge shared by Indigenous knowledge keepers. It is sacred. Information acquired from our deep relationship with the places we are from. Intergenerational awareness, passed through lineages about plants,

animals, places, and how we care for them. Knowledges acquired in ways beyond that of the physical. Knowledges continuing to be practised and gained, building upon our ancestral understanding. Knowledges generated and their use guided by community values and needs.

There is great benefit to learning and applying our traditional ecological knowledge in a settler's world. However, the full benefit will not be realized without a broader understanding of our relational worldview. To use only fragmented pieces of our knowledge is to admire a tree without admiring its roots. My love of the standing people (trees) is not only in admiration of their immense beauty, which I can see, but in their foundation, which I cannot. Their beginning as a seed, their extensive roots, the community they are part of beneath the soil that nurtures and stewards them so that they can then make their majestic appearance on the landscape, their deep connection with Mother Earth, their continued connection and contributions to their communities as they grow. Understanding and acknowledging this is to know the power of the standing people.

Chief Dan George offered his wisdom when he spoke about the integration of Indigenous children into the public school system. I think it speaks to the integration of Indigenous knowledge into any colonial structure:

“Can we talk of integration until there is integration of hearts and minds? Unless you have this, you have only a physical presence, and the walls between us are as high as the mountain range.”

To know our worldview is to know our hearts and minds. To know only our traditional ecological knowledge is to have only a superficial relationship, leaving our knowledges vulnerable to misuse and misunderstanding. You must know and appreciate our roots to understand our real power, our worldview. The headwaters from which our knowledge flows. Only then can you see the world as we do. And by doing this, as Jane Goodall said in her book *Reason for Hope: A Spiritual Journey*, you will be able to “make the old new again.”

Is there any better remedy for an old problem than seeing it from a fresh perspective? This is the puzzle piece missing to heal our planet. While the world begins to turn to Indigenous Peoples for solutions to a colonial-caused climate crisis, fragmented bits of our knowledges are being used to fill in perceived gaps of a pre-existing puzzle picture. This “inclusion” is wrong. There is nothing about the overall picture that is just about right when the image itself is fundamentally incompatible with our knowledges. The missing puzzle piece is, in fact, the missing lens of a relational, Indigenous worldview. A lens that we need to transform how we see our Earth Mother and all relations and relationships upon it. A lens that stops the chasing of tails and illuminates our collective path forward. A lens that catalyzes new paths of inquiry and alternate understandings.

Imagine yourself putting on glasses. Your first look through the lenses shows you the world as a web of connections that span both space and time. You no longer see things or people or animals as individuals. Instead, it's palpably evident how each of these things and beings is connected to all the others and the environment. You look down at yourself and see your own connections. Your feet to the Earth. Your breath to the trees. Your heart to your grandparents and great-grandparents. You become overwhelmed by the intricacy and abundance of these connections. You are surprised by the relationships you have that you never knew you did. What else do you see? Perhaps you can see for the first time that you are not outside the natural environment but very much a part of it. You are in relation with the beings upon our Earth Mother. This is the relational, Indigenous worldview."

Integrative Science and Two-Eyed Seeing: Enriching the Discussion Framework for Healthy Communities

Our tools: patterns ... seeing “big pictures” and using “organics”

In contemporary Canada, the words “healing” and “reconciliation” are words that frequently travel together in discussions configured by Aboriginal perspectives and contexts. Elder Murdena offers a key insight with respect to healing; Willie Ermine offers a key insight with respect to reconciliation. Integrative Science has adopted and adapted both. For Murdena’s insight, we realize that participants in the co-learning journey need to be able to place the actions, values, and knowledges of their own culture out in front of themselves like an object, to take ownership over them, and to be able to say “that’s me”. Furthermore, as guided by Two-Eyed Seeing, we need these “objects” for both the Indigenous and Western worldviews. In this way, participants can learn both “that’s me” and “that’s you” to foster working together. Thus, we have developed simple responses (in text and visual form) to four “big picture” philosophical questions.

These depictions enable us to put these philosophical considerations for our knowledge systems out in front of ourselves like an object (tool). In the Spirit of the East, we believe such can help encourage “our place of beginnings” towards the thought frameworks that Ermine’s (2007) insight indicates are required to reconcile the solitudes of Indigenous and Western cultures. That is, we suggest herein that the first phase of entering ethical space for the purpose of reconciling our scientific knowledges and ways of knowing – the ethical space conceived within Ermine’s insight – includes learning to appropriately, correctly, and respectfully acknowledge the “that’s me” and the “that’s you” of our worldviews, as they configure our sciences. Furthermore, in the overall Integrative Science co-learning journey we talk about “growing” rather than “going” forward and knowledge “gardening” more than knowledge translation or transfer

(Bartlett 2011). In the words of journey participant Marilyn Iwama: “We are learning to weave back and forth between our knowledges, our worldviews and our stories. We are learning to navigate that weaving by recognizing patterns that help us do that. Call those patterns knowledge orientations. Call them maps – maps for the garden. We have learned the importance of making our knowledges, our stories, visual.”

In regards to this desire to “make our knowledges, our stories, visual”, we have developed four “big picture” understandings (which are patterns in their own right) that can be put, as “objects” of ourselves, in front of us, congruent with Murdena’s explanation of the healing tense. These are explained below. In sharing them herein, we reiterate that our approach is intended to help orient within “our place of beginnings” and we also reiterate our concurrence with Watson and Huntington

(2008, p. 276) that the “intellectual traditions we assemble, ‘Western’ and ‘Indigenous,’ are not entirely separable into our individual selves, who are instead a ‘multiplicity of multiplicities.’”

1. Our World: This relates to ontologies, as we share a desire for our knowledges to have an overarching understanding of “how our world is”, albeit with differences as to what we deem these to be. The “big pattern” question here is: What do we believe the natural world to be?

- A possible response from within Indigenous science is: beings ... interconnective and animate ...spirit + energy + matter ...with constant change (flux) within balance and wholeness.
- A possible response from within Western science is: objects ... comprised of parts and wholes characterized by systems and emergences ... energy + matter ...with evolution.

2. Our Key Concepts and Actions: This relates to epistemologies, as we share a desire for our knowledges to observe key values albeit with differences as to what we deem these to be. The “big pattern” question here is: What do we value as “ways of coming to know” the natural world, i.e. what are our key concepts and actions?

- A possible response from within Indigenous science is: respect, relationship, reverence, reciprocity, ritual (ceremony), repetition, responsibility (after Archibald, J., 2001, Editorial: sharing Aboriginal knowledge and Aboriginal ways of knowing. Canadian Journal of Native Education, 25(1), 1-5).
- A possible response from within Western science is: hypothesis (making and testing), data collection, data analysis, model, and theory construction.

3. Our Languages and Methodologies: We can focus on core concepts for the languages and methodologies that structure our knowledges, as we share a tendency to want such albeit with differences as to what we deem these to be. The “big pattern” question here is: What can remind us of the complexity within our ways of knowing?

- A possible response from within Indigenous science is: weaving of patterns within nature’s patterns via creative relationships and reciprocities among love, land, and life (vigour) that are constantly reinforced and nourished by Aboriginal languages.
- A possible response from within Western science is: un-weaving of nature’s patterns (especially via analytic logic and the use of instruments) to

cognitively reconstruct them, especially using mathematical language (rigour) and computer models.

4. Our Overall Knowledge Objectives: We can focus on objectives, as we share a desire for our knowledges to have overall purpose albeit with differences as to what we deem these to be. The “big pattern” question here is: What overall goals do we have for our ways of knowing

- A possible response from within the Indigenous sciences is: collective, living knowledge to enable nourishment of one’s journey within expanding sense of “place, emergence and participation” for collective consciousness and interconnectiveness ... towards resonance of understanding within environment ... towards long-term sustainability for the people and natural environment (tested and found to work by the vigorous challenges of survival over millennia).
- A possible response from within the Western sciences is: dynamic, testable, published knowledge independent of personal experience that can enable prediction and control (and “progress”) ...towards construction of understanding of environment ... towards eventual understanding of how the cosmos works (tested and found to work by the rigorous challenges of experimental design).

Indigenous ways of knowing are shaping climate solutions

Indigenous knowledge carries ancient and intergenerational wisdom that is flexible, fluid, and adaptive as it evolves through relationships with the land and other beings. This knowledge evolves from and is responsive to the natural world, which makes it ideal for developing and advancing meaningful climate solutions.

Walter Andreef, Métis knowledge keeper and scientist, spends a lot of his time in the bush. “I feel that when I'm in the forest – the boreal forest where it's deep and dark, with all kinds of animals, and bountiful with life – I feel very much at home,” Andreef explains. “It's kind of a place where you feel connected to the land, just as you are in yourself.”

Indigenous knowledge is not uniform across the diversity of Indigenous peoples in Canada, and cannot be separated from the people who hold it. It is embodied.

At the same time, there are some common principles across these knowledge systems which some suggest are important in the context of addressing climate change. For example, the concepts of relationality and stewardship carry teachings that all living things are interconnected and therefore must be respected and cared for.

“Traditional knowledge for us is certainly about how we can survive the odds in harsh environments, the wisdom of all of that has sustained us for millennia...” describes Watt-Cloutier. “What we're trying to teach is that traditional knowledge is not just for Indigenous people, it's for everybody... All you have to do, really, is start to respect and understand traditional knowledge of Indigenous peoples and you will see there will be a groundswell of new creative and innovative ways and means in which to address these challenges that we face today in the world.”

In the most general sense, Indigenous knowledge systems can offer a more holistic approach, that may compliment the disciplinary nature of western sciences.

Blackfoot Knowledge Keeper and scholar Leroy Little Bear says that we must move beyond the either/or mentality of western thought: “We're not talking about either Western science or native science. What we're talking about is a marriage of the two, because that'll bring about enrichment. That's what we refer to as a holistic approach.”

Indicator: Forest communities

Forests offer significant benefits to communities throughout Canada and across urban and rural areas, in terms of the environment, economy and culture.

- Over one-third of Canada's population live in or close to forests.
- In about 300 Canadian communities, the forest industry is a key source of employment and income.
- The communities that rely on the forest sector account for about 2% of Canada's population, or about 615,000 people.
- As of 2021, nearly one million Indigenous people live in or close to forested areas and the forest sector employs over 11,000 Indigenous people.

Why is this indicator important?

- Not only is forest sector employment in rural and Indigenous communities important for Canada's overall economic health, but supporting Indigenous-led forestry projects is one of many ways to promote reconciliation, self-determination and economic development in Indigenous communities. Additionally, forests have cultural significance for many Indigenous Peoples. Respecting the relationship between Indigenous communities and forests and recognizing the value of Indigenous knowledge is intrinsic to implementing the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) and fostering innovation in the forest sector.
- Forest-reliant communities have shown resilience in the face of challenges like climate change and mill closures. Supporting these communities by providing education and capacity-building is important for maintaining sustainable partnerships to overcome obstacles.



Canada's forests are a significant factor in the lives of people in many Indigenous and rural communities, where the forest sector is one of the largest employers.



What is the outlook?

- Forest-dependent communities were presented with new opportunities during the COVID-19 pandemic due to higher demand for solid wood products, in response to the increased construction of single-family homes and the use of personal hygiene paper products at home.
- A skilled and resilient forest workforce is crucial for the sector to adapt to market changes and support Canada's transition to a low-carbon economy. Therefore, it is important for Canada to make continuous efforts in recruiting, training and retaining workers to sustain the sector.
- Communities in Canada that depend on forests continue to experience the effects of climate change and natural disturbances, such as frequent and severe wildfires and pest infections, which impact forest health.
- Since 2017, the [Green Construction through Wood](#) (GCWood) program has been successfully encouraging the use of innovative wood-based building technologies in construction projects, including generating awareness and implementation of innovative wood building systems with First Nations across Canada. For example, the Tsleil-Waututh First Nation's Administration and Health Centre in British Columbia is a primary structure that is all wood. It showcases the values of the community's cultural heritage that is embodied in the design solutions and were developed through an integrated collaborative design process with the entire Tsleil-Wautuh community.
- Since 2017, the [Indigenous Forestry Initiative](#) (IFI) has been successfully accelerating Indigenous entry to the sector, supporting Indigenous businesses, skills training, and capacity building for Indigenous-led forest sector projects. For example, one project in Ontario resulted in 40 First Nation participants receiving training as truck drivers, millwrights or heavy equipment mechanics, developing skills to succeed in the forest products sector.
- The IFI continues to evolve to better align with Indigenous priorities, most recently broadening its mandate to include targeted support for forest stewardship. The program's new grants stream has the potential to directly increase Indigenous participation in forest management planning and SFM policy discussions.
- Ensuring diverse perspectives in forest sector dialogues is important, as communities in Canada that depend on forests continue to experience the effects of climate change and natural disturbances, such as frequent and severe wildfires and pest infections, impacting forest health.

4.0 Strategies for adaptation and mitigation

A photograph of a young pine tree with green needles, standing in a field of tall, dry, brownish-purple grasses. The background is a soft-focus forest with various shades of green and autumnal colors.

Ontario's forests are set to change with the climate, but the specifics are unknown. With so many gaps in our knowledge, it can be difficult to make predictions. Tools such as vulnerability assessments can determine how susceptible forest ecosystems are to potential disturbances, and an adaptive forest management system can be used to ensure the forests are maintained even in unpredictably changing conditions.

In this section, we will look at mitigating the impacts of climate change on ecosystems, adapting to change, and ways biodiversity can be conserved.

Key terms: adaptation, vulnerability assessment, resilience, mitigation, biodiversity, seed zones

Discussion Questions:

1. What are four (4) things you need to effectively adapt to future uncertainty in our forests?
2. What is an example of something the forest sector is using or doing to adapt to change?
3. How are birds impacted by forest harvesting? Provide two specific examples. How can these impacts be mitigated?
4. In your own words, explain assisted migration and the three types of assisted migration.
5. Why are tree seeds important?
6. What differentiates seed zones, and how are they used?
7. How can afforestation be used to restore landscapes? What are some of the considerations needed when building a forest from the ground up?
8. Based off the charts on pages 64 and 65, what species are most tolerant to different soil types? Least tolerant?



Adaptation

How exactly is the climate forecast to change, and what could that mean for Canada's forests and forest management?

Canada is working to answer these questions in order to help the forest sector and society in general adapt to changing climate conditions. Today, forest managers must consider a range of possible future climates—those involving, for example, altered growing seasons, more insect infestations, more wildland fires and greater permafrost melting.

An important first step is to identify social, economic and environmental vulnerabilities to changing forest conditions. The next important step is to plan ways to reduce the impact of those vulnerabilities.

For example, projected increases in drought, fire, windstorms, and insect and disease outbreaks are expected to result in greater tree mortality. Fewer trees will reduce Canada's timber supply, which in turn will affect the economic competitiveness of Canada's forest industry. This would leave forestry-dependent communities vulnerable to job losses, closure of forestry processing facilities and an overall economic slump.

New thinking to deal with new conditions

Forest managers have traditionally assumed that the climate conditions of previous decades would be the conditions of future decades. Now, with more knowledge about climate and its patterns of change, forest managers are shifting their thinking.

Adaptation will mean taking action to minimize the negative effects of change. Yet at the same time some changes (such as longer growing seasons or moister weather patterns) may in fact offer new opportunities for the forest sector. Adaptation will therefore also mean taking advantage of the positive impacts brought about by climate change.

The challenge of uncertainty

Many uncertainties exist about how, and to what extent, climate change will affect Canada's forests. This makes planning adaptation efforts a challenging exercise.

Dealing effectively with uncertainty requires having:

- the use of new tools and techniques for decision-making, such as scenario-planning exercises
- a good knowledge of the forest
- an understanding of risks
- the flexibility to adjust to changes

Risk management is a proven technique for identifying potential problems and then developing ways to:

- reduce or avoid them
- respond to them to reduce negative outcomes, where they are unavoidable

In forestry, this means setting management objectives that recognize that the forests of the future will be different from those of today. By identifying the risks associated with these new conditions, forest planners and managers can then focus on finding ways to reduce or optimize the impact of those risks.

Support for adaptation from all parties

The [Canadian Council of Forest Ministers](#) (CCFM) has identified climate change adaptation as a priority for the forest sector. Many parties are working to support this priority:

- Forest scientists and forest practitioners across the country are assessing adaptation needs and adaptation options.
- The federal, provincial and territorial governments are collaborating in creating a range of products to help forest managers begin taking adaptation action.

- Provincial and territorial governments are developing approaches to addressing climate change, supporting climate research and raising awareness of the need for adaptation.
- Forest companies are beginning to address issues related to climate change in their management plans.

Practical tools aid adaptation strategies

Tools to analyze forest vulnerabilities

Forest scientists are developing a range of tools for assessing and managing climate-related risks and adaptation options. For example:

- Canadian Forest Service (CFS) researchers have developed a new software tool, BioSIM, which can predict stages in insect development during the growing season. BioSIM has been used to predict how climate change might affect the risk of [mountain pine beetle](#) infestations in western Canada.
- CFS scientists have updated Canada's [plant hardiness zones](#) using recent climate data. The new map produced shows changes in the hardiness zones consistent with climate change.
- In partnership with provinces, the CFS is developing frameworks, guidebooks and tools to help forest management practitioners:
 - better understand their readiness to adapt
 - identify sources of vulnerability to sustainable forest management

Tools to help forests and the forest sector adapt

Work is underway on several fronts to find ways to help forest stands adapt to new climatic conditions and disturbance regimes. For example:

- Researchers are looking at ways to reduce forests' vulnerability to fire and insect damage.
- Industry is exploring new markets for beetle-killed wood.
- Some forest companies have started using high-flotation tires to navigate wet areas, allowing them to extend their operating season.

Tools to inform forest management decision-making

Scientists are incorporating the data they have on changes in climate conditions into research and planning tools. This gives forest managers better information with which to make decisions. For example:

- [Seedwhere](#) is a geographic information system (GIS) tool that can guide planting and seeding decisions for forest regeneration. It can also help forest managers decide where to collect seeds and how far those seeds can be moved.

Looking to the long term

Forest managers need to include climate change considerations in long-term planning if Canada is to maintain a competitive position in world markets. This means enhancing our ability to assess climate effects and identifying ways to adapt forests to ensure a healthy ecosystem and sustained supply of fibre.

Involving everyone in adaptation efforts—government, industry, academia, the public—will be the most effective approach. Good communication and information exchange will help Canadians address shared problems and pool resources to solve them.

Understanding how birds respond to disturbances in the forest

Scientists are studying birds in Canada's boreal forest. Birds are abundant in the boreal because of its vast size and the variety of habitats that it provides.

Birds are part of the enduring beauty of Canada's forests. They are also a barometer of environmental change. How they respond to disturbances in the forest can suggest how other less visible or harder-to-study species are faring. Canadian Forest Service research aims to inform management decisions that account for bird habitat.

Population trends

The overall long-term population trends of most boreal bird species are either stable or increasing. But populations of some common bird species are in decline around the world, including some found in Canada's boreal forest—for example, the rusty blackbird (*Euphagus carolinus*), Canada warbler (*Wilsonia canadensis*) and Connecticut warbler (*Oporornis agilis*).

Bird populations vary naturally, and the causes of population changes are complex and hard to attribute to any single factor. Population fluctuations may result from both natural causes (weather, fire, insect cycles) and human-related causes (climate change, fire suppression, forest management, forest loss, industrial activities).

The declines seen in some boreal bird species are likely related to various environmental changes and habitat loss and/or degradation that could be occurring on the breeding grounds, the wintering grounds or in migration stopover habitats. Research suggests that winter habitat degradation is one of the most significant factors affecting many migratory birds. Significant amounts of forest cover have been lost in some countries where birds that breed in Canada overwinter.

Impacts of forest harvesting

In Canada's boreal forest, the impact of timber harvesting on bird populations is complicated, differing by species, region, forest type, harvest prescription, length of time after harvest, and so on. Forest harvesting may cause changes in bird species composition, diversity and abundance, and these changes can be positive, neutral or negative, depending on the species and the types of habitat that it uses.

For example, early successional species such as mourning warbler (*Oporornis philadelphia*), chestnut-sided warbler (*Dendroica pensylvanica*) and white-throated sparrow (*Zonotrichia albicollis*) benefit from harvesting, as they prefer a younger forest. But some forest-dependent species, such as brown creeper (*Certhia Americana*), boreal chickadee (*Poecile hudsonica*) and ovenbird (*Seiurus aurocapilla*) are sensitive to the loss of old forest habitat.

Other species, such as woodpeckers, require dead or dying trees for nesting and feeding, while others require the cavities created by woodpeckers in which to nest. Still others, such as raptors and flycatchers, use standing live or dead trees in clear cuts and burned areas, as perches from which to hunt. Protecting forests from fire can reduce the availability of these types of habitat features across the landscape.

Research has shown that harvesting patterns that emulate natural disturbances tend to benefit birds and other wildlife, and promote forest biodiversity in general. As a result, jurisdictions in Canada either require or are moving toward harvesting practices that aim to mimic natural disturbances, and are implementing ecosystem management practices to conserve wildlife habitat. Many provinces have also developed action plans to improve their knowledge of biodiversity in the forest by completing inventories, conducting research and carrying out environmental monitoring. In addition, industry is partnering with environmental non-governmental organizations to develop projects that advance boreal forest science and conservation.



Figure 1..Boreal chickadee



Assisted Migration

Forests are climate sensitive, and a range of climate change impacts are already evident across Canada. Trees appear to be responding to warming temperatures by dispersing into more climatically suitable habitats. However, some populations will be unable to keep up with the rapid rate of environmental change.

Numerous adaptation options are being considered as ways to maintain the biodiversity, health and productivity of Canada's forests under continued climate change. One option that is of increasing interest is "assisted migration," the human-assisted movement of plants or animals to more climatically suitable habitats.

In order to ensure that seeds used in reforestation are adapted to their environment, many jurisdictions have developed seed transfer guidelines that recommend where seed from specific geographical areas should be planted. Some jurisdictions in Canada have begun to implement assisted migration of tree species on a small scale by modifying these guidelines. For example, British Columbia has extended seed transfer zones 200 metres higher in elevation for most species, and introduced new policy to allow the planting of western larch outside of its previous range. Alberta has extended seed transfer zones 200 metres higher in elevation and 2 degrees of latitude northward for most species. And Quebec has incorporated the risk of climate change maladaptation into seed transfer functions, planting seed mixtures composed of local and more southern seed sources in some regions. In all cases, it is critically important that the seed used in assisted migration has been documented, tested and stored appropriately, and has come from a wide range of sources and species.

Assisted migration can be contemplated for both conservation goals (e.g., to save a species) and forestry goals (e.g., to maintain health and productivity). Currently, given existing knowledge and established best practices, assisted migration is more feasible for major commercial tree species than for rare species of conservation concern.

Issues to be considered

Assisted migration has the potential to alleviate some of the risks posed by climate change to biodiversity and tree health and productivity, such as species extinction. However, there are possible risks in implementing assisted migration. These might include the impact of the introduced species on the hosting environment, a species becoming invasive, mortality and investment loss if the species or population is not well adapted to the local conditions, and so on. These risks must always be balanced against the risk of not doing it.

Assisted migration describes a wide range of concepts and practices at various scales. But three types of assisted migration, each with a different level of risk and uncertainty, can be distinguished:

- Assisted population migration—The human-assisted movement of populations within a species' established range—*Lower risk*
- Assisted range expansion—The human-assisted movement of species to areas just outside their established range, facilitating or mimicking natural range expansion—*Intermediate risk*
- Assisted long-distance migration—The human-assisted movement of species to areas far outside their established range (beyond areas accessible through natural dispersal)—*Higher risk*

In order to ensure that assisted migration is beneficial and that the risks are minimized, decisions need to be supported by the best possible scientific knowledge. A range of dimensions other than climate, such as photoperiod and soil properties, will need to be considered when deciding what species to move and where to move it to. Where assisted migration is undertaken, migrated populations and the receiving ecosystems should be carefully monitored over time.

Assisted migration is an emerging concept with potential benefits as a climate change adaptation strategy but it poses many questions and offers many unknowns. The idea that humans can help fill the gap between the ability of species to migrate and the rate of change in climate conditions is increasingly being considered and debated as a possible management option.

The Canadian Forest Service is expanding knowledge of assisted migration on several fronts, including research aimed at filling knowledge gaps, development of practical research tools and models, and the conservation of vulnerable species, in addition to collaborating with national and international entities.

Climate Change

Note: Text is from the Afforestation Guide for Southern Ontario – Forest Health, pg. 185-187

When a forest manager is making afforestation decisions they are essentially trying to predict the future. They are combining knowledge of the current environment (soils, bylaws, growth rates, markets, climate, weather, etc.) with either explicit predictions or implicit assumptions of future conditions. Any prediction of the future will be uncertain. Projected climate change increases that uncertainty and has the potential to push some conditions outside of our collective experience. This may be changes in the frequency or severity of events (freezing rain, drought, etc.) we are already familiar with, or novel conditions not yet experienced (e.g. inadequate chill periods).

To a large extent afforestation decisions are based on relatively routine and time-tested approaches and techniques that have been successful over the range of conditions experienced in the past several decades. Standing 'on the shoulders of giants' we have collectively learned what works, under what circumstances, and at least some amount of the why. The better we understand the 'why', the more transferable that knowledge will be to new circumstances, and indeed the projected changes associated with climate change will test just that. Fundamentally sound afforestation decisions are the foundation from which a climate change response can be built.

Predicting climate change

A number of resources exist to project future conditions under a changing climate (e.g. www.climatedata.ca). These can provide estimates of the climate variables most relevant to your site and proposed management activities. These might include: mean annual temperature, summer temperature, winter temperature, rainfall, snowfall, growing season length, and "degree-days".

Climate change products are typically labelled as projections, not predictions (MacCracken, 2001). Predictions tend to be of shorter duration and based on existing natural conditions, while projections are often longer term and based on assumptions of future human related activities such as socioeconomic and technical

developments. Because these assumptions may not be fulfilled, climate projections are subject to a high degree of uncertainty (UNITAR, 2015).

When considering the projected future conditions for your area it is important to not confuse the high resolution of climate data products with high accuracy. Due to the uncertainty inherent in predicting the future, and particularly in translating global climate models into locally relevant results (e.g. Pielke 2011), adaptation strategies that work under a wide range of future conditions are preferable over planning for a single specific future (e.g. Wilby and Desai 2010).

Predicting impacts

Determining the likelihood of a particular climate impact requires a combination of expert knowledge and scientific information. As such, landowners and forest managers are encouraged to engage a knowledgeable professional to help guide them to appropriate sources.

Conducting a vulnerability assessment, even if rudimentary and informal, can help inform how you deploy the limited resources that are available to you to address the climate related impacts your plantation may encounter (maladaptation, extreme events, pests, etc.). A number of guides and case studies are available to adopt or modify based on your needs. These include Gleeson et al. (2011), Edwards et al. (2015), and Swanston et al (2016).

Managing risk

A simple listing of the vulnerabilities can be overwhelming. Indeed, if one were to list the vulnerabilities even without considering climate change you may wonder why anyone would take on an afforestation project at all. To help make sense of the potentially long list of vulnerabilities it is helpful to think about risk.

Risk is the intersection of impact and probability. What will happen if a vulnerability materializes (impact), and how likely is that to happen (probability)? Using a combination of expert opinion, model projections, and empirical information you can categorize the impact and probability associated with each vulnerability. The possible combinations coming out of this exercise range from low impact / low likelihood to high impact / high likelihood.

Characterizing risk in this way does not tell you what to do but rather provides a useful framing of the problem to begin talking about solutions and where to focus efforts. It is not possible to mitigate all risk as some will be technologically or economically infeasible. For other risks the mitigation action may come with its own impacts, potentially greater than the initial risk. It is the responsibility of the landowner and forest manager to determine what risks are acceptable, what risks

need to be addressed through an adaptation action, and the opportunity cost of doing so.

Adaptation (addressing impacts)

Healthy trees are more resilient than stressed or unhealthy trees, so any measure that will promote the health of your plantation will increase its resilience in a changing climate.

Given the wide variety of things that could be done, it is beyond the scope of this document to provide specific recommendations for what should be done. It is worth repeating the introductory caution from Swanston et al (2016):

The adaptation strategies and approaches do not... make recommendations or set guidelines for management decisions. It is up to the land manager to decide how this information is used. A combination of location-specific factors and manager expertise is needed to inform the selection of any strategy or approach (box 9, pg 29).

Mitigation (addressing cause)

Afforestation projects can contribute to climate change mitigation by sequestering carbon from the atmosphere (wood fibre, litter, soil, etc.). Several factors affect the amount of carbon absorbed and stored by a forest including age, species mix, silvicultural treatments, and local climate. Various third-party systems have been developed to register and verify carbon credits. The precise calculus for each system can be complex (defining baselines, storage in long-lived products, leakage, etc.) and may influence management options. Forest managers and landowners interested in obtaining carbon credits for their afforestation efforts are encouraged to carefully research the details of each system.

Monitoring

Developing a monitoring plan to understand and respond to the condition of your plantation has always been important (e.g. section 2.12). With the potential impacts of climate change, particularly when a “wait and see” approach to adaptation has been selected, monitoring becomes even more critical. For example catching a forest pest problem early (e.g. invasive species)...

...may be the difference between having some options and having no options. In addition to monitoring for basic plantation performance (e.g. growth rates), and scheduling of subsequent treatments (e.g. competition control and thinning) monitoring should be tailored to the specific climate vulnerabilities identified for your plantation.

Engaging a knowledgeable professional can expand your informal monitoring network to help you make predictions about the future performance of your own – substituting time for space. A knowledgeable professional can not only provide regional context for what other landowners are experiencing, but can provide early feedback on the success of any adaptation strategies employed.

2.3.1 Seed and genetic resource management

Ontario's tree species have evolved for thousands of years to become adapted to their local environment. To take advantage of the superior performance of adapted seeds and avoid the drawbacks of poorly adapted seeds, it's important to understand the basic principles of genetic resource management, starting with the need to obtain high-quality seed from a known source. Genetic quality is ensured by using seed collected in a good seed year and from many individual trees within a healthy population (Fig 2.3). Because of the importance of genetic adaptation to local climate conditions, most forest jurisdictions set standards that limit seed and stock movement; moving even high-quality seed to areas where climate conditions differ from those at the seed's geographic origin can result in poor adaptation, including greatly decreased growth and increased risk of damage by insects and diseases.



Figure 2.3: A red oak seed crop. Left: Acorns developing in early summer. [Photo source: Melissa Spearing, Forest Gene Conservation Association] Right: Acorns maturing in September. [Photo source: Sean Fox, University of Guelph]

OMNRF's Tree Seed Zone Directive defines seed movement guidelines by establishing 38 tree seed zones (Fig. 2.4). These guidelines (OMNR 2010d) govern the seed used on Crown land (land owned by the government) and trees planted with government funds. This directive provides good basic advice on the movement of any seed and planting stock within Ontario. The guidelines are not specific to any species (i.e., they apply to all species), as the zones are based primarily on a difference of 12 to 14 days in the length of the growing season. For some species, such as red oak, this division may be too broad whereas for other species, such as white pine, it may be too restrictive. Though we know too little about the critical thresholds for growing season length (and other climate variables) for most species, the seed zones provide a reasonable approximation. Seed or stock that originates within a given zone can be planted anywhere in the same zone, should generally be adapted to current climate conditions, and when matched to soil types (see section 2.2), should generally perform well.

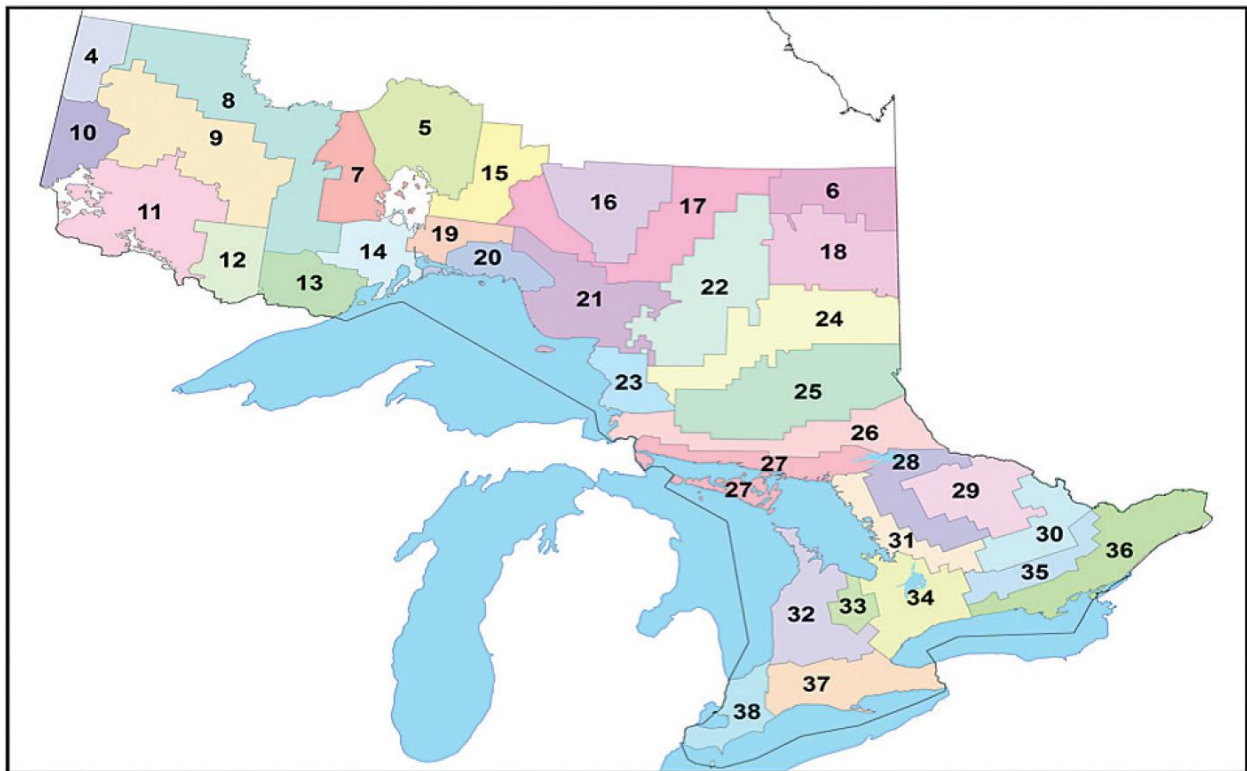


Figure 2.4: Tree seed zones of Ontario.

The 2010 Seed Zone Policy is currently being reviewed by OMNRF, including consideration of projected changes in climate. Any approach to seed transfer guidelines relies on the documentation of its source. This allows for strategic decisions to deploy seed to areas where it can be expected to survive and thrive, potentially far from where it was produced.

It's essential for successful afforestation that accurate information be available about the source of seed, so it can be compared to potential planting sites. McKenney et al. (1999) developed the SeedWhere software, which can answer several types of questions related to selection of an appropriate seed source:

- How similar is the climate at a seed collection site to the climate in potential regeneration areas?
- How similar is the climate in a regeneration area to the climate at potential seed collection sites?
- How similar is the climate at a regeneration area to that of the source area for seed already in storage?

The Forest Gene Conservation Association (FGCA) and Natural Resources Canada are using SeedWhere, with current climate and climate change projections to perform these analyses (FGCA 2017). The tool is particularly helpful in years with limited seed and planting stock.

It is recommended that you follow seed movement standards and maintain chain-of-custody documentation for all tree planting, whether you plant one tree or thousands. For most landowners and forest managers this will mean working with their grower to understand the suitability of available stock

and acquire these records. For landowners and forest managers that wish to collect their own seed it is highly recommended that you engage a knowledgeable professional.

The Forest Gene Conservation Association (FGCA) has been working to spread knowledge of the importance of genetic diversity and seed source control under the Ontario's Natural Selections voluntary seed source certification program (www.ontariosnaturalselections.org). Under this program Certified Seed Collector workshops (www.forestsontario.ca) have been designed to promote control of seed sources by identifying their geographic and genetic origins and promoting the collection of high-quality seed. See Appendix 2 and OTSP (2014) for more details.

The Seed Collection Area Network (SCAN) developed by FGCA identifies good collection areas for each species within each seed zone. Sites in this network range from high-quality natural stands to productive plantations and the untested white pine seed orchards that were established across south-central Ontario in the 1980s and 1990s. Gaps in the network exist, but efforts are underway by the FGCA and partners to address them. In some cases, this may mean establishing planting areas specifically so the resulting forests will become future seed production areas. This represents an opportunity for landowners who want to contribute to gene conservation and to improve seed availability in southern Ontario.

High-quality seed can lead to good results: Whether seeds are used to establish hedges of woody shrub species or plantations of conifers and hardwoods, it is critical to use the best-quality seed—seed that is genetically diverse and well adapted to local conditions so that the plants can adapt to site conditions that fluctuate between years and in the long term.

4.5.5 Biodiversity

Biodiversity—the variety of life on earth—represents Ontario’s rich natural bounty of plant and animal species, and the habitats that sustain them. OBC (2011) reminds us that Ontario’s ecosystems provide us with a healthy environment, clean air, productive soils, food, and clean water. This natural infrastructure supports many industries, and provides jobs in the forestry, agriculture, recreation, and tourism sectors. Afforestation projects can sustain or create a variety of ecosystem services during their life, including providing food, raw materials, and water supplies; regulating the climate and preventing floods; supporting water and carbon cycles, soil formation, and habitat for plants and animals; and providing social and cultural benefits to landowners and their communities. Therefore, you should carefully consider the goals of OBC (2011) during all phases of an afforestation project, including the need “to protect, restore and recover Ontario’s genetic, species and ecosystem diversity and related ecosystem impacts and functions” and to “use Ontario’s biological assets sustainably”.

The Ontario Biodiversity Strategy (<http://ontariobiodiversitycouncil.ca/ontarios-strategy/>) outlines the following management principles for the conservation and sustainable use of biodiversity in the context of afforestation projects:

- Use an ecosystem approach for integrated management of land, water, and living resources.
- Maintain biodiversity as the first priority in conservation initiatives, because this is more cost-effective and less risky than being forced to recover or restore biodiversity.
- Use an adaptive management approach, supported by long-term monitoring and reporting.

As outlined in Chapter 1, one of the most important lessons from previous afforestation efforts was the recognition of the constraints imposed by soils and sites, and that before one can restore the forest (and biodiversity) to a more natural state after the large-scale disturbances that have occurred for centuries, one must first restore the site.

You can consider many approaches, techniques, and tactics throughout the life of a forest to incorporate biodiversity conservation goals and principles into a planting project. We encourage you to consult OMNR (2010b) for a more comprehensive discussion of biodiversity values and forest management options and approaches to support biodiversity. In the rest of this section, we will discuss some of the basics.

Season of operations

- Site preparation and planting should be done during the growing season. Avoid mowing or brush-cutting from late spring to early summer, as this is the fledging period for many birds, and the season for rearing offspring of bats and mammals. Some of these animals may be species-at-risk and require special considerations or government authorizations.
- Thinning is best done in the late summer, fall, and winter from the perspective of tree health (the bark, roots, and site are less likely to be damaged by equipment).
- Some birds and mammals will use a plantation year-round. Conduct an assessment before thinning and other operations to identify the species most likely to be adversely affected so you can develop a mitigation strategy (e.g., performing the operation when it will produce the lowest impacts).

Species selection

- Match the species to be planted to the local soil and site characteristics. (Section 2.2 provides details of the factors to consider. However, if your goal is to protect or promote certain animal species, choose tree species that meet their needs.)
- Plant stock grown from local seed sources. (See Section 2.3.1 for details.)
- Where practical, consider planting a mix of native species, including native herbaceous species (e.g., using wildflowers as a cover crop, as described in Section 3.1.3).

Coarse woody debris

As a plantation matures, natural mortality and damage will create increasing numbers of cavity trees and dead trees, and increasing quantities of downed woody debris. This material serves important roles in creating habitats for a range of organisms. Thus:

- Protect and promote these micro-habitats.
- Allow mature pine to persist beyond the final harvest to become super-canopy trees (trees that extend above the canopy, generally >60 cm in DBH). When such trees are available, OMNR (2010b) recommends retaining at least one such tree per 4 ha.
- About a quarter of all birds and mammals use holes or cavities in trees for nesting, denning, roosting, resting, feeding, or hibernating (Naylor 1998). OMNR (2010b) recommends retaining at least 10 cavity trees per hectare once the plantation approaches maturity.

Bird habitat

Stick nests are platforms that large birds create from sticks and twigs and that they use for nesting. Many are used for many years by the birds that built them. Once they have been abandoned by their builders, they may still be used by other species that do not build their own nests (OMNR 2004). Raptors commonly build such nests, and are beneficial for forests because they prey upon the mice and voles that cause damage to plantations. Thus, you should protect and preserve nest trees wherever possible:

- When you discover a stick nest, ask someone with appropriate knowledge (e.g., an ornithologist or experienced bird-watcher) to confirm the identity and status of the nest.
- Depending on the tree species, age, and location of the plantation, the stick nest may belong to any number of birds.
- Birds that most commonly build such nests in a plantation setting include Cooper's hawk, the northern goshawk (Fig. 4.19), the broad-winged hawk, red-tailed hawk, and sharp-shinned hawk. Crows and ravens are also common. Szuba and Naylor (1998) provide more detailed information.
- Leaving perching trees (i.e., trees with exposed, leaf-free branches) or constructing artificial perches adjacent to the planting site may encourage raptors and owls to move in and help control rodent problems.



Figure 4.19: (Left) A northern goshawk guards its nest. [Photo source: Geoff McVey, Leeds and Grenville Community Forest] (Right) Nests can be difficult to find because they are built in the upper canopy of the plantation. [Photo source: Martin Streit, OMNRF]

Mast trees

Mast trees produce large quantities of edible fruits, including both soft fruits such as cherries and hard fruits such as acorns and beech nuts. These species are sources of food for about 25% of the birds and mammals found within the Great Lakes–St Lawrence forest region (Naylor 1998). Look for ways to incorporate such species in your plantation:

- Oaks, cherry (Fig. 4.20), basswood, hickories, ironwood, walnuts, and butternut are important mast species.
- When available, try to retain a minimum of 10 mast trees per hectare. There may be special requirements under the *Endangered Species Act* regarding individual butternut trees, as this is an endangered species. Discuss these requirements with the local OMNRF office.

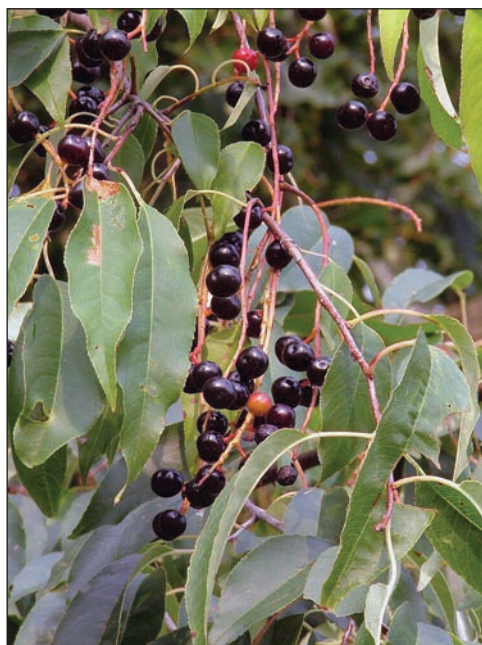


Figure 4.20: Mast is a valuable food source for many species of birds and mammals. (Left) Red oak acorns. [Photo source: John Enright, Upper Thames River Conservation Authority] (Right) Black cherry [Photo source: Mary Gartshore, private ecological consultant]

- Encourage natural regeneration of these species from adjacent hardwood stands. (See sections 2.9 and 4.6.5 for more information.)

Landscape considerations

- Maintain or create other micro-habitat features, such as vernal ponds, drainage areas (small streams and seepages), and old fencerows (Kristensen 1996).
- Consider measures to improve landscape-level connectivity between existing and new forests (OMNR 2011) and avoid operations that permanently reduce existing connectivity.
- Consider creating a larger area of interior forest habitats (i.e., habitats that are not close to the edge of the forest) by planting larger blocks or expanding existing forest areas (Riley and Mohr 1994, OMNR 2000).

2.2 Soil and site considerations

Before you begin an afforestation program, consider the site characteristics so you can make any necessary adjustments to your management approach. For example, von Althen (1990) cautioned that hardwoods will not produce high-quality timber when they are planted on dry, exposed slopes and ridges, or in areas where the topsoil is shallow and the subsoil consists of heavy compacted clay. If those conditions exist at your site, you may need to grow conifers instead. Even if the production of high-quality timber is not your primary objective, the survival, growth, and general health of a hardwood forest may be unsatisfactory on such sites. Site conditions that are unfavourable for certain species can increase the length of time it takes to achieve crown closure and the effort required to maintain trees as the dominant plants. In addition, future tending costs are likely to increase. In the von Althen example, poor survival and growth leads to wider spacing, an extended period in which it's necessary to control competition from other plants, and ultimately poorer tree form and height growth.

Table 2.2 summarizes the species that are likely to perform well on certain soil types. Their performance depends on the soil moisture content, which will be determined by the natural drainage at your site. Sites with poor drainage are easy to detect, as they tend to have standing water for most of the growing season. There may also be no trees present, or only trees such as willows and alders that tolerate or prefer wet soils. Areas with fair (imperfect) drainage will lack surface water, but will reveal damp soil if you dig into the earth. Some will also show blue–grey streaks called “gleying” that indicate a lack of sufficient oxygen. Areas that lack these characteristics will generally have good drainage.

Table 2.2: Summary of the suitability of typical Ontario tree species for different soil types. Adapted from OMAF and AC (1992) and OMNR (1995a).

Soil texture ^a	Natural drainage		
	Good	Fair (imperfect)	Poor
Coarse (very gravelly, gravelly sandy, sandy)	Norway spruce Red pine White pine White spruce European larch Sugar maple Red oak Black locust Eastern white cedar Hybrid poplar Tulip tree ^b	Norway spruce Red pine White pine Eastern white cedar Hybrid poplar Silver maple Black locust Hackberry ^b Eastern cottonwood ^b Big shellbark hickory ^b Sycamore ^b	Norway spruce White spruce Silver maple Eastern white cedar Black spruce Tamarack Willows Swamp white oak ^b
Medium (gravelly loamy, coarse loamy, silty)	Norway spruce Red pine White pine Japanese larch European larch Sugar maple Red oak Bur oak Eastern white cedar Hemlock White spruce Hybrid poplar Black locust Hackberry ^b Sassafras ^b Shagbark hickory ^b Shumard oak ^b Tulip tree ^b	Norway spruce Red pine White pine Eastern white cedar Hybrid poplar Silver maple Bur oak Black locust Black cherry Black walnut American beech Basswood Big shellbark hickory ^b Hackberry ^b Eastern cottonwood ^b Sassafras ^b Shagbark hickory ^b Shumard oak ^b Sycamore ^b	Silver maple Red maple Norway spruce White spruce Tamarack Willows Bur oak Swamp white oak ^b

Soil texture ^a	Natural drainage		
	Good	Fair (imperfect)	Poor
Fine (fine loamy)	Norway spruce White spruce Japanese larch European larch Eastern white cedar Hemlock Hybrid poplar Black locust Sugar maple Black maple Black gum ^b Eastern cottonwood ^b Hackberry ^b Shagbark hickory ^b Shumard oak ^b	Norway spruce Silver maple White spruce Eastern white cedar Black locust Hybrid poplar Black gum ^b Big shellbark hickory ^b Eastern cottonwood ^b Hackberry ^b Shumard oak ^b	Silver maple Red maple White spruce Black spruce Tamarack Willows Eastern white cedar Swamp white oak ^b Black gum ^b
Very fine (clayey)	Norway spruce White spruce Black locust Eastern white cedar Bur oak Pin oak ^b Hackberry ^b	Silver maple Norway spruce White spruce Hybrid poplar Bur oak Pin oak ^b Hackberry ^b	Silver maple White spruce Willow Tamarack Pin oak ^b Swamp white oak ^b
^a Table 2.1 defines the soil textures.			
^b This species should only be considered for Site Region 7E (the Carolinian zone).			

Table 2.3 provides additional factors to consider after selecting a species that seems likely to perform well on the soils at your site. Appendix 1 summarizes the study of species suitability and productivity by soil properties in southern Ontario (Taylor and Jones 1986a, 1986b). Together, Tables 2.2 and 2.3 and this appendix will help you choose the best species for your site. If your site has two or more areas with distinctly different conditions, particularly for the soil and drainage, you'll need to choose different species for each area to avoid problems (OMNR 2000). The tables will also help you to group species that have similar survival and growth potential if you are considering a mixed-species planting to (for example) achieve an ecological goal such as increasing biodiversity. However, although the information in these tables is broadly applicable, there are sometimes exceptions. Don't neglect the value of visiting existing plantations on similar sites in your area so you can learn from the experience of other forest managers.

5.0 Sustainable forest management policies



Sustainable forest management practices are implemented with the long-term health of the forest in mind, and have to take many values into consideration. With change on the horizon for all forests, long-term sustainable forest management requires an awareness of change and flexibility to meet new demands as they arise.

In this section, we will look at sustainable forest management and forest certification.

Key terms: sustainable forest management, nature-based solutions, forest management certifications, stakeholders

Discussion questions:

1. How long do forest management plans last?
2. What is the adaptive forest management cycle? Draw and explain each step.
3. Name five federal acts that protect Canada's forests.
4. How can sustainable forest management help mitigate climate change?
5. What three forest certification organisations are used in Canada? What standards must be met for a forest to be certified?
6. What is the value for forest management certification?

Managing for diversity:

How sustainable forest management conserves and protects Canada's diverse forest values

Canada's forests are much more than just trees. Forests are complex ecosystems that also include soil, air, water and all the living organisms that depend on them for survival. Canada manages its forests for diverse values through the principles of sustainable forest management (SFM), taking not only today's needs, but future needs into consideration.

- The many forest types across the country hold an array of environmental, economic, social and cultural values that are important to diverse groups and individuals.
- SFM aims to protect and conserve the integrity of forest ecosystems and their inherent values.
- SFM is based on sound forest science, resource monitoring and reporting, as well as consultations with stakeholders, the public and Indigenous communities.

The sustainable forest management planning process

Most public land in Canada is regulated by provincial and territorial governments who have the primary authority to create and enforce laws related to natural resource management. Forest harvesting on public lands is enabled through forest management agreements with forest companies, often referred to as tenures or licences. Under these agreements, companies are permitted to operate on public lands for a substantial period (usually 20–25 years) and must adhere to SFM principles. Forest management plans are required for these public lands and must be approved by the province or territory before any harvesting occurs. Forest management plans are very complex and require input from a variety of subject area experts. The planning team for such is led by a registered professional forester who is licenced under provincial legislation (an “ingénieur forestier” in Québec) and subject to high ethical standards and continuing education.

Typically, forest management plans are 5–10 years in length. They outline forest management objectives for diverse values that support a long term forest management strategy. A key component of the forest management planning process is public and stakeholder engagement to ensure locally and regionally important values and objectives are identified and captured. Public and stakeholder engagement occurs multiple times throughout the development of the management plan. In addition to formal meetings, local citizen committees are encouraged to have frequent

communication with the forest planning team throughout the process. Public consultation is also extremely important in the forest management planning process to consider the diverse societal values and perspectives.

Indigenous participation is another extremely important part in the management planning process and is increasing in many jurisdictions, especially where traditional uses and treaty rights may be impacted. Formal agreements featuring Indigenous-led forest management zones are in place in certain regions of Canada, as are agreements pertaining to the management and conservation of old-growth forests. Forest management planning, in most provinces and territories, has begun to formally incorporate local and Traditional Knowledge. Indigenous communities are progressively acquiring more forest management rights within their traditional territories.

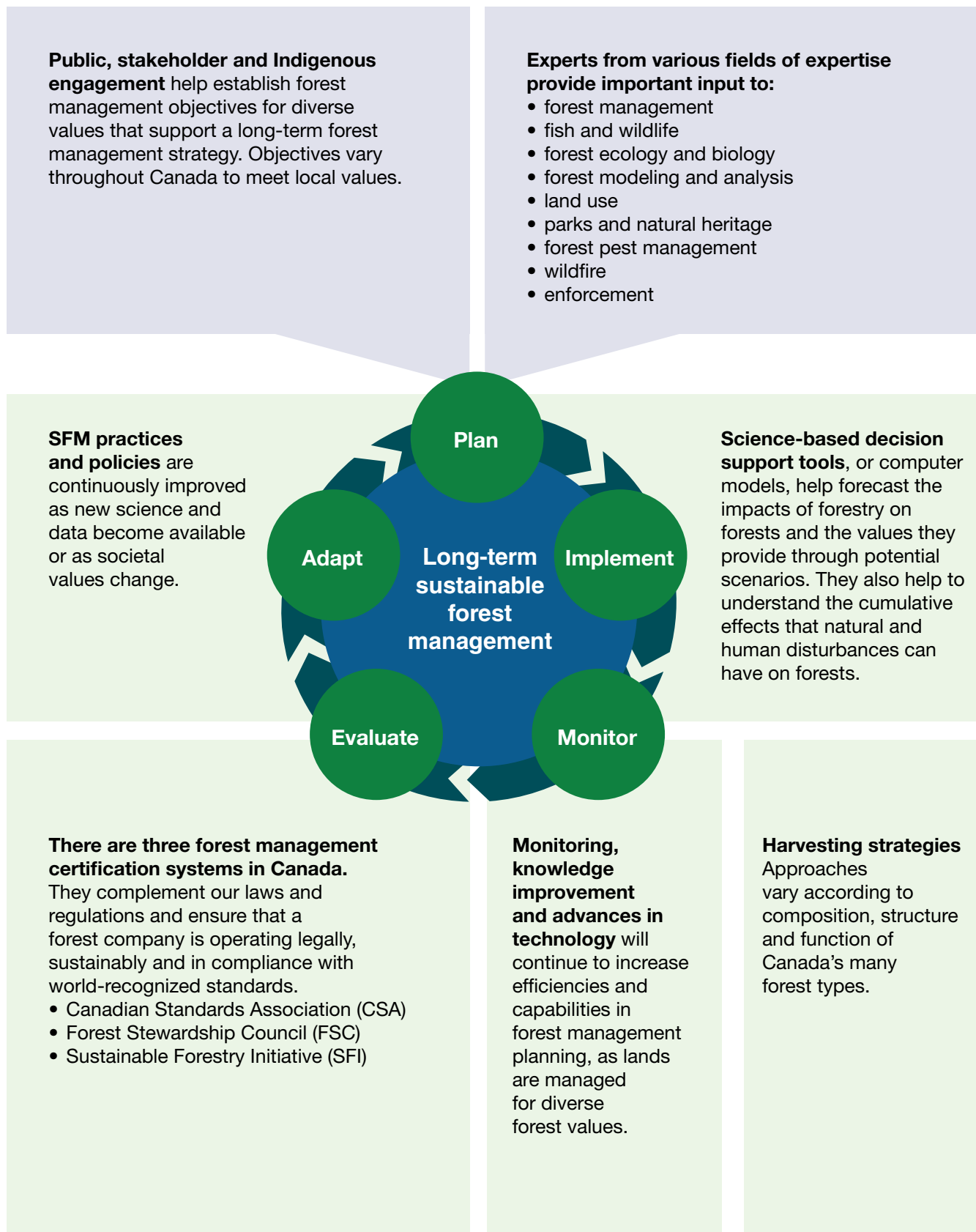


Values and objectives can go above and beyond what is required by legislation. To minimize conflicting values, forest managers can use an Integrated Resource Management (IRM) approach, whereby many values and interests are considered in the management process.

Those values could include:

- **ensuring sufficient habitat is available for locally important wildlife**
- **working to reduce the wildfire risk around communities**
- **addressing the impacts of climate change**
- **ensuring enough timber is harvested to provide local forestry jobs**

Overview of the adaptive forest management cycle used to sustainably manage Canada's public forests



Sustainable forest management: A careful balancing of diverse values

One SFM pillar is **economic values**. Forest harvesting and wood product manufacturing are critical sources of jobs for many communities in Canada, particularly rural and Indigenous communities. These jobs depend on a long-term, stable supply of wood. Sustainable harvesting of trees is determined through an annual allowable cut (AAC), which the province or territory establishes to maintain a wood supply in perpetuity.

The **environmental values** pillar of SFM can be represented by numerous values, but usually includes the protection of biodiversity, soils and water, and the reduction of carbon in the atmosphere. Forest managers strive to emulate natural disturbances in the management plan. Forest management practices supporting environmental values can involve:

- maintaining various stages of forest development, including old-growth forests, for providing diverse habitats
- managing the presence of a range of tree species of various ages over time
- leaving forest corridors to improve landscape connectivity
- varying the size and shape of harvested areas to represent natural disturbance patterns
- keeping a variable number of live and old trees, often called “veteran trees,” and cavity trees for birds and other wildlife within harvest areas
- providing buffers around nesting trees and streams to preserve wildlife habitats and water quality

The third SFM pillar is **social or cultural values**. Cultural heritage and spiritual values are significant to many individuals and groups, including Indigenous Peoples. These values, along with the locations of particularly important sites, are identified during the planning process and should be included in scenario modeling activities. Indigenous rights are considered throughout the management planning process and any historically significant locations are identified for preservation.

Sustainable forest management: A driver of change

It is important to recognize that the balance of economic, environmental and cultural values changes over time. For instance, sustainable timber harvest used to be the primary focus of SFM. More recently, environmental values have been growing as the top priority for SFM. Forest management and conservation laws, policies, regulations and management guides are also shifting toward more emphasis on the ecological well-being of the forest.

- There is an **increased commitment to preserving biodiversity**, which includes the adoption and implementation of the [Kunming-Montreal Global Biodiversity Framework](#) (GBF) to halt and reverse biodiversity loss by 2030.
 - To support the global goals and targets set out in the framework, Natural Resources Canada (NRCan) is supporting Environment and Climate Change Canada (ECCC) to develop [Canada’s 2030 National Biodiversity Strategy](#).
 - At the provincial level, Nova Scotia has introduced a stand-alone [Biodiversity Act](#), which provides for conservation and sustainable use of biodiversity in the province.
- **Alternative silviculture options are used to reduce clearcutting.** For example, Nova Scotia is adopting [ecological forestry](#) where public land is divided into three zones that work together to balance a range of interests (conservation, high production forest and mixed forest or matrix).
- **Old-growth forests are increasingly being protected and conserved.**
 - For example, [the Province of British Columbia has introduced a plan](#) to establish new Forest Landscape Planning tables to improve old-growth management, including the incorporation of Traditional Knowledge.
 - The Government of Canada, through ECCC and supported by NRCan, has also committed to the establishment of the Old Growth Nature Fund in collaboration with the Province of British Columbia, non-governmental organizations, and Indigenous and local communities.
- **Conservation areas are increasing.** As a Party to the United Nations Convention on Biological Diversity and the new GBF, Canada has committed to conserving 30% of Canada’s lands and water by 2030.
 - To achieve this goal, the Government of Canada has committed to establishing ten new national parks in the next five years, including the [proposed national park reserve in the South Okanagan-Similkameen](#) in British Columbia.
 - The Government of Canada also continues to designate many of its federally managed lands as other effective area-based conservation measures (OECMs), which are specific areas that have conservation and biodiversity objectives in addition to other primary objectives. OECMs, such as [Boishébert and Beaubears Island Shipbuilding National Historic Sites](#) in Miramichi, New Brunswick and the [Acadia Research Forest](#) (ARF) near Fredericton, New Brunswick contribute to achieving Canada’s conservation target by protecting old-growth forest ecosystems and representative natural forest conditions common to the Acadian Forest Region.

- **Forests play a key role in our nature-based climate solutions.**

- [The Government of Canada's 2 Billion Trees Program \(2BT\)](#) provides funding over 10 years to support provinces and territories, municipalities, Indigenous organizations and governments, and for-profit and not-for-profit organizations in planting an incremental two billion trees across Canada that will support climate change mitigation and adaptation, while increasing biodiversity and human well-being.
- Canada's [National Adaptation Strategy \(NAS\)](#) sets out a blueprint to reduce the risk of climate-related disasters, improve health outcomes, protect nature and biodiversity, build and maintain resilient infrastructure while supporting a strong economy and workforce.

- [NRCan's Climate Change Adaptation Program](#) (2022–2027) provides funding for projects to help position Canada's regions and sectors to adapt to climate change.

Sustainable forest management is the driver of practices and policies to balance a complex diversity of values in forest ecosystems, communities, and economies. Managing forests for societal values that are increasing in number and often changing is an immense challenge. However, it is a challenge that Canada's forest managers are addressing through ongoing engagement with the public and stakeholders and through adaptive sustainable forest management.

Canada's forests are protected through strong laws and regulations at the federal, provincial/territorial and even municipal levels. SFM is a concerted effort among all levels of government, industry, and the public. There are several overarching federal acts that support SFM objectives, including the:

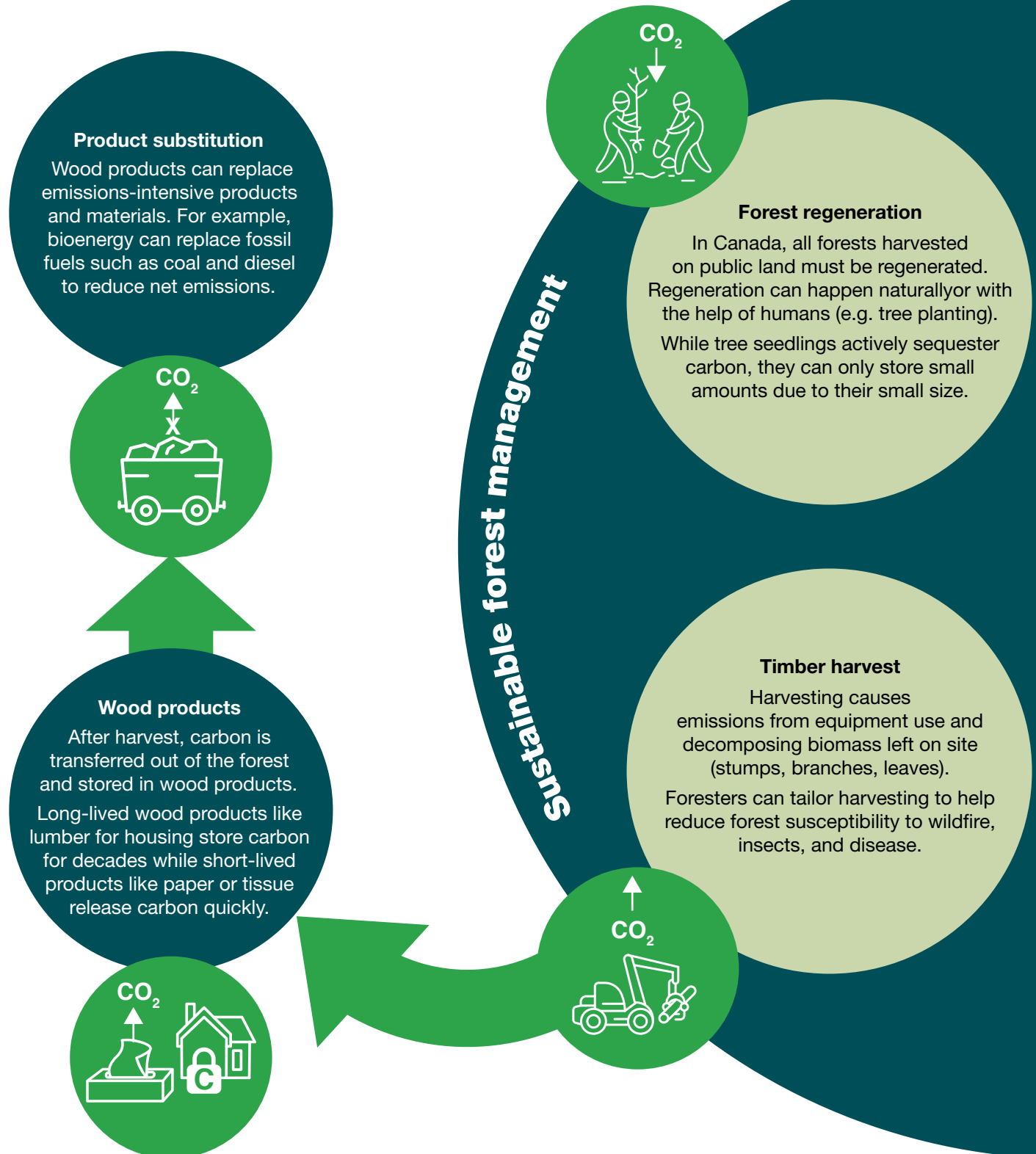
- *Forestry Act*
- *Species at Risk Act*
- *Migratory Birds Convention Act*
- *Fisheries Act*
- *Impact Assessment Act*
- *Canadian Environmental Protection Act*
- *Pest Control Products Act*
- *Fertilizers Act*

The *Species at Risk Act* is a fundamental part of Canada's strategy to preserve biodiversity. It was created to meet Canada's commitment under the United Nations Convention on the Conservation of Biodiversity.



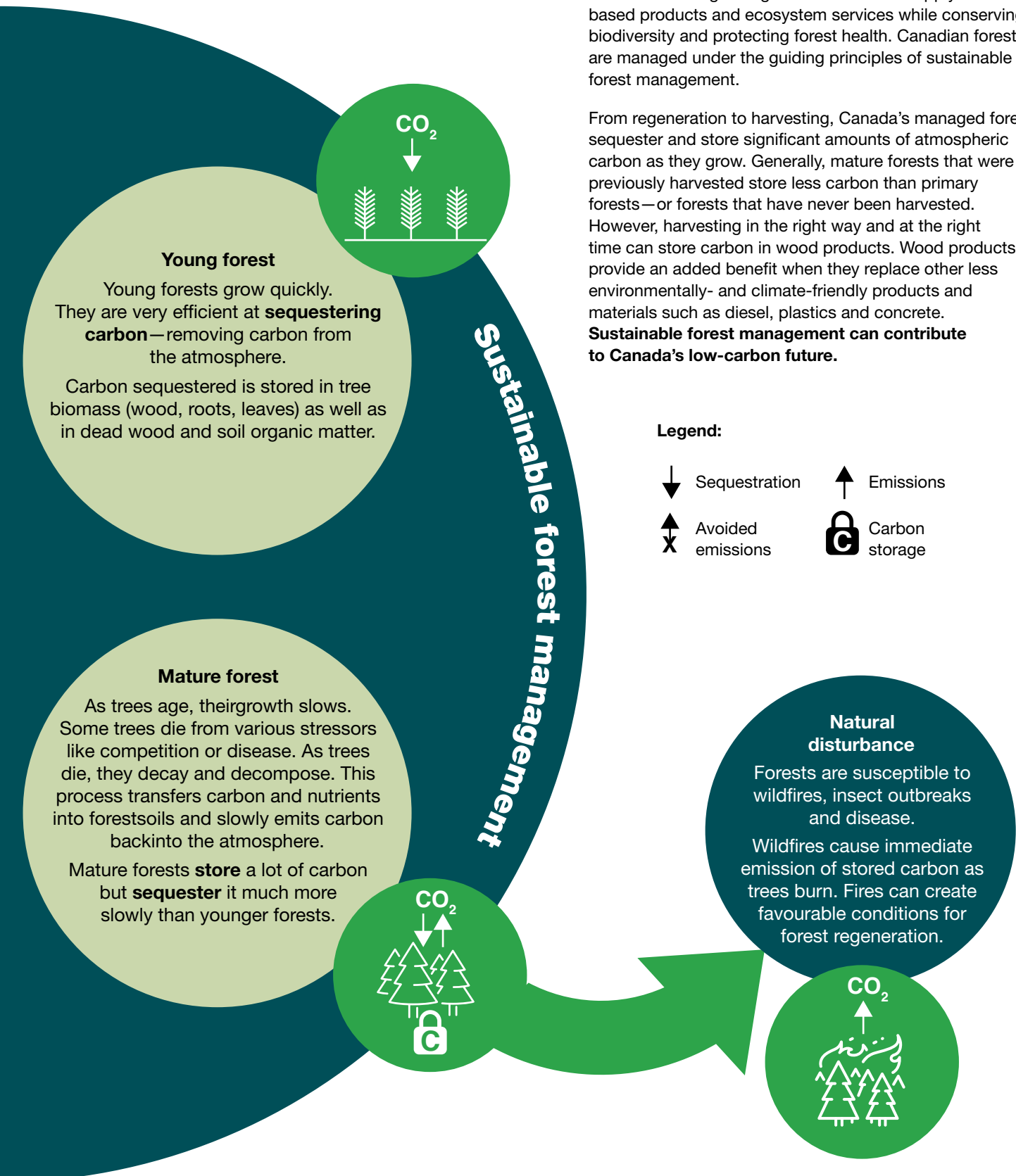
Growing trees and capturing carbon:

How sustainable forest management helps to mitigate climate change



Sustainable forest management aims to maintain and enhance the environmental, social and economic values of forests for the benefit of present and future generations. It involves ensuring a long-term sustainable supply of wood-based products and ecosystem services while conserving biodiversity and protecting forest health. Canadian forests are managed under the guiding principles of sustainable forest management.

From regeneration to harvesting, Canada's managed forests sequester and store significant amounts of atmospheric carbon as they grow. Generally, mature forests that were previously harvested store less carbon than primary forests—or forests that have never been harvested. However, harvesting in the right way and at the right time can store carbon in wood products. Wood products provide an added benefit when they replace other less environmentally- and climate-friendly products and materials such as diesel, plastics and concrete. **Sustainable forest management can contribute to Canada's low-carbon future.**



Sustainable forest management aims to maintain and enhance the ecological, social and economic values of forests, ensuring their availability for present and future generations. Canada follows sustainable forest management principles for managing its forests; in 2021, approximately 698,000 hectares (ha) of forests were harvested in Canada, which represents roughly 0.2% of forested land.

Most forests in Canada are publicly owned

In Canada, provincial or territorial governments own nearly 90% of the forests. These forests are managed according to diverse regulations and policies, which adhere to the overarching principles of sustainable forest management, notably through ecosystem-based forest management planning.

Harvested volumes are based on forest growth

Forest management is a multidisciplinary process involving ground surveys, remote sensing and growth models to determine the composition, age, structure, and growth rates of forests. These factors are used to estimate the volume of wood that can be sustainably harvested while preserving ecosystem functions, such as carbon sequestration and wildlife habitats. Ongoing research aims to integrate climate factors into modeling tools to better understand the impact of climate on forest growth.

Managing forests: Desired states and strategies

Forest management plans outline the current and desired states and values of forest lands, including strategies to achieve sustainable forest management objectives, taking natural disturbances and climate change into consideration. These plans are developed by professional foresters in accordance with laws, regulations and policies. The process involves consultation and collaboration with Indigenous Peoples and other stakeholders, with increasing efforts to incorporate Indigenous knowledge and traditional practices into decision-making.

Climate change presents forest management with new challenges and opportunities

Like other regions around the world, Canadian forests and the forest sector face substantial challenges generated by global change. The shifting climate impacts the ability of some tree species to regenerate and alters forest ecosystems. At the same time, the changing climate can make Canadian forests suitable for growing new tree species that are currently not adapted to grow in northern latitudes.

As a complement to managing forests to favour natural regeneration, planting new trees usually results in higher productivity thanks to tree breeding programs and a better use of available growing space. This also allows for control over forest composition, so that ecosystems can be adapted to future climate conditions and other pressures from global environmental change. Researchers and practitioners are collaborating to develop adaptive silviculture to climate change. They are also working to create a sustainable forest-based bioeconomy sector to help reduce carbon emissions and maintain resilient forest ecosystems.



Forest management plans are created by involving and working together with Indigenous Peoples and other partners who are affected by forest management on public lands.

Forest management certification in Canada

Approximately three-quarters of Canada's managed Crown forest land is certified to at least one sustainable forest management (SFM) standard. In Canada, [three organizations](#) provide forest management certifications that evaluate commercial forestry operations against comprehensive environmental and social standards.

Value of forest management certification

Forest management certification offers benefits to:

- forest companies seeking to demonstrate responsible resource management
- consumers considering sustainably sourced forest products in their buying decisions

Forest management certification was adopted across Canada between the late 1990s and 2008, after which adoption continued to increase at a less rapid pace. Since 2013, certified forest area has stayed relatively steady, ranging from 153 million hectares (ha) certified to 170 million ha certified. As of 2021, 158 million ha of forests are certified.

Third-party forest management certification complements our comprehensive and rigorous [forest management laws and regulations](#). It provides assurance that a forest company is operating legally, sustainably and in compliance with world-recognized standards.

Canada has the largest area of forests in the world that is sustainably managed with third-party certification, along with strong forest management governance. This supports our reputation for being a reliable source of [legally and sustainably produced forest products](#).

Canada's forest management certification systems

Three internationally recognized forest certification organizations are used in Canada:

- the Sustainable Forestry Initiative (SFI)
- the Forest Stewardship Council (FSC)
- the Canadian Standards Association (CSA)

Internationally, FSC Canada is recognized through FSC International. The Programme for the Endorsement of Forest Certification (PEFC) endorses the SFI and the CSA systems. The PEFC is a global alliance of national forest certification systems that promotes sustainable forest management through independent third-party certification.

As of 2021, Canada has 164 million ha of certified forest land, or 36% of the world's total certified forest area. For comparison, Canada's total area of certified forest land is about the same size as the aggregate total area of France, Spain, Germany and the UK combined.

Separate from the three forest certification organizations described above, there is also a unique international certification scheme that is specific to woody biomass. The Sustainable Biomass Program provides assurance that woody biomass (such as wood pellets) is derived from legal and sustainable sources.

Certification systems and standards

Although the forest certification systems used in Canada differ, all are based on rigorous standards that reflect the principles of sustainable forest management.

According to the [Canadian Council of Forest Ministers](#), all [three certification systems](#):

- set high thresholds that forest companies must clear, in addition to Canada's tough regulatory requirements
- provide a stamp of approval showing customers they are buying products originating from forests that meet

comprehensive environmental, social and economic standards

- issue certificates only after a thorough review and determination of conformity with the standards by third-party auditors
- are tailored to consider global forestry issues and circumstances specific to the Canadian landscape, such as the livelihood of local communities and the interests of Indigenous peoples

The standards on which forest certification is based are not static. Expectations of what certification should demonstrate are always changing. Certification standards are regularly revised to keep pace with new knowledge and emerging concerns about sustainable forest management. Additionally, new standards are developed to reflect changing market needs.

Each year, Natural Resources Canada publishes its [State of Canada's Forests report](#), which tracks indicators pertaining to the certification of Canada's forests and provides the most up to date statistics on forest certification in Canada. Read the report to learn more about Canada's efforts to protect the health of our forests.

Find out more

[How much forest does Canada have?](#)

[Forest management planning in Canada](#)

[Information for importers of Canadian forest products](#)

[5 ways Canada prevents illegal logging](#)

[Canadian Forest Service Publications](#)

Related information

[Forest management certification in Canada - Forest Products Association of Canada](#)

[Sustainable Forestry Initiative \(SFI\)](#)

[PEFC Canada](#)

[The Forest Stewardship Council \(FSC\)](#)

[Programme for the Endorsement of Forest Certification \(PEFC\)](#)

Maple syrup production and climate change:

Does the future taste as sweet?



Still seen as a secondary economic sector, maple syrup production is in fact a dynamic industry that imbues new energy into the regions where the next generation is present in numbers. However, climate change is having an impact on sugar maple stands and it is a significant concern to maple syrup producers.

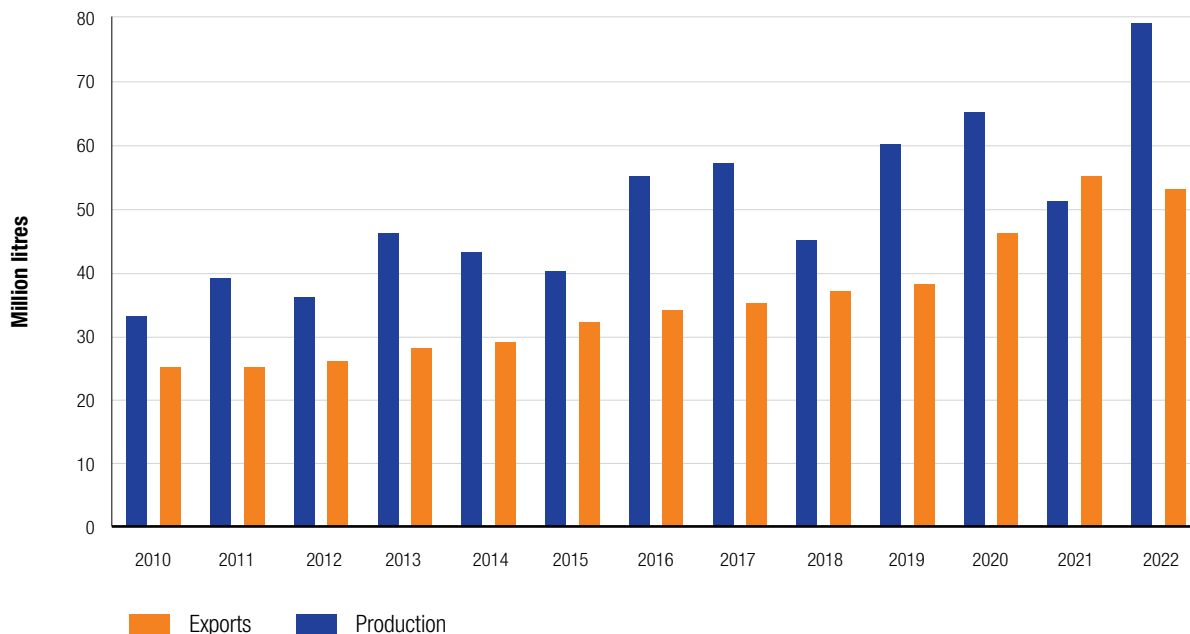
- Canadian maple syrup production is an innovative, growing, and lucrative industry, making Canada the biggest producer of maple syrup in the world.
- Climate change, exotic insects and diseases are becoming more of a threat to maple stands and maple syrup production in North America.
- The maple syrup industry can promote the resilience of current maple stands by using silvicultural practices that increase the vigour of maples and functional diversity of maple stands.
- As climate shifts, it is possible to promote the establishment of maple stands farther north by encouraging the growth of maples where they are already present, and by planting them in a mix with other deciduous species where they are absent.

Maple syrup production, a growing industry in Canada

The use of maple sap, a non-timber forest product, is well rooted in North American history. European colonists learned from First Nations to use maple sap. Maple sugar then became a key staple for early settlers and was later replaced by maple syrup. For many Canadians, maple syrup production has been a source of income, hobby opportunities and family traditions. But over the last 50 years, Canadian maple syrup production has increased sevenfold, from 11 to 79 million litres (M L). This dramatic increase is the result of technological advancements (e.g., maple tubing systems, reverse osmosis, filter presses, high-performance evaporators), and maple syrup producer groups who had a far-reaching and expansive vision.

Maple syrup production in 2022	Québec	New Brunswick	Ontario	Nova Scotia	Canada
Number of taps	48,672,648	3,523,948	2,013,549	420,383	54,647,591
Number of businesses	8,653	188	2,469	120	11,541
Maple syrup produced (M L)	72.5	3.7	2.7	0.2	79.1
Revenues (M \$)	621.6	33.0	31.2	3.0	688.7

Canadian maple syrup production and exports, 2010–2022



Canada produces approximately 70% of the world's maple syrup. The rest comes from the US.

Québec alone is responsible for 90% of Canada's production.

Canadian maple products are exported to nearly 75 countries. The US imports more than 60% of Canadian maple products.

Canadian maple product exports reached \$616 million in 2022.



What does the future hold for maple trees and maple syrup production in terms of climate change and other biotic threats?

The impact that climate has on maple syrup production in Canada is increasing. Early bud break (bud development) in spring increases leaf exposure to late frost and the risk of damage to new developing tissues. This late-frost damage is possibly more significant than exposure to early frost in the fall. If such events become chronic, frost could reduce annual wood growth and the accumulation of reserves.

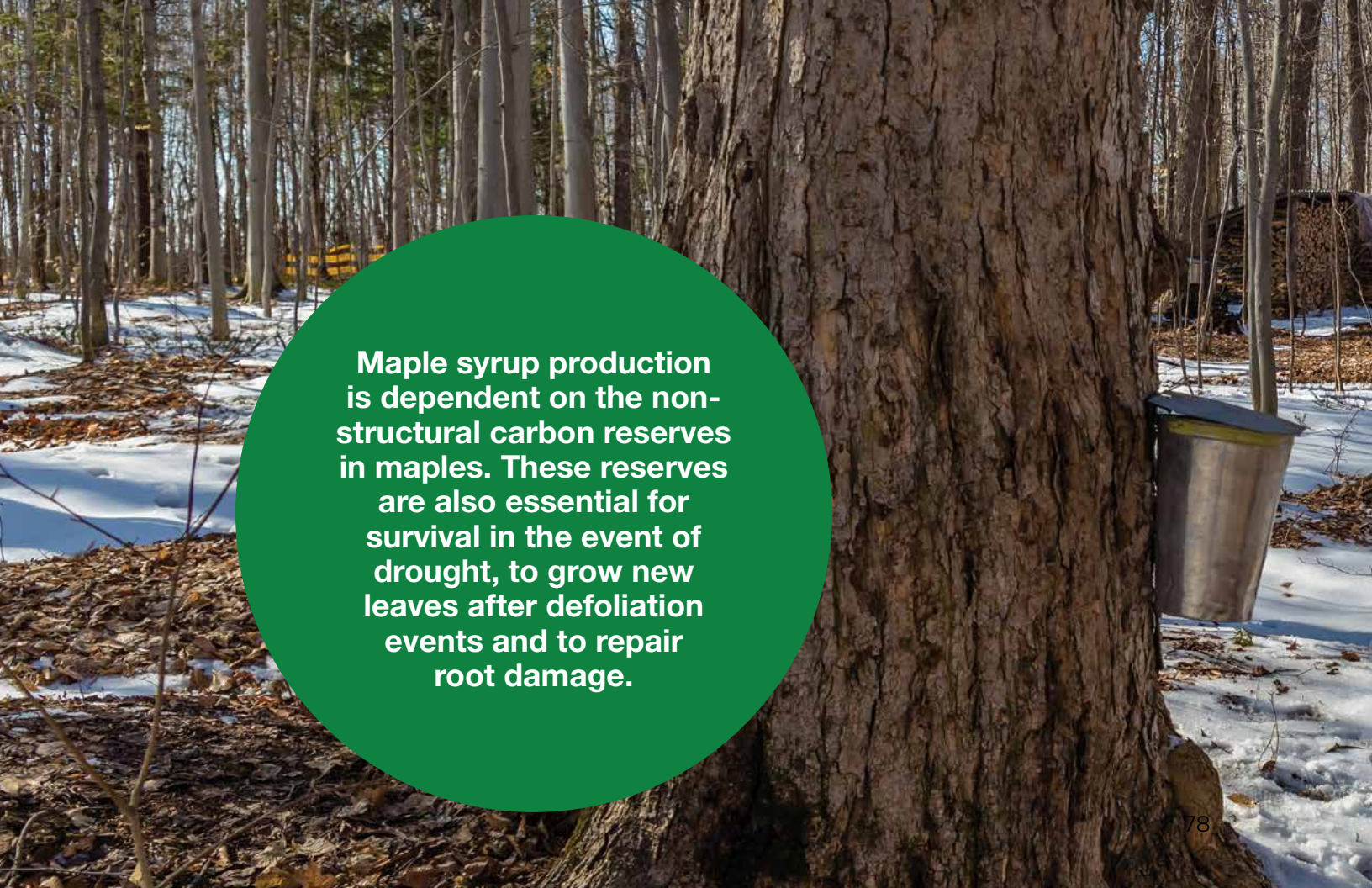
The maple sap season is also starting earlier than in the past. By the end of the century, the season is expected to start another two to three weeks earlier because of the earlier spring. Despite this, the effects of climate change on maple syrup yields are less obvious. Some authors predict that maple syrup production in Québec will increase due to higher temperatures, whereas others foresee little change. However, these predictions do not consider upsurges in extreme weather events (e.g., prolonged droughts, false springs and/or late frosts, periods of extreme heat) and epidemics of alien insects that could have a negative impact on the vigour and survival of our maples, and consequently, maple syrup production.

What can we do to help maple stands?

The maple syrup industry is aware of the impact of climate change and other biotic threats on its activities and is committed to both preserving maple stand health and increasing their adaptive capacity. To that end, silvicultural strategies may be implemented to mitigate climate risks and other threats to maple syrup production, such as:

- liming for select trees or stands, which increases the vigour of maples, enabling them to recover better in response to climate or biotic stress
- thinning, which aims to reduce the water demand of maples during periods of extreme drought
- diversifying, by maintaining a certain number of companion species with complementary functions (functional diversity) in maple stands to promote stand resistance and resilience

Extreme weather events will become more and more frequent in the future. In 2022, a derecho-type storm devastated hundreds of square kilometres of forest in Eastern Ontario and Western Québec. Several maple syrup producers were affected. In October, Hurricane Fiona destroyed forests in Nova Scotia. Some maple syrup producers lost 30% of their taps, others even more. These trees are not replaceable; it takes about 40 years for a maple to reach average sap production levels.

A photograph of a large maple tree trunk in a snowy forest. A metal collection bucket is attached to the trunk. A green circular overlay contains text.

Maple syrup production is dependent on the non-structural carbon reserves in maples. These reserves are also essential for survival in the event of drought, to grow new leaves after defoliation events and to repair root damage.

A slow march north for maple stands

Maples will take hundreds of years, if not more, to migrate north naturally and follow their climate niche. In fact, the strong presence of conifers affects the germination capacity and growth of maples, slowing down their migration. However, there are forest management tools that can help to counter these limiting factors and facilitate their progression to new territories.

When maples start naturally colonizing more northern forests, it may be possible to increase the growth of young maples through thinning. The purpose of thinning is to reduce the number of conifers that slow down the establishment and growth of maples, while increasing the amount of available light. This type of management could facilitate the transition of mixed forests to maple stands. Where maples are absent but weather conditions permit, it may be possible to plant them with other deciduous species that improve the soil to facilitate their establishment and sustain their growth. Such movements, which constitute a form of assisted migration, are best limited to modest northward distances (e.g. < 200 km) to reduce survival risks of the migrated planting stock and to the recipient ecosystem.



Factors slowing the northward progression of sugar maples

- **Very slow growth of maples:** a tree achieves its full maturity between 50 and 100 years
- **Short seed dispersal distance:** most seeds drop to the ground within a radius of thirty metres from the parent tree
- **Adverse soil conditions in boreal forests:** reduced germination and initial survival of seedlings
- **Competition with different species:** lower performance of young trees
- **Seed predation by small mammals**
- **Herbivory (browsing) by deer and moose**



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References

Bartlett et al (2015) Integrative Science and Two-Eyed Seeing: Enriching the Discussion Framework for Healthy Communities.

<https://cbu.scholaris.ca/items/a9c92d9e-fa23-4e34-8f05-33c9a7852fcf>

Climate Atlas of Canada (2019). Indigenous Knowledges and Climate Change: Indigenous ways of knowing are shaping climate solutions.

<https://climateatlas.ca/indigenous-knowledges-and-climate-change>

Crins, William J., Paul A. Gray, Peter W.C. Uhlig, and Monique C. Wester. (2009) The Ecosystems of Ontario, Part I: Ecozones and Ecoregions. Ontario Ministry of Natural Resources, Peterborough Ontario, Inventory, Monitoring and Assessment.

<https://www.ontario.ca/page/ecosystems-ontario-part-1-ecozones-and-ecoregions>

Grenz J (2024). Medicine Wheel for the Planet: A Journey Toward Personal and Ecological Healing. Excerpt from Chapter 2: The Missing Puzzle Piece: The Indigenous Worldview. Book.

Government of Canada (2024). Adaptation.

<https://natural-resources.canada.ca/climate-change/climate-change-impacts-forests/adaptation>

Government of Canada (2024) Assisted Migration.

<https://natural-resources.canada.ca/climate-change/climate-change-adaptation/assisted-migration>

Government of Canada (2024) Birds.

<https://natural-resources.canada.ca/forest-forestry/sustainable-forest-management/birds>

Mahoney R (2019). Understanding Climate Change Impacts on Temperate Forests. Climate, Forests, and Woodlands Extension Community of Practice.

<https://climate-woodlands.extension.org/understanding-climate-change-impacts-in-temperate-forests/>

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References

Natural Resources Canada (2024) Forest Management Certification in Canada.
<https://natural-resources.canada.ca/forest-forestry/sustainable-forest-management/forest-management-certification-canada>

Natural Resources Canada (2015) Forest Pest Management.
<https://natural-resources.canada.ca/forest-forestry/insects-disturbances/forest-pest-management>

Natural Resources Canada (2024). Managing for Diversity: How sustainable forest management conserve and protects Canada's diverse forest values.
<https://natural-resources.canada.ca/forest-forestry/state-canada-forests/managing-diversity-sustainable-forest-management-conserves-protects-canada-s-diverse-forest-values>

Natural Resources Canada (2024) Shape-shifting forests: A tale of climate, wildfires, and surprising outcomes.
<https://natural-resources.canada.ca/stories/simply-science/shape-shifting-forests-tale-climate-wildfires-surprising-outcomes>

Natural Resources Canada (2024). State of Canada's Forests: Annual Report 2023.
https://natural-resources.canada.ca/sites/nrcan/files/forest/sof2023/NRCAN_SofForest_Annual_2023_EN_accessible-vf.pdf

OMNRF (2019). Afforestation Guide for Southern Ontario.
<https://files.ontario.ca/ndmnrf-afforestation-guide-for-southern-ontario-en-2022-01-06.pdf>

Snow M, US Fish and Wildlife Service (2022). How Does Wildfire Impact Wildlife and Forests (graphic). <https://www.fws.gov/story/2022-10/how-does-wildfire-impact-wildlife-and-forests>