ENVIROTHON

NEW BRUNSWICK 2023

2023
NCF-ENVIROTHON
NEW BRUNSWICK

FORESTRY
STUDY RESOURCES

Table of Contents

2023 NCF-Envirothon New Brunswick

Forestry Study Resources

Key Topic 1—Tree Physiology and Identification

1. Explain the fundamentals of plant anatomy as they apply to trees and other common plants, including the parts and tissues of:
    a. Trees
    b. Twigs
    c. Leaves
    d. Reproductive structures (flowers, cones, seeds, et cetera)

2. Explain the formation and function of different types of tissues found in trees and other plants (such as heartwood, sapwood/xylem, phloem, cambium, cuticle, stomata, vascular bundle, terminal bud, lateral bud, leaf scar, etc.)

3. Explain how a tree grows and describe the physical signs of this growth.

4. Explain the chemical processes that take place within plants (including their fundamental importance, basic chemical reaction equations, and impact on plant survival) such as:
    a. Photosynthesis
    b. Respiration
    c. Transpiration

5. Identify common trees of the Acadian Forest Region by leaves, bark, branching patterns, buds, fruit, and other characteristics using scientific or common name without the use of a key.

6. Describe the important characteristics of common trees in the Acadian Forest Region and the uses of these species, including shade tolerance, height, longevity, and importance to Indigenous Peoples.

Study Resources

Resource Title	Source	Located on
Parts of a Tree	*North Carolina Forestry Association, 2022*	Pages 5 - 6
Plant Structures: Stems	Selected excepts from: *Master gardener/Colorado State University Extension/CMG GardenNotes #133, 2016*	Page 7

Plant Structures: Leaves	Selected excerpts from: *University of Georgia Extension/Georgia 4H, 2020* and Selected excepts from: *Colorado State University Extension/CMG GardenNotes #134, 2017*	Pages 8 - 9
Photosynthesis, Respiration, and Transpiration	*Colorado State University Extension, CMG GardenNotes #141, 2016*	Pages 10 - 12
Trees of the Acadian Forest (Adapted from Interactive Guide to Common Native Trees of Nova Scotia)	*Province of Nova Scotia, 2022* and Selected excerpts from: *A Mi'kmaq Traditional and Ecological Knowledge Review of three Wind Project Development Properties. AMEC Environment & Infrastructure, Dartmouth, Nova Scotia. 2013*	Pages 13 - 31

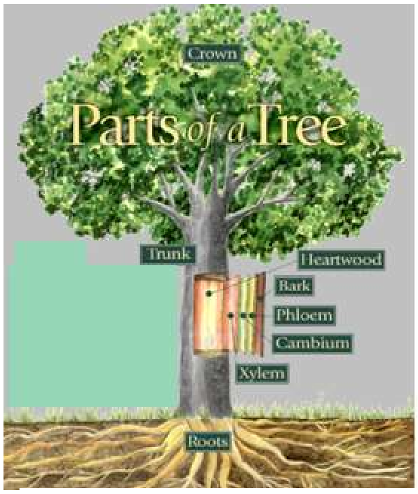
Study Resources begin on the next page!

Parts of a Tree

Crown

The crown, which consists of the leaves and branches at the top of a tree, plays an important role in filtering dust and other particles from the air. It also helps cool the air by providing shade and reduces the impact of raindrops on the soil below.

The leaves are the food factories of a tree. They contain chlorophyll and give leaves their green colour. Through a process called photosynthesis, leaves use the sun's energy to convert carbon dioxide from the atmosphere and water from the soil into sugar and oxygen. The sugar, which is the tree's food, is either used or stored in the branches, trunk, and roots. The oxygen is released into the atmosphere.



Parts of a tree (North Carolina Forestry Association)

Roots

A tree's roots absorb water and nutrients from the soil, store sugar and anchor the tree upright in the ground. All trees have lateral roots that branch into smaller and smaller roots and usually extend horizontally beyond the branch tips. Some trees have a taproot that reaches down as far as 4 to 5 meters. Each root is covered with thousands of root hairs that make it easier to soak up water and dissolved minerals from the soil. The majority of the root system is located in the upper 30 to 50 cm of soil because the oxygen that roots require to function properly is most abundant there.

Trunk/Stem

The trunk, or stem, of a tree supports the crown and gives the tree its shape and strength. The trunk consists of four layers of tissue. These layers contain a network of tubes that runs between the roots and the leaves and acts as the circulatory system for the tree. These tubes carry water and minerals up from the roots to the leaves, and they carry sugar down from the leaves to the branches, trunk, and roots.

Heartwood

As a tree grows, older cells in the center of the tree become inactive and die, forming heartwood. Because it is filled with stored sugar, dyes and oils, the heartwood is usually darker than the sapwood. The main function of the heartwood is to support the tree.

Sapwood

The sapwood comprises the youngest layers of wood. Its network of thick-walled cells brings water and nutrients up from the roots through tubes inside of the trunk to the leaves and other parts of the tree. As the tree grows, sapwood cells in the central portion of the tree become inactive and die. These dead cells form the tree's heartwood.

Cambium

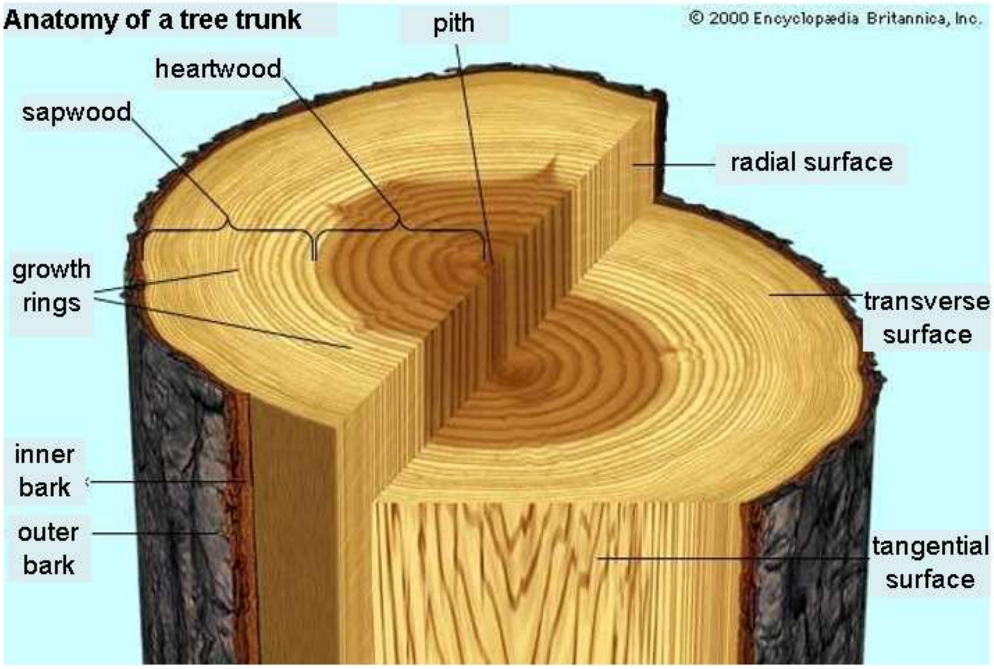
The cambium is a very thin layer of tissue that produces new cells that become either sapwood, phloem or more cambium. Every growing season, a tree's cambium adds a new layer of wood to its trunk, producing a visible growth ring in most trees. The cambium is what makes the trunk, branches, and roots grow larger in diameter.

Phloem

The phloem is located between the cambium and the outer bark. The phloem acts as a food supply line by carrying sap (sugar and nutrients dissolved in water) from the leaves to the rest of the tree.

Bark

The trunk, branches and twigs of the tree are all covered with bark. The outer bark, which originates from old phloem cells, acts as a suit of armor against the world by protecting the tree from insects, disease, storms, and extreme temperatures. In certain species, the outer bark also protects the tree from fire.



Transverse slice of tree trunk, depicting major features visible to the unaided eye in transverse, radial, and tangential sections. (Encyclopædia Britannica, Inc.)

Common Types of Stems in Woody Plants

Shoot – First year growth on a woody or herbaceous plant.

Twig – Woody stem less than one year old.

Branch – Woody stem more than one year old.

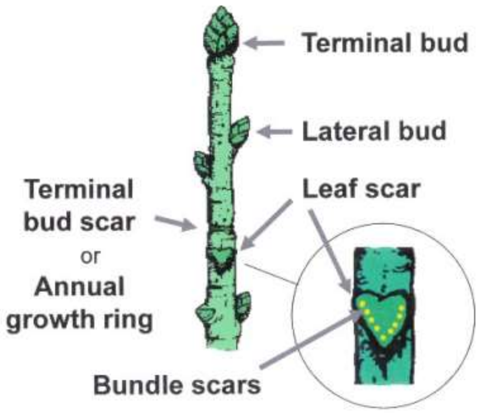
Trunk – Main support stem(s) of woody plants.

Water sprouts – Juvenile adventitious shoots arising on a branch. Generally very rapid, upright-growth, and poorly attached to the main limb.

Suckers – Juvenile adventitious shoots arising from the roots, generally rapid, upright-growing.

Canes – Stems with relatively large pith and usually living for only one to two years (roses, grapes, blackberries, and raspberries).

Plant Structures: Stems



Bud – A stem's primary growing point. Buds can be either leaf buds (vegetative) or flower buds (reproductive). These buds can be very similar in appearance, but flower buds tend to be plumper than leaf buds.

Terminal bud – Bud at the tip of a stem. In many plants, auxin (a plant hormone) released from the terminal bud suppresses development of lateral buds, thereby focusing the growth of the plant upward rather than outward. If the terminal bud is removed during pruning (or natural events) the lateral buds will develop and the stem becomes bushy.

Lateral buds – Grow from the leaf axils on the side of a stem.

Leaf scar – Mark left on stem where leaf was attached. Often used in woody plant identification.

Bundle scar – Marks left in the leaf scar from the vascular tissue attachment. Used in woody plant identification.

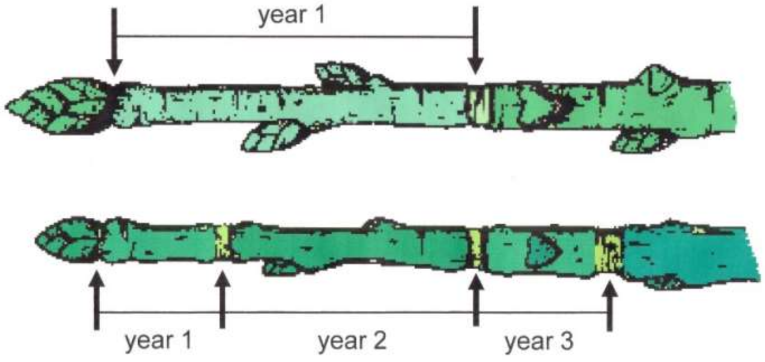
Lenticels – Pores that allow for gas exchange.

Terminal bud scale scars or **annual growth rings** – Marks left on stem from the terminal bud scales in previous years. Terminal bud scale scars are an external measure of annual growth. Therefore, they are important in assessing plant vigour.

Node – Segment of stem where leaves and lateral buds are attached.

Internode – Section of a stem between two nodes.

Bark – Protective outer tissue that develops with age. Used in woody plant identification.



Terminal bud scars or annual growth rings

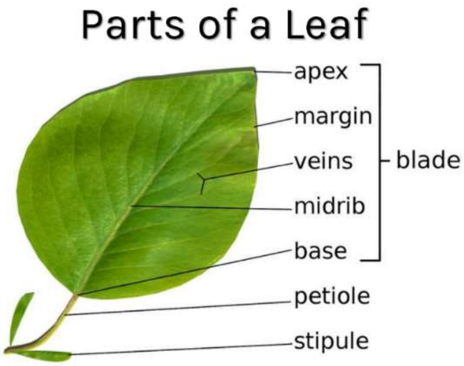
Plant Structures: Leaves

Leaves are the principal structure, produced on stems, where photosynthesis takes place. Cacti are an exception. The leaves are reduced to spines, and the thick green, fleshy stems are where photosynthesis takes place.

Functions of leaves

- To compete for light for photosynthesis (the manufacture of sugars).
- Evapotranspiration from the leaves to move water and nutrients up from the roots.
- Regulate moisture, gas exchange and temperature through small openings on the leaf, known as stomata.

Parts of a leaf



- **Blade**: consists of the apex, margin, veins, midrib, and base. It is the large, flat part of the leaf where photosynthesis occurs.
- **Apex**: tip of the leaf
- **Margin**: edge of the leaf
- **Veins**: carry food/water throughout leaf; act as a structure support
- **Midrib**: thick, large single vein along the midline of the leaf
- **Base**: bottom of the leaf
- **Petiole**: stalk that joins a leaf to the stem; leafstalk
- **Stipule**: the small, leaf-like appendage to a leaf, usually found in pairs at the base of the petiole

Overall Leaf Shape

Leaf shape is a primary tool in plant identification. Descriptions often go into minute detail about general leaf shape, and the shape of the leaf apex and base. The figure below 4 illustrates some common shapes as used in the Manual of Woody Landscape Plants.

Cordate – heart-shaped
Elliptical – leaf widest in the middle, tapering on both ends
Lanceolate – leaf is 3x or longer than wide and broadest below the middle
Linear – leaf narrow, 4x longer than wide (width remains roughly same)
Ovate – leaf is broadest below the middle and about 2x as long as the width (egg-shaped)


Cordate


Elliptical

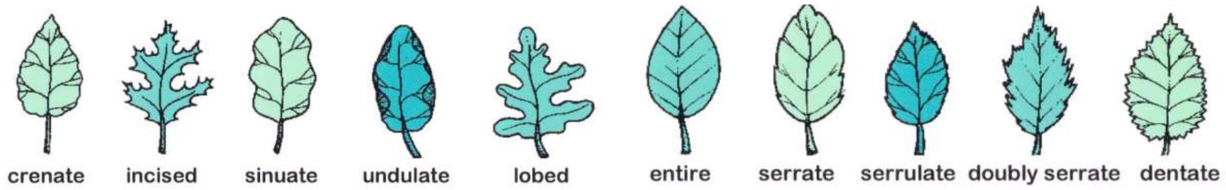

Lanceolate


Linear


Ovate

Leaf Margins

The leaf margin is another tool in plant identification. The figure below illustrates common margin.



Crenate – leaf edge has blunt, rounded teeth
Incised – leaf margins have deep, irregular teeth
Sinuate – margins are slightly wavy
Undulate – very wavy margins
Lobed – leaf edges are deep and rounded
Entire – leaf edge is smooth
Serrate – leaf edges are sharp and saw-like (think serrated knife)
Serrulate – leaf edges with smaller, more evenly spaced serrations than a serrated leaf
Doubly serrate – edges with saw like teeth that have even smaller teeth within the larger ones
Dentate- leaf has triangular or tooth-like edges

Photosynthesis, Respiration, and Transpiration

The three major functions that are basic to plant growth and development are:

- Photosynthesis – The process of capturing light energy and converting it to sugar energy, in the presence of chlorophyll using carbon dioxide (CO_2) and water (H_2O).
- Transpiration – The loss of water vapour through the stomates of leaves.
- Respiration – The process of metabolizing (burning) sugars to yield energy for growth, reproduction, and other life processes.

Photosynthesis

A primary difference between plants and animals is the plant's ability to manufacture its own food. In photosynthesis, carbon dioxide from the air and water from the soil react with the sun's energy to form photosynthates (sugars, starches, carbohydrates, and proteins) and release oxygen as a by-product (Figure 1)

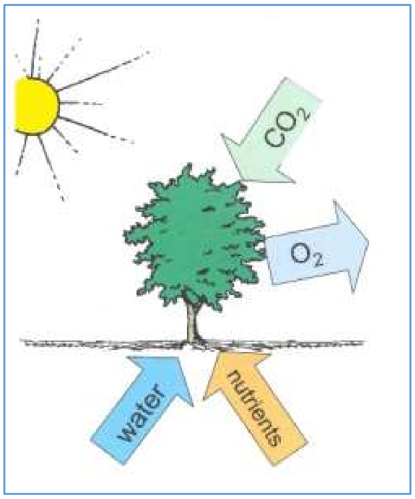


Figure 1. *In photosynthesis, the plant uses water and nutrients from the soil and carbon dioxide from the air, with the sun's energy to create photosynthates. Oxygen is released as a by-product.*

Photosynthesis literally means to put together with light. It occurs only in the chloroplasts, tiny sub-cellular structures contained in the cells of leaves and green stems. A simple chemical equation for photosynthesis is given as follows:

carbon dioxide + water + light energy = glucose + oxygen

$$6CO_2 + 6H_2O + \text{light energy} = C_6H_{12}O_6 + 6O_2$$

This process is directly dependent on the supply of water, light, and carbon dioxide. Limiting any one of the factors on the left side of the equation (carbon dioxide, water, or light) can limit photosynthesis regardless of the availability of the other factors. An implication of drought or severe restrictions on landscape irrigation is a reduction in photosynthesis and thus a decrease in plant vigour and growth.

Transpiration

Water in the roots is pulled through the plant by transpiration (loss of water vapour through the stomates of the leaves). Transpiration uses about 90% of the water that enters the plant. The other 10% is an ingredient in photosynthesis and cell growth.

Transpiration serves three essential roles:

- Movement of minerals up from the root (in the xylem) and sugars (products of photosynthesis) throughout the plant (in the phloem). Water serves as both the solvent and the avenue of transport.

- Cooling – 80% of the cooling effect of a shade tree is from the evaporative cooling effects of transpiration. This benefits both plants and animals.

- Turgor pressure – Water maintains the turgor pressure in cells much like air inflates a balloon, giving the non-woody plant parts form. Turgidity is important so the plant can remain stiff and upright and have a competitive advantage when it comes to light. Turgidity is also important for the functioning of the guard cells, which surround the stomates and regulate water loss and carbon dioxide uptake. Turgidity also is the force that pushes roots through the soil.

Water movement in plants is also a factor of osmotic pressure and capillary action.

Osmotic pressure is defined as water flowing through a permeable membrane in the direction of higher salt concentrations. Water will continue to flow in the direction of the highest salt concentration until the salts have been diluted to the point that the concentrations on both sides of the membrane are equal. A classic example is pouring salt on a slug. Because the salt concentration outside the slug is highest, the water from inside the slug’s body crosses the membrane that is his "skin”. The slug dehydrates and dies. Envision this same scenario the next time you gargle with salt water to kill the bacteria that are causing your sore throat.

Capillary action refers to the chemical forces that move water as a continuous film rather than as individual molecules. Water molecules in the soil and in the plant cling to one another and are reluctant to let go. You have observed this as water forms a meniscus on a coin or the lip of a glass. Thus when one molecule is drawn up the plant stem, it pulls another one along with it. These forces that link water molecules together can be overcome by gravity.

Respiration

In respiration, plants (and animals) convert the sugars (photosynthates) back into energy for growth and other life processes (metabolic processes). The chemical equation for respiration shows that the photosynthates are combined with oxygen releasing energy, carbon dioxide, and water. A simple chemical equation for respiration is given below. Notice that the equation for respiration is the opposite of that for photosynthesis.

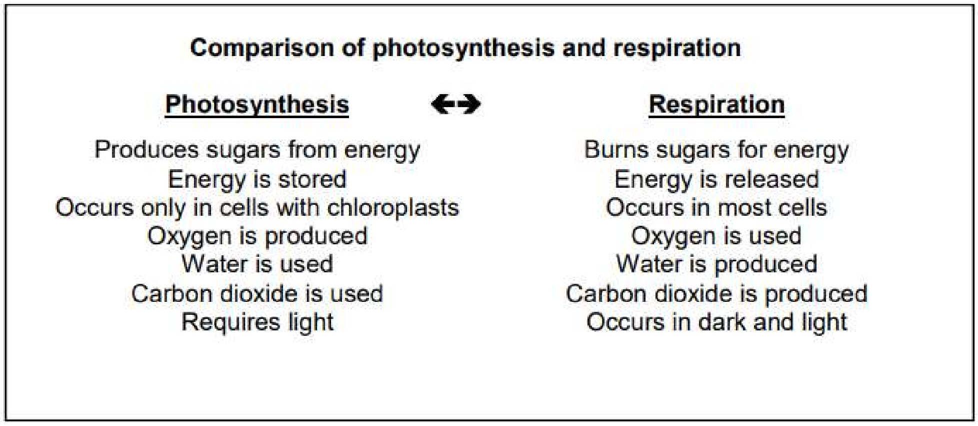
glucose + oxygen = energy + carbon dioxide + water

C6H12O6 + 6O2 = energy + 6CO2 + 6H2O

Chemically speaking, the process is similar to the oxidation that occurs as wood is burned, producing heat. When compounds combine with oxygen, the process is often referred to as “burning”, for example, athletes “burn” energy (sugars) as they exercise. The harder they exercise, the more sugars they burn so the more oxygen they need. That is why at full speed, they are breathing very fast. Athletes take in oxygen through their lungs. Plants take up oxygen through the stomates in their leaves and through their roots.

Again, respiration is the burning of photosynthates for energy to grow and to do the internal “work” of living. It is very important to understand that both plants and animals (including microorganisms) need oxygen for respiration. This is why overly wet or saturated soils are detrimental to root growth and function, as well as the decomposition processes carried out by microorganisms in the soil.

The same principles regarding limiting factors are valid for both photosynthesis and respiration.

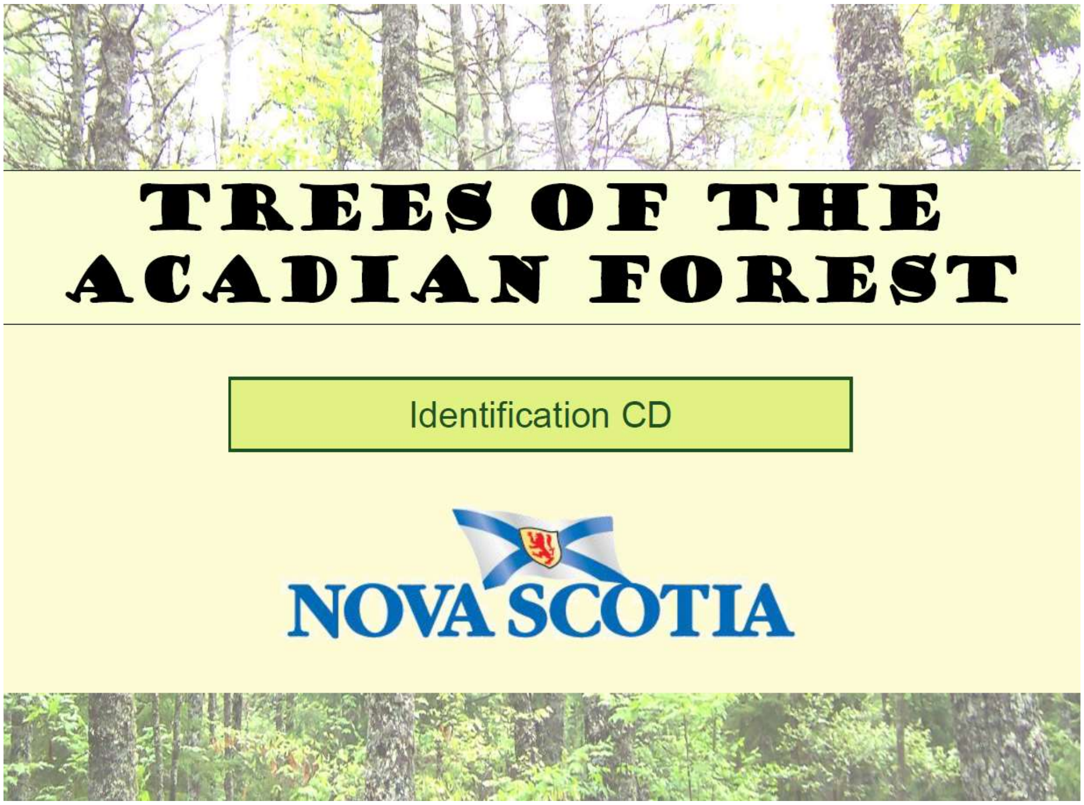


Comparison of photosynthesis and respiration

Photosynthesis	↔	Respiration
Produces sugars from energy		Burns sugars for energy
Energy is stored		Energy is released
Occurs only in cells with chloroplasts		Occurs in most cells
Oxygen is produced		Oxygen is used
Water is used		Water is produced
Carbon dioxide is used		Carbon dioxide is produced
Requires light		Occurs in dark and light

Trees of the Acadian Forest

Most of the content in this section was taken from interactive Guide to common native trees of Nova Scotia. Some content was modified to better represent the situation in New Brunswick https://novascotia.ca/natr/forestry/treeid/



TREES OF THE ACADIAN FOREST

Identification CD

NOVA SCOTIA

HARDWOODS

Black ash
Butternut
Largetooth aspen
Red maple
Red oak
Sugar maple
Trembling aspen
White ash
White birch
Yellow birch

SOFTWOODS

Balsam fir
Black spruce
Eastern hemlock
Eastern white cedar
Eastern white pine
Red spruce
White spruce

Black ash (*Fraxinus nigra*)

Other common name(s): swamp ash, basket ash, brown ash, hoop ash, water ash

Life expectancy: Up to 200 years

Mature height: 18–21 m (60–70 ft)

Mature stem diameter: 20–60 cm (7–24 in) at dbh

Shade tolerance: Intolerant

Timber value(s): Though not as strong as other ash species, it is commercially used for domestic products, cabinets, and some furniture.

Wildlife value(s): The seeds are an important food to game birds, songbirds, and small animals, and the twigs and leaves provide browse for deer and moose.

Indigenous uses: The growth rings of black ash can be separated by beating. The separated growth rings are then cut into strips and used to make baskets. Other uses include canoe ribs, barrel hoops, snowshoe frames, and materials for woven chairs.

TREE-VIA: Black ash is culturally and economically important to First Nations in the Northeastern U.S. and Maritime provinces. Black ash is easily distinguished from green ash and white ash by its foliage. The leaflets do not have a petiole (leaf stalk) and are attached directly to the central stalk. The leaflets of green ash and white ash have petioles and do not attach directly to the central stalk.

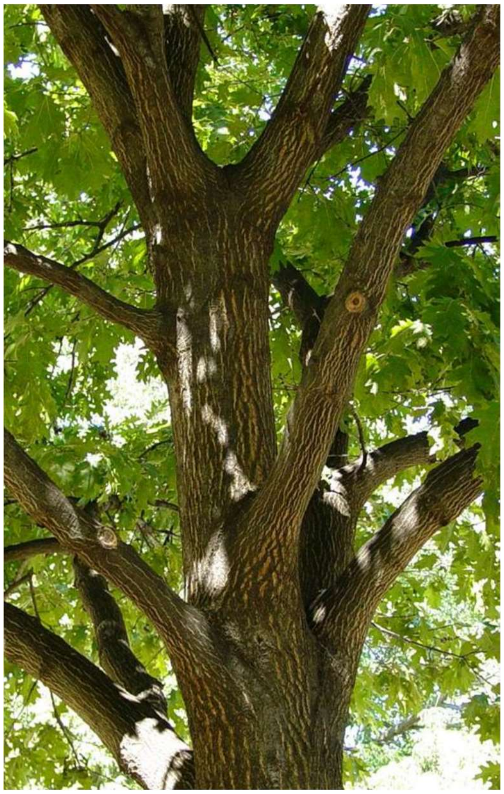
Leaves

- Opposite, compound
- Oval shape that tapers at tip
- Leaflets have no petiole

Bark

- Light gray in colour
- Furrowed edges with corky texture

Butternut (*Juglans cinerea*)



Other common name(s): white walnut

Life expectancy: 60–80 years

Mature height: Seldom exceeding 20 m (70 ft) tall

Mature stem diameter: Up to 90 cm (36 in) at dbh

Shade tolerance: Tolerant

Timber value(s): Not an important timber species but it is used for interior trim, cabinet work, furniture, and small household woodenware

Wildlife value(s): Woodpeckers, fox and grey squirrels crack open the tough shells to get at the tasty butternuts inside. Wood ducks, finches and songbirds eat the buds.

Indigenous uses: The large egg-shaped nuts were collected for food. Although more difficult to extract than walnuts, the flesh of butternuts is delicious. Indigenous People made dyes from different parts of the butternut tree. The husks of butternuts were used to make a light brown dye. A darker brown dye was made from the bark and a black dye from the roots. The wood of butternut is soft and used for carving.

TREE-VIA: The bark can be used for dyeing wool a dark brown colour and was even used to dye hair up until the early 20th century. The butternut tree is threatened by the butternut canker and is listed as endangered.

Leaves

- Leaves: broad, flat, compound leaf with 11 to 17 finely toothed leaflets
- Alternate with terminal leaflet usually present

Fruit

- Elongated, pointed
- Hang in clusters of 2 to 5
- Husk covered in dense, sticky hairs

Largetooth aspen (*Populus grandidentata*)

Other common name(s): aspen, poplar, popple, bigtooth aspen

Life expectancy: 60–100 years

Mature height: 12–18 m (40–60 ft) tall

Mature stem diameter: 30–48 cm (12–18 in) at dbh

Shade tolerance: Intolerant

Timber value(s): Although not very strong or suited for fuelwood, the wood from largetooth aspen is excellent for mouldings.

Wildlife value(s): Important source of wildlife forage for moose, deer, ruffed grouse, beaver, snowshoe hare, and mice.

Indigenous uses: Different parts of the tree used for medicinal purposes.

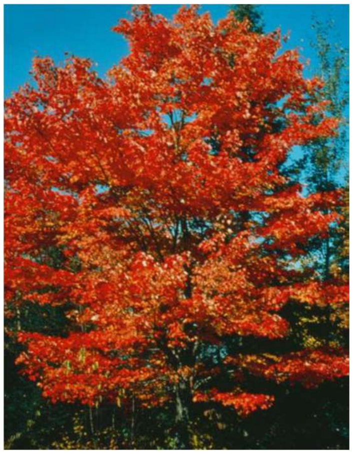
TREE-VIA: A single tree may produce more than 1.5 million seeds!

Leaves

- Simple, alternate
- Dark green above, paler below
- Obvious, round indentations along margin

Immature bark (left): smooth, olive green

Mature bark (right): brownish and furrowed



Red maple (*Acer rubrum*)

Other common name(s): soft maple, white maple, swamp maple, Maritime maple,

Life expectancy: 80–130 years

Mature height: 8–22 m (25–70 ft) tall

Mature stem diameter: 30–46 cm (12–18 in) at dbh

Shade tolerance: Intermediate

Timber value(s): Flooring, furniture, interior finishing, veneers, sporting goods, musical instruments

Wildlife value(s): Sapsuckers utilize as sap trees; important source of winter browse for moose and deer.

Indigenous uses: Although it had a lesser sugar content than sugar maple, red maple sap was collected and boiled to make syrup and sugar that was used in cooking and as a sweet treat. Different parts of the tree used for medicinal purposes. The wood was used to make spoons, bowls, and baskets.

TREE-VIA: Red maple trees have some structure that is red in every season – winter: red buds, spring: red flowers, summer: red petioles or leaf stems, and autumn: red leaves

Leaves

- Opposite, simple
- 3–5 lobes with v-shaped indentations and coarse, saw-like teeth
- Green above, silvery green below
- Turns yellow to red in autumn

Mature bark has deep, vertical ridges

Red maple can regenerate by producing sprouts from a stump, as shown here

It can also reproduce by seed

Red oak (*Quercus rubra*)

Other common name(s): Northern red oak

Life expectancy: 200–250 years

Mature height: 15–21 m (50–80 ft) tall

Mature stem diameter: 30–75 cm (12–30 in) at dbh

Shade tolerance: Intermediate

Timber value(s): Used for flooring, interior finishing, and furniture. Good quality trees are very valuable as ship building lumber.

Wildlife value(s): Acorns eaten by squirrels, deer, insects, and small rodents.

Indigenous uses: Red oak acorns have a high tannin content and have a bitter taste. Boiling the acorns removed the tannins and the acorns were ground into powder and used as flour. Different parts of the tree used for medicinal purposes.

TREE-VIA: Red oak is the provincial tree of the province of Prince Edward Island.

Leaves
- Simple, alternate
- Dull, dark green above and yellow green below
- 7–11 lobes each tipped by a stiff bristle
- Dead leaves sometimes stay on tree all winter

Fruit of red oak is an acorn

Mature bark brown broken into wide ridges

Inner bark orange or yellow

Sugar maple (*Acer saccharum*)

Other common name(s): rock maple, hard maple

Life expectancy: 150–250 years

Mature height: 24–27 m (80– 90 ft) tall

Mature stem diameter: 30–60 cm (12–24 in) at dbh

Shade tolerance: Very tolerant

Timber value(s): Flooring, furniture, interior finishing, veneers, sporting goods, musical instruments.

Wildlife value(s): Young shoots provide food for deer, porcupines feed on bark, sapsuckers utilize as sap trees, and squirrels feed on seeds, buds, leaves, and twigs.

Indigenous uses: Sugar maple sap has a high sugar content which Indigenous People boiled to make syrup and sugar that provided a sweet treat and in cooking. Different parts of the tree were used for medicinal purposes. The wood was used to make bows and arrows, baskets, fish traps, snowshoes, spear handles, and paddles. The fibrous inner bark of maples can be turned into baskets, ropes and even clothing.

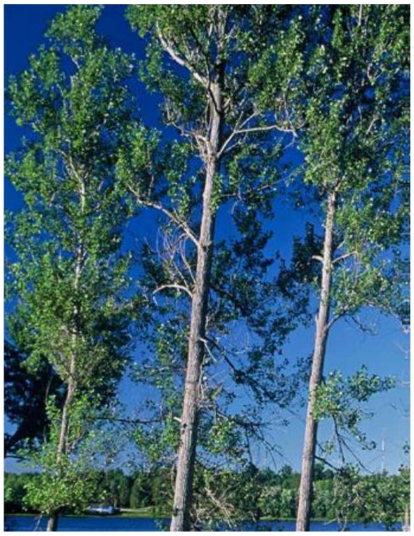
TREE-VIA: It takes up to 40 litres of sap to make 1 litre of syrup!

Leaves

- Opposite, simple
- Thin with 3–5 lobes separated by rounded indentations
- Dark green above and paler below
- Turns wine, scarlet, orange, or yellow in autumn

Mature bark has deep vertical ridges

Fruit of sugar maple is a winged samara, 30–35 mm long and borne in pairs on slender stalks 30–70 mm long



Trembling aspen (*Populus tremuloides*)

Other common name(s): aspen, poplar, popple, quaking aspen

Life expectancy: 60–100 years

Mature height: 12–18 m (40–60 ft) tall

Mature stem diameter: 25–40 cm (10–16 in) at dbh

Growth: Fast growing

Shade tolerance: Intolerant

Timber value(s): Has limited use for pulpwood, matches, and fuelwood.

Wildlife value(s): Important source of wildlife forage for moose, deer, ruffed grouse, beaver, snowshoe hare, and mice.

Indigenous uses: Different parts of the tree used for medicinal purposes

TREE-VIA: Trembling aspen is the most widely distributed tree in North America. It grows from Cape Breton to Alaska and south to Mexico! Trembling aspen gets its name because of the trembling of the leaves, even when little wind is blowing. The trembling of the leaves is the result of a flattened petiole, which is less stable than rounded petioles on most leaves.

Leaves

- Leaf simple, alternate
- Lustrous dark green above
- Dull yellow green below
- Leaf is on a vertically flattened stem about as long as the leaf is wide
- Leaf flutters or trembles in the slightest breeze

Immature bark (left): smooth and pale grey with diamond-shaped indentation

Mature bark (right): furrowed and dark brown or grey

White ash (*Fraxinus americana*)

Other common name(s): American ash

Life expectancy: 100–200 years

Mature height: 18–21 m (60–70 ft) tall

Mature stem diameter: 45–75 cm (18–30 in) at dbh

Shade tolerance: Intermediate

Timber value(s): Highly prized for its strong, shock-resistant wood which makes excellent tool handles and sporting goods.

Wildlife value(s): Shoots browsed by beaver and deer. Porcupine like bark. Seeds eaten by birds and small mammals.

Indigenous uses: White ash wood is strong and has a straight grain. It was used to make bows and arrows, and a variety of tools where a strong wood that resists splitting is required. Although not as good as black ash, white ash is also used to make baskets.

TREE-VIA: Juice made from white ash leaves gives topical relief to mosquito bite swelling and itching.

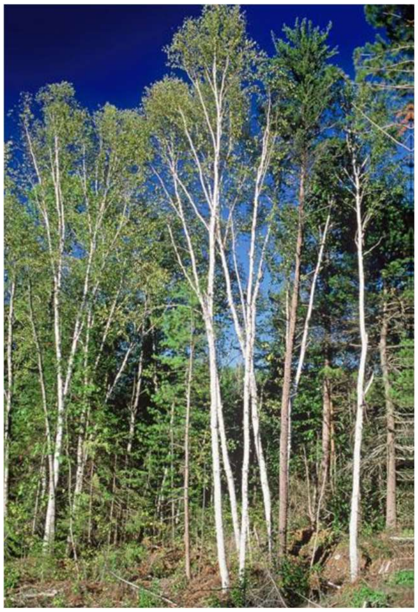
Leaves

- Opposite, compound
- 20–30 cm long, made up of 5, 7 or 9 smooth, sparsely toothed leaflets that are usually oppositely arranged
- Dark green above and paler below

Immature bark (left): smooth, ashy grey, sometimes with an orange cast

Mature bark (right): ashy grey with a fine diamond shaped interlacing, flat topped ridges

White birch (*Betula papyrifera*)



Other common name(s): paper birch, canoe birch

Life expectancy: 80–130 years

Mature height: 15–21 m (50–70 ft) tall

Mature stem diameter: 25–60 cm (10–24 in) at dbh

Shade tolerance: Intolerant

Timber value(s): It can be used as veneer, pulpwood, and fuel wood. Often used for turning.

Wildlife value(s): Important browse for deer and moose.

Indigenous uses: White birch bark is light, strong, water resistant, and pliable and was widely used by Indigenous People. Although the birch bark canoe is what immediately comes to mind, white birch bark was also used for house covering (teepees) to make baskets, boxes, containers for collecting maple sap, dishes, and even coffins.

TREE-VIA: Although white birch bark is one of the best natural tinder, do not rip birch bark off a living tree for your campfire – it will kill the tree. White birch is the provincial tree of the province of Saskatchewan.

Leaves

- Leaves alternate, simple
- Leaf base varies from heart-shaped to rounded
- Smooth, dark green above
- Paler and slightly hairy below

Immature bark (left) is dark brown and thin

Mature bark is many-layered, creamy white, sometimes with a pink tinge

Yellow birch (*Betula alleghaniensis*)

Other common name(s): curly birch, black birch, silver birch

Life expectancy: 150–200 years

Mature height: 18–24 m (60–80 ft) tall

Mature stem diameter: 30–60 cm (12–24 in) at dbh

Shade tolerance: Intermediate

Timber value(s): Yellow birch is the second most commercially valuable hardwood in Nova Scotia and New Brunswick, after sugar maple. It is commonly used for flooring, furniture, cabinets, and veneer.

Wildlife value(s): It is a preferred food of deer and snowshoe hare. Buds are the favourite food source of yellow-bellied sapsucker and grouse.

Indigenous uses: Sap was collected, boiled, and rendered into syrup and sugar, and used in cooking and as a sweet treat. Yellow birch twigs have a wintergreen smell and taste, and a wintergreen-flavoured tea was made by boiling the twigs. Different parts of the tree used for medicinal purposes.

TREE-VIA: Early surveyors often referred to yellow birch as black birch as old trees lose their golden colour and turn black. Yellow birch is the provincial tree of the province of Quebec.

Leaves opposite
Double serrate

Catkins (cylindrical flower cluster without petals) appear in spring

Young bark thin, papery, shiny, golden becoming less golden as tree ages

Balsam fir (*Abies balsamea*)

Other common name(s): fir, balsam

Life expectancy: 70–150 years

Mature height: 15–25 m (45–80 ft) tall

Mature stem diameter: 20–36 cm (8–14 in) at dbh

Shade tolerance: Tolerant

Timber value(s): Pulpwood, lumber, boxes, crates, and of course, Christmas trees!

Wildlife value(s): Shelter for deer, snowshoe hare, mice, voles, and black bears. Seeds are food for several bird species, including spruce and ruffed grouse and the shoots provide deer and moose browse.

Indigenous uses: Different parts of the tree used for medicinal purposes. The boughs were used for as floor covering and for bedding.

TREE-VIA: Balsam fir is the provincial tree of the province of New Brunswick.

Foliage
- Dark, shiny green above
- 2–4 cm long
- White lines on underside of the needles

Bark is smooth, thin, and gray, with bubbles of resin

Cones are cylindrical, erect, 4–10 cm long and break apart when seeds are mature leaving a vertical spike on the twig

Black spruce (*Picea mariana*)

Other common name(s): bog spruce, swamp spruce

Life expectancy: 150–250 years

Mature height: 20–25 m (60–80 ft) tall

Mature stem diameter: 25–30 cm (10–12 in) at dbh

Shade tolerance: Intermediate

Timber value(s): Pulpwood, mine timbers, and rough construction

Wildlife value(s): Spruce grouse and many songbirds all use black spruce for habitat

Indigenous uses: Different parts of the tree used for medicinal purposes. Resin used for patching holes and waterproofing seams in canoes, pails, and other water-resistant objects. Roots used for sewing or lashing many objects including baskets, canoes, snowshoes. Spruce boughs were used as bedding material.

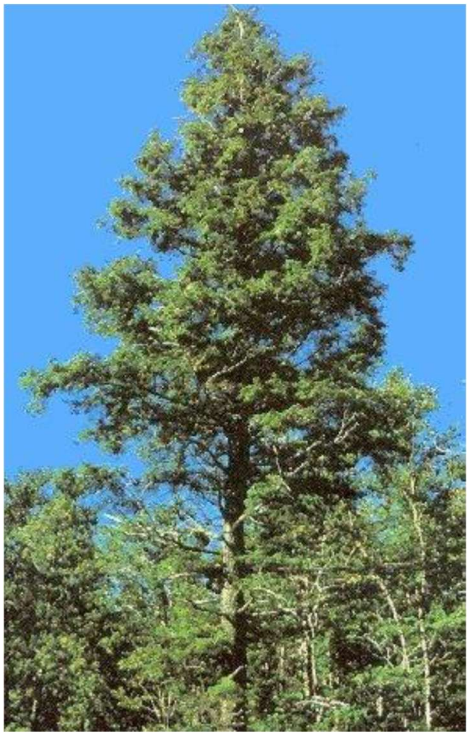
TREE-VIA: Can form a hybrid species with red spruce that is difficult to distinguish from either parent tree. Black spruce is the provincial tree of the province of Newfoundland and Labrador.

Foliage
- Needles blue-green in colour, 0.5–3 cm long
- Four cornered
- Blunt pointed on stunted trees
- Needles sometimes curve to upper side of twig

Cones
- 2–3 cm long
- Cone scales toothed or serrated and brittle

Bark
- Thin, grey to reddish-brown
- Inner bark usually olive green

Eastern hemlock (*Tsuga canadensis*)



Other common name(s): hemlock

Life expectancy: 300–400 years

Mature height: 18–21 m (60–70 ft) tall

Mature stem diameter: 60–122 cm (24–48 in) at dbh

Shade tolerance: Very tolerant

Timber value(s): Bridges, planks, sills, boxes, crates, and general construction

Wildlife value(s): Deer and snowshoe hare browse hemlock and porcupine gnaw bark. Mice, voles and squirrels feed on seeds and small seedlings.

Indigenous uses: Different parts of the tree used for medicinal purposes. Bark used to make dye and for tanning leather. Hemlock wood resists rot and was used for construction.

TREE-VIA: In the late 1800's hemlock was a popular Christmas tree. This was short-lived because the branches were not strong enough to hold ornaments.

Foliage

- Needles dark shiny green, 1–2 cm long
- Needles are flat with two white lines on underside

Cones

- Egg-shaped, 12–20 mm long

Bark

- Inner bark with purplish to cinnamon streaks

Eastern white cedar (*Thuja occidentalis*)

Other common name(s): Northern white cedar, arbor-vitae

Life expectancy: 150–350 years

Mature height: 12–15 m (40–50 ft) tall

Mature stem diameter: 30–60 cm (12–24 ft) at dbh

Shade tolerance: Tolerant

Timber value(s): Fence posts, shingles and canoes, chests

Wildlife value(s): Stands are often used as winter deeryards. Snowshoe hare eat foliage and gnaw the bark of young trees. Many birds use cedar during the summer. Pileated woodpecker often use mature cedar for cavity nests.

Indigenous uses: Cedar is very important to Indigenous People. The foliage is used to make smudge sticks that are used in rituals and cleansing ceremonies. Cedar is one of the four scared medicines along with tobacco, sweet grass, and sage. Cedar bark can be woven into bags and mats or used as twine for sewing. The wood was used to make arrow shafts, canoe slats, kindling and fuel.

TREE-VIA: Arbor-vitae, a common name for cedar, is Latin for “Tree of Life”.

Foliage
- Scale-like, about 0.3 cm long
- Pointed, flattened, overlapped in opposite pairs
- Tightly covering the twig like shingles
- Dull yellow green

Bark
- Thin and fibrous
- Reddish to greyish- brown
- Inner bark is tough enough to make into string or rope

Cones
- Oval in shape, upright
- Grow in clusters on short, curved stalk
- Numerous, leathery scales

Eastern white pine (*Pinus strobus*)

Other common name(s): white pine, soft pine, yellow pine, majestic pine

Life expectancy: 200–400 years

Mature height: 30–35 m (80–100 ft) tall

Mature stem diameter: 60–90 cm (24–36 in) at dbh

Shade tolerance: Intermediate

Timber value(s): Most valuable softwood lumber in eastern Canada. It is highly prized for interior finishing.

Wildlife value(s): Dense young stands make excellent wildlife cover. Whitetail deer eat needles and twigs of white pine. Red squirrels and many species of birds eat seeds.

Indigenous uses: Different parts of the tree used for medicinal purposes. Wood used for kindling and fuel and boughs used for bedding.

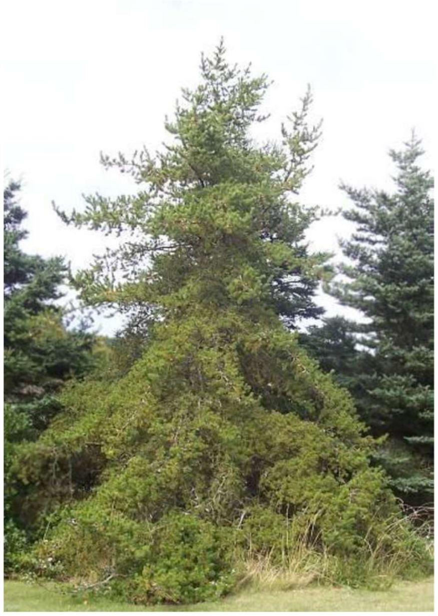
TREE-VIA: Because of its size and strength, white pine was used to make masts for sailing ships. Eastern white pine is the provincial tree of the province of Ontario.

- Needles in clusters of five
- 10 cm long

Immature bark (left)is smooth, dark green
Mature bark (right) deeply furrowed, dark grey

Cones measure 8–20 cm long and are attached to twig by a curved stalk

Jack pine (*Pinus banksiana*)



Other common name(s): princess pine, scrub pine, grey pine

Life expectancy: 80–130 years

Mature height: 12–18 m (40–60 ft)

Mature stem diameter: 20–30 cm (8–12 in) at dbh

Shade tolerance: Intolerant

Timber value(s): Generally used for railway ties, poles and fuelwood.

Wildlife value(s): Jack pine cones and seeds are food for red squirrels, other rodents and birds. Stands provide food and shelter for snowshoe hare and white tail deer.

Indigenous uses: Different parts of the tree used for medicinal purposes.

TREE-VIA: Jack pine cones are serotinous and need a lot of heat to open. That is why it often establishes after a fire.

Needles

- In clusters of two, 2-4 cm long
- Each pair usually twisted and spreading apart
- Light yellow green

Cones

- Yellowish brown; thick scaled
- Usually curved toward branch tip; often borne in pairs
- Remain closed on tree for many years
- Require extreme heat such as fire to open

Bark

- Becomes scaly and furrowed with age

Red spruce (*Picea rubens*)

Other common name(s): yellow spruce, Maritime spruce

Life expectancy: 250–350 years

Mature height: 21–24 m (70–80 ft) tall

Mature stem diameter: 30–60 cm (12–24 in) at dbh

Shade tolerance: Very tolerant

Timber value(s): Valuable lumber and pulpwood species

Wildlife value(s): Winter cover for deer and moose. Also good habitat for ruffed grouse, snowshoe hare, woodcock, mink, skunks, fishers, weasels, and many songbirds.

Indigenous uses: Different parts of the tree used for medicinal purposes. Resin used for patching holes and waterproofing seams in canoes, pails, and other water-resistant objects. Roots used for sewing or lashing many objects including baskets, canoes, snowshoes. Boughs used for bedding.

TREE-VIA: Red spruce is the provincial tree of Nova Scotia and is considered the “holy grail” of woods for acoustic steel string guitars.

Foliage

- Bright yellow green needles are four cornered and up to 1.5 cm long
- Will roll between fingers

Cones

- Egg-shaped, measure 3–5 cm long
- Cone scales stiff
- Margin of cone scales usually not serrated

Bark

- Finely scaled, thin reddish-brown
- Inner bark is black, brownish-yellow

White spruce (*Picea glauca*)

Other common name(s): cat spruce, pasture spruce, skunk spruce

Life expectancy: 100–200 years

Mature height: 18–24 m (70–80 ft) tall

Mature stem diameter: 30–60 cm (12–24 in) at dbh

Shade tolerance: Intermediate

Timber value(s): Pulpwood, lumber, boxes and crates, general construction.

Wildlife value(s): Provides habitat for moose, snowshoe hare, red squirrel, spruce grouse, and many songbirds.

Indigenous uses: Different parts of the tree used for medicinal purposes. Resin used for patching holes and waterproofing seams in canoes, pails, and other water-resistant objects. Roots used for sewing or lashing many objects including baskets, canoes, snowshoes.

TREE-VIA: Black bears will peel away the bark to get at the sweet sapwood. The common names cat spruce and skunk spruce come from the pungent odor of the needles when crushed. White spruce is the provincial tree of the province of Manitoba.

Foliage

- Needles are four cornered, 1–2 cm long
- Sharp pointed
- Blue-green in colour

Cones

- 3–6 cm long
- Cone scales pliable when squeezed

Bark

- Thin, scaly, ash-brown to silver
- Inner bark streaked with rust-brown layer

2023 NCF-Envirothon New Brunswick

Forestry Study Resources

Key Topic 2—Forest Ecology

7. Identify the different Forest Regions of Canada and the tree species that characterize each region.

8. Describe the typical structure of a forest soil and identify unique characteristics of forested soils.

9. Describe the role of fire in ecosystems (including fire-dependent and non-fire-dependent systems) and explain the prominent role that fire plays in the boreal forest.

10. Describe the role that forests and plant communities play in the carbon cycle, including carbon sequestration.

11. Differentiate between primary and secondary succession.

Study Resources

Resource Title	Source	Located on
Forest Regions of Canada	*C.R. Stanton and R.J. Bourchier. The Canadian Encyclopedia, 2015*	Pages 33 - 35
2015 International Year of Soils	*Food and Agriculture Organization of the United Nations, 2015*	Pages 36 - 38
Canada's Forests: CO_2 Sink or Source?	*Canadian Council of Forest Ministers, 2022*	Pages 39 - 42
Forest Fires: Fire ecology	*Government of Canada, 2020*	Pages 43 - 44
Forest Fires: Fire behaviour	*Government of Canada, 2021*	Pages 45 - 46

Study Resources begin on the next page! ➡

Forest Regions of Canada

A forest region is defined as a major geographic belt or zone characterized by a broad uniformity both in physiography and in the composition of the dominant tree species. Canada can be divided into eight forest regions. Sometimes tundra and grasslands are included as forest regions nine and 10, but they are not real forests.

Boreal Forest Region

Approximately 80 per cent of Canada's forested land is in the immense boreal forest region, which swings in an arc south from the Mackenzie River Delta and Alaskan border to northeast British Columbia, across northern Alberta and Saskatchewan, through Manitoba, Ontario, and Quebec terminating in northern Newfoundland on the shores of the Labrador Sea. The northern boreal region consists of open forest with trees growing farther apart and smaller in size as the forest stretches towards the tundra, where only dwarf specimens persist.

The southern boreal region presents a denser, closed forest, which, at its southwest boundary in the Prairie Provinces, gives way to a transitional zone dominated by poplar. Known as the aspen grove, this part of the forest thins out into open, almost treeless prairie. White and black spruce are the principal species of the predominantly coniferous boreal forest, but other conifers (e.g., balsam fir, jack pine and tamarack) also have a wide distribution. There is a general mixture of broad-leaved trees in the region, including white birch, balsam poplar and the wide-ranging trembling aspen.

Great Lakes-St. Lawrence Forest Region

Although it is less than one-tenth the size of the boreal forest, the Great Lakes-St Lawrence is Canada's second-largest forest region. With the exception of a 322 km gap where the boreal region touches the north shore of Lake Superior, this forest stretches from southeastern Manitoba to the Gaspé Peninsula. It is bordered to the south by the deciduous forest region and is a transitional forest between the coniferous and broad-leaved regions. Characteristic species are eastern white pine, red pine, eastern hemlock and yellow birch. Sugar and red maples, beech, red oak, basswood and white elm are also found, as are many boreal species.

Acadian Forest Region

Closely related to the Great Lakes-St Lawrence Forest Region, this region is confined to Nova Scotia, Prince Edward Island, and a large portion of New Brunswick. Red spruce, balsam fir, yellow birch and sugar maple are commonly found. Black spruce, white and grey birch, red oak, white elm, black ash, beech, red maple, trembling aspen, and balsam poplar are also widely distributed.

Deciduous Forest Region

Canada's smallest forest region, this area borders the southeast shore of Lake Huron and the northern shores of Lakes Erie and Ontario. Despite its small size, this region contains the largest number of native tree species of any region. Along with the broad-leaved trees common to the Great Lakes-St Lawrence Forest Region are found the cucumber tree, tulip tree, black gum, blue ash, sassafras, black walnut, and others, which are at the northern limits of their range. Conifers occur only as a scattering of eastern white pine, tamarack, eastern red cedar and eastern hemlock.

Coastal Forest Region

This region covers the lower seaward slopes of British Columbia's Coast Mountains and extends to the coastal islands. Characteristic species are western hemlock, Douglas fir, western redcedar and Sitka spruce, all renowned for their value as timber-producing trees. By comparison, the region's broad-leaved trees (e.g., black cottonwood, red alder, big-leaf maple) have a limited distribution and are of minor economic importance.

Subalpine Forest Region

Composed of coniferous forests, this region is situated on the mountain uplands of British Columbia and western Alberta. Characteristic trees are Engelmann spruce, alpine fir and lodgepole pine, while occasional species include western larch, whitebark pine and limber pine, together with yellow cypress and mountain hemlock on the more westerly ranges. The subalpine region makes an impressive contribution to the scenic splendour of the Canadian Cordillera and offers unique features of watershed protection and stream control in high-mountain source areas. The trees at lower elevations are harvested for timber.

Montane Forest Region

This region includes British Columbia's central plateau and several valley pockets adjacent to the Alberta boundary, areas which share a prevailing dry climate. The characteristic tree of this region is the blue Douglas fir, a smaller variety of the coast-region type. Lodgepole pine and trembling aspen are generally present and white spruce is found in cooler, shaded valley locations. In southern parts of the region's more open forest, ponderosa pine is common. Engelmann spruce and alpine fir from the subalpine region, together with western white birch, are important species of this region's northern limits.

Columbia Forest Region

This region lies in southeast British Columbia between the Rockies and the central plateau and fingers its way through the subalpine region along river valleys and lakes. The forest of this interior wet belt strongly resembles that of the coastal region, although fewer species occur in the interior. Characteristic trees are western redcedar and western hemlock. The blue Douglas fir is widely distributed, and in southern parts western white pine, western larch, grand fir, and western yew are found. Engelmann spruce is found in the upper Fraser Valley and occasionally at higher elevations in the region.

2015
International
Year of Soils

healthy soils for a healthy life

Forests and forest soils: an essential contribution to agricultural production and global food security

Forests and forest soils play a broad, complex, and interactive role within the environment

Soils have provided the foundation for trees and entire forests over millions of years. Soil is an important component of forest and woodland ecosystems as it helps regulate important ecosystem processes, such as nutrient uptake, decomposition, and water availability. Soils provide trees with anchorage, water, and nutrients. In turn, trees as well as other plants and vegetation, are an important factor in the creation of new soil as leaves and other vegetation rot and decompose.

However, the relationship between soils and forests is much more complex and far-ranging. Soils and forests are intrinsically linked, with huge impacts on each other and on the wider environment. The interactions between forests and forest soils help to maintain the environmental conditions needed for agricultural production. These positive effects are far reaching and ultimately help to ensure a productive food system, improved rural livelihoods and a healthy environment in the face of change.

Forests, forest soils, and their interactions carry out key functions that contribute to food security and a healthy environment

1. Climate change: what forests and forest soils do

Carbon emissions are a major contributor to climate change. The world´s forests, in one of their many roles, act as a significant carbon store. 650 billion tonnes of carbon, or nearly one third of the total in terrestrial ecosystems, are captured in forests. Forest soils also store a quantity of carbon equalling that of the global forest biomass, about 45 percent each. An additional ten percent of carbon is found in forest dead wood and litter. In total, forests store as much carbon as the atmosphere.

2. Sustainable soil management needs sustainable forest management, including restoration

The planet needs sustainably managed forests to control soil erosion and to conserve soil. Tree roots stabilize ridge, hill and mountain slopes and provide the soil with the necessary mechanical structural support to prevent shallow movements of land mass: landslides rarely occur in areas with high forest cover.

Sound forest management practices, including measures to introduce or maintain forest cover on erosion-prone soils and run-off pathways, will help control or reduce the risk of soil erosion and shallow landslides. Forest restoration in dryland areas is vital for soil protection.

3. Major ecosystem benefits of forests and soils: clean water and watershed management

By reducing soil erosion and the risk of landslides and avalanches, sustainably managed forests contribute significantly to the systems providing and maintaining the planet's supplies of clean water, while also ensuring a balanced water cycle.

Forests are also a key component of watershed management – an integrated approach of using natural resources in a geographical area drained by a watercourse. Watershed management is a very sound way to protect and rehabilitate areas prone to soil degradation and erosion in upland areas. Forest and soil characteristics are among the key parameters assessed in watershed management planning. Moreover, measures to restore and enhance soil fertility, e.g., through reforestation, have many benefits and are therefore an integral part of any watershed management plan.

4. Soil conservation in semi-arid and arid areas starts with forests and trees

By helping to prevent soil erosion, forests act as a crucial protector of soil resources, for example in preventing or reducing salinization. The challenge in arid-zone forests is therefore to optimize the trade-offs, between water yield and soil protection.

5. Forests can reduce mountain soils' sensitivity to degradation

Steep slopes and thin soil make mountain ecosystems extremely vulnerable to erosion. Mountain soils are often degraded and invariably do not provide enough nutrients for plants to grow well. FAO estimates that around 45 percent of the world's mountain area is not or only marginally suitable for agriculture. The degradation of mountain soil and vegetation cover may happen gradually or rapidly but often takes many years to repair; in some cases, it is irreversible.

The challenges that mountain farmers must overcome are many: short vegetation periods, steep slopes, shallow soils, and the occurrence of landslides. To survive, they have had to develop different ways of averting or spreading risks, employing complex and diversified farming systems on croplands, pastures, and forests. They know that they must make use of different soil types at different altitudes and at different times of the year.

In order to protect our soils, we need to protect our trees and forests

The importance of these effects has often been ignored in the past, with the clearance of tree vegetation and the subsequent loss of millions of hectares of productive land. Furthermore, as forests continue to be cleared-exposing the land to direct attack from wind and rain-soil erosion and land degradation are still undermining agriculture's resource base. In order to protect our soils, we need to protect our trees and forests. Both of these vital resources play pivotal roles in food security and a healthy environment.

CANADIAN
COUNCIL
OF FOREST
MINISTERS

FACT SHEET

CANADA'S FORESTS: CO_2 SINK OR SOURCE?

The world's forests contain more carbon in living trees and plants, organic matter and soil than is contained in the atmosphere—and, each day, forests continue to accumulate and emit vast quantities of CO_2. Canada's managed forest lands store large amounts of CO_2 in trees and soil, but in some years they are net sinks for CO_2—removing more CO_2 from the atmosphere than they emit—while in other years they are net sources. Effective forest management practices can enhance the sink potential of forest lands, thus providing an important opportunity for climate change mitigation.

Photograph from "The Forests of Canada" collection, Natural Resources Canada, Canadian Forest Services, 2003.

How Sequestration Works

The mechanism for carbon sequestration in trees and plants is photosynthesis, the conversion of atmospheric carbon dioxide into plant material using energy from the sun, releasing oxygen in the process. A single hectare of mature trees absorbs approximately 6.4 tonnes of CO_2 per year—an amount approximately equal to the amount produced by driving a mid-sized car with an average fuel efficiency rating of 7.5 litres per 100 kilometres more than 30,000 kilometres.

When a tree is harvested and converted into forest products, the CO_2 it has sequestered over a lifetime is retained within its cellular structure. If the wood is used, for instance, to build a typical 216 square metre wooden house, the house will contain 28.5 tonnes of CO_2.

However, there is another side to the story. When trees die and decompose or are burned, some of the sequestered carbon remains as forest litter and soils, but much of the rest is released back into the atmosphere as carbon dioxide. This is also true for residues left on the forest floor after harvesting. Similarly, as wood products such as paper or building materials decay gradually over time, they, too, return their sequestered CO_2 to the atmosphere.

So, depending on circumstances, forests have the potential to perform either as net *carbon sinks* (sequestering more carbon than they release), or net *carbon sources* (releasing more stored carbon than they capture). Most of this exchange between forests and the atmosphere is by natural processes such as tree growth, decomposition of plant material and disturbances such as forest fires. Human actions such as logging, tree planting, and the long-term preservation of wood products in buildings, furniture or other goods can also strongly influence the forest's role in the global carbon cycle.

Harvesting and Forest Carbon

Forest management activities such as harvesting, tree planting and efforts to fight forest fires and insects have a modest impact on the forest carbon balance. Less than one per cent of the managed forest is harvested in any given year in Canada. During harvesting activities, only a fraction of the carbon in the harvested wood is emitted into the atmosphere as carbon dioxide through processes such as the decay of branches, roots and leaves left on the forest floor. Regeneration of

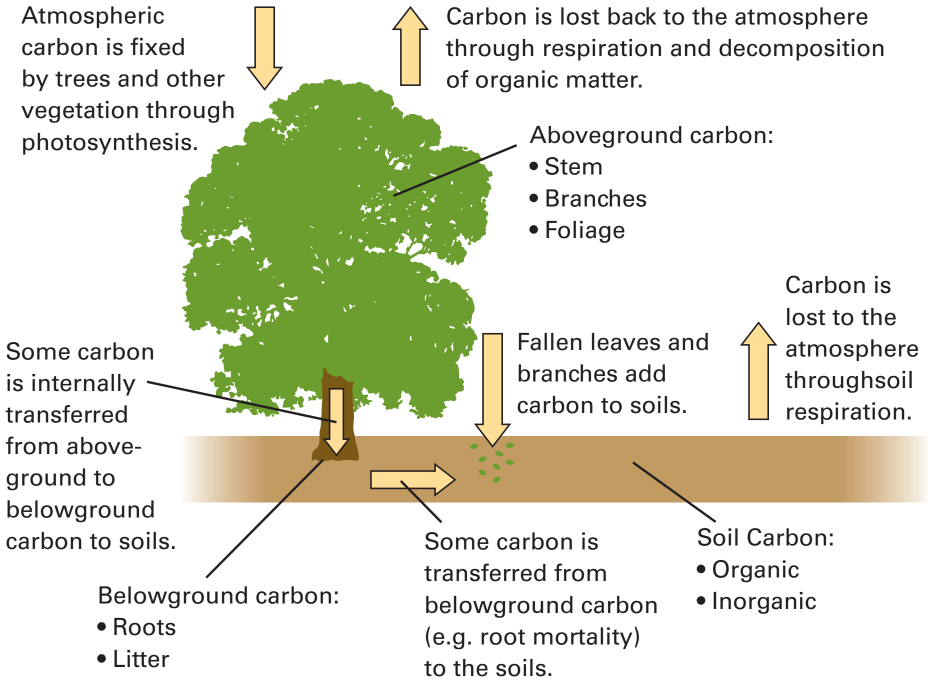
What is Embodied Energy?

Every material used in construction has embodied energy. This is the sum of the energy required to extract, harvest, process, manufacture, transport, construct and maintain a material or product used in building applications. Embodied energy is also related to emissions of water and air pollutants, including greenhouse gases, associated with the production and use of a given product. Consequently, embodied energy plays an important role in determining the environmental friendliness of a building product.

Lumber, with an embodied energy value of approximately 2.5 MJ/kg (megaJoules per kilogram), is thus much more environmentally friend-ly than building materials such as gypsum wallboard (6.1 MJ/kg), glass (15.9 MJ/kg), steel (32 MJ/kg), or aluminum (227 MJ/kg).

Photograph from "The Forests of Canada" collection, Natural Resources Canada, Canadian Forest Services, 2003.

The CO_2 Sequestration Cycle



Source: US Environmental Protection Agency
http://www.nrs.fs.fed.us/niacs/forests/carbonsequestration/

the forest, as well as the absorption of CO_2 and nutrients by other plants, animals and organisms, then takes up large amounts of carbon in the area harvested, which tends to balance earlier emissions.

Much of the harvested carbon is stored for a long time in forest products. In Canada, about 50 per cent of the carbon harvested and removed from the forest is stored in long-lasting structures such as houses, with another 25 per cent going into less-durable products such as wooden pallets and paper products. The remaining carbon (about 25 per cent) is in the form of harvesting residues. There is increasing interest in using these residues to produce bioenergy, which substitutes for fossil fuels.

Are Canada's Forests a Carbon Sink?

Throughout most of the past century, Canada's managed forest has been a strong *carbon sink*, adding more and more carbon to the amount already stored. However, in recent decades, the average annual *carbon sink* provided by Canada's managed forest has decreased.

According to estimates prepared by Natural Resources Canada's Canadian Forest Service and reported in Environment Canada's annual greenhouse gas *National Inventory Report*, between 1990 and 2010, Canada's managed forest was an overall sink in 11 out of 21 years. It ranged from a sink of 101 million tonnes CO_2e (carbon dioxide equivalents) in 1992, to a source of 182 million tonnes CO_2e in 1995.

Can the Forest Sector Help Mitigate Climate Change?

Ongoing research at Natural Resources Canada's Canadian Forest Service Forest has established that management activities and the use of forest products can contribute substantially to reductions in greenhouse gas emissions.

In the short term, the most effective approach is to seek emission reductions, for example, through protection against fire and insects and the use of site preparation methods that conserve carbon, such as avoiding the burning of logging slash. Avoiding deforestation—the permanent removal of forests and conversion of the land to other uses such as agriculture, roads or urban development—is also an effective means or reducing carbon emissions.


Photograph from "The Forests of Canada" collection, Natural Resources Canada, Canadian Forest Services, 2003.

In the long term, increasing the forest area through afforestation (planting new forests) and forest management practices that increase forest carbon stocks, such as lengthening harvesting rotations and ensuring prompt regeneration after harvest and disturbances, can also contribute to increased forest carbon stocks.

Wood products extend the time period during which the sequestered carbon is kept out of the atmosphere after harvesting. In addition, products and fuels derived from wood produced through sustainable forest management can offset fossil fuel emissions from other sectors of the economy, helping to reduce greenhouse gas emissions.

The fluctuation in the sink–source carbon balance during this period was closely associated with annual forest fires. In Canada, a full fire-suppression response is used in attempts to control fires as quickly as possible in forests managed for wood products. In other forest areas, mainly in northern Canada, a modified fire-suppression response attempts to control fires in a limited way or simply to monitor their progress. Wildfires started by natural phenomena such as lightning are responsible for about 85 per cent of the area burned in the total forest (managed plus unmanaged) each year. In extreme fire years, such as 1995, direct emissions from wildfires in the managed forest have represented up to 45 per cent of Canada's total greenhouse gas emissions.

In addition, since 1999, the mountain pine beetle infestation in western Canada has been increasing emissions as trees are killed and begin to decay. Accelerated harvesting of these trees is helping to reduce the climate change impacts of the infestation.

As natural conditions change and as effective forest management practices are applied, it is expected that the *sink* potential of Canada's forest lands will, more often than not, continue to play a significant role in climate change mitigation.

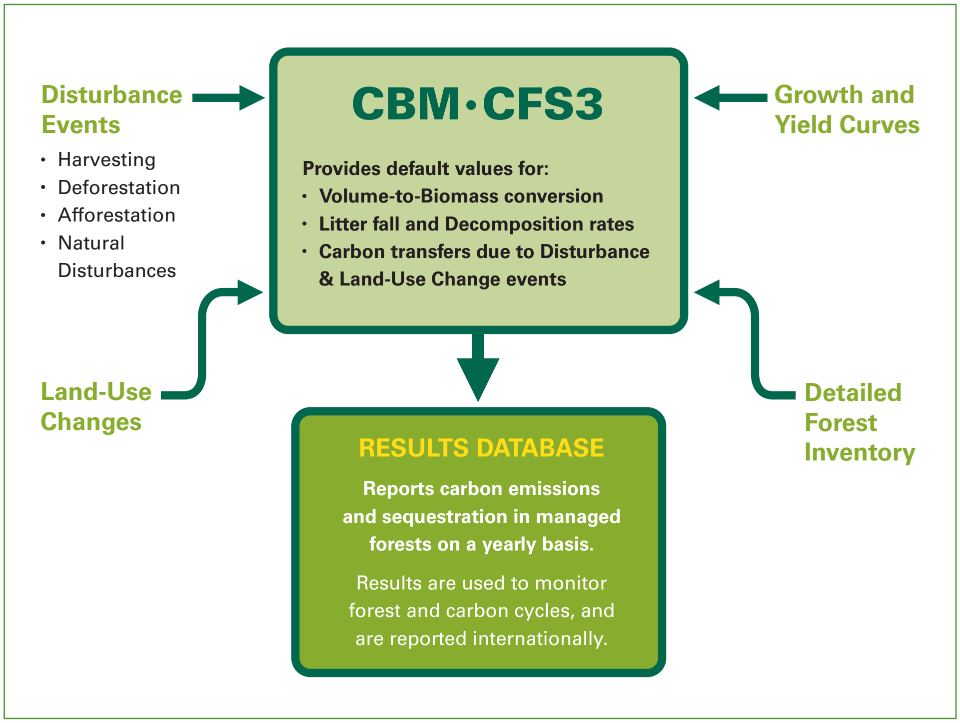
CANADIAN COUNCIL OF FOREST MINISTERS

FACT SHEET

Photograph from "The Forests of Canada" collection, Natural Resources Canada, Canadian Forest Services, 2003.

Canada's Carbon Budget Model

The Canadian Forest Service (CFS) has developed a sophisticated model of Canada's forest carbon budget to help forest agencies and companies calculate carbon stocks for monitoring or projection purposes. The *Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3)* is a computer simulation program based on the latest scientific understanding of the factors that affect forest carbon. Drawing on the best available information on forests and tree growth from resource management agencies in all of Canada's provinces and territories, the simulation model enables users to apply their own stand- or landscape-level forest management information to simulate and compare various forest management scenarios in order to assess impacts on carbon.



Disturbance Events

- Harvesting
- Deforestation
- Afforestation
- Natural Disturbances

Land-Use Changes

Growth and Yield Curves

Detailed Forest Inventory

CBM·CFS3

Provides default values for:

- **Volume-to-Biomass conversion**
- **Litter fall and Decomposition rates**
- **Carbon transfers due to Disturbance & Land-Use Change events**

RESULTS DATABASE

Reports carbon emissions and sequestration in managed forests on a yearly basis.

Results are used to monitor forest and carbon cycles, and are reported internationally.

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Forest Fires: Fire ecology

Fire in Canada’s forests varies in its role and importance.

In the moist forests of the west coast, wildland fires are relatively infrequent and generally play a minor ecological role.

In boreal forests, the complete opposite is true. Fires are frequent and their ecological influence at all levels—species, stand and landscape—drives boreal forest vegetation dynamics. This in turn affects the movement of wildlife populations, whose need for food and cover means they must relocate as the forest patterns change.

The boreal: A forest shaped by fire

The Canadian boreal forest is a mosaic of species and stands. It ranges in composition from pure deciduous and mixed deciduous-coniferous to pure coniferous stands.

The diversity of the forest mosaic is largely the result of many fires occurring on the landscape over a long period of time. These fires have varied in frequency, intensity, severity, size, shape, and season of burn.

This photo sequence shows: 1) A fire, 2) The regrowth of aspen 1 year after fire, 3) Burned tree with black-backed woodpecker, 1 year after fire, 4) A 50-year stand, 5) A 100-year stand, 6) 150 years of growth, 7) Old-growth forest (with gap dynamics)

The biodiversity of northern circumpolar boreal forests is largely a fire induced diversity—sometimes termed “pyrodiversity”.

How various boreal species respond to fire

Fire strongly influences the structure, growth and renewal of many of Canada’s forest and grassland communities. Different species, however, respond differently to fire.

After a fire, forest regeneration on burned sites begins with the establishment of pioneer species, notably aspen, white birch, jack pine and lodgepole pine. All of these species require full sunlight to thrive, and all are well adapted to landscapes where fires regularly recur. Aspen and birch are able to re-establish quickly by sprouting from stumps and roots of burned trees. These species are also able to recolonize burned sites by producing abundant seeds that can be blown by wind over long distances.

Black spruce, with its semi-serotinous cones may also become established in the years following a fire, but this species grows slower in full sunlight than the pioneer species do. If fire does not occur for more than 100 years, the early pioneer trees eventually die and become replaced by the black spruce growing in the understory. Other shade tolerant species then establish under the shady cover.

Species such as balsam fir, white spruce and white cedar have no special adaptations to fire. They can colonize burned areas only by coming in from unburned refugia. (This might occur, for example, when the seeds of these species are blown into a burned area by the wind or carried by animals.) As a result, these species take a long time to reappear in burned stands after a fire—in some cases, as long as 150 years. Because extensive fires place balsam fir and cedar at a disadvantage, these species are rare in areas that are repeatedly severely burned or where fires are large.

The fire management balancing act

Fire is a vital ecological component of Canadian forests and will always be present. The ongoing challenge for fire management agencies is therefore how to manage fire to protect human values while still allowing fire to play its important ecological role in maintaining healthy forests.

Forest Fires: Fire behaviour

Fire behaviour refers to the manner in which fuel ignites, flames develop and fire spreads. In wildland fires, this behaviour is influenced by how fuels (such as needles, leaves and twigs), weather and topography interact.

Once a fire starts, it will continue burning only if heat, oxygen, and more fuel are present. Together, these three elements make up the “fire triangle.”

To put out a fire requires eliminating one or more of the fire triangle’s elements. Firefighters work to do that by:
- cooling fuels below the combustion temperature through the use of water, foam, retardant, or dirt
- cutting off the oxygen supply through the use of water, retardant, or dirt
- removing fuel by clearing a swath of trees and brush ahead of the advancing fire

There are three basic types of forest fires:

1. **Crown fires** burn trees up their entire length to the top. These are the most intense and dangerous wildland fires.
2. **Surface fires** burn only surface litter and duff. These are the easiest fires to put out and cause the least damage to the forest.
3. **Ground fires** (sometimes called underground or subsurface fires) occur in deep accumulations of humus, peat and similar dead vegetation that become dry enough to burn. These fires move very slowly, but can become difficult to fully put out, or suppress. Occasionally, especially during prolonged drought, such fires can smoulder all winter underground and then emerge at the surface again in spring.

Lightning strikes cause slightly less than half of all wildland fires in Canada, but account for nearly 67% of the land area burned. There are two main reasons for this:

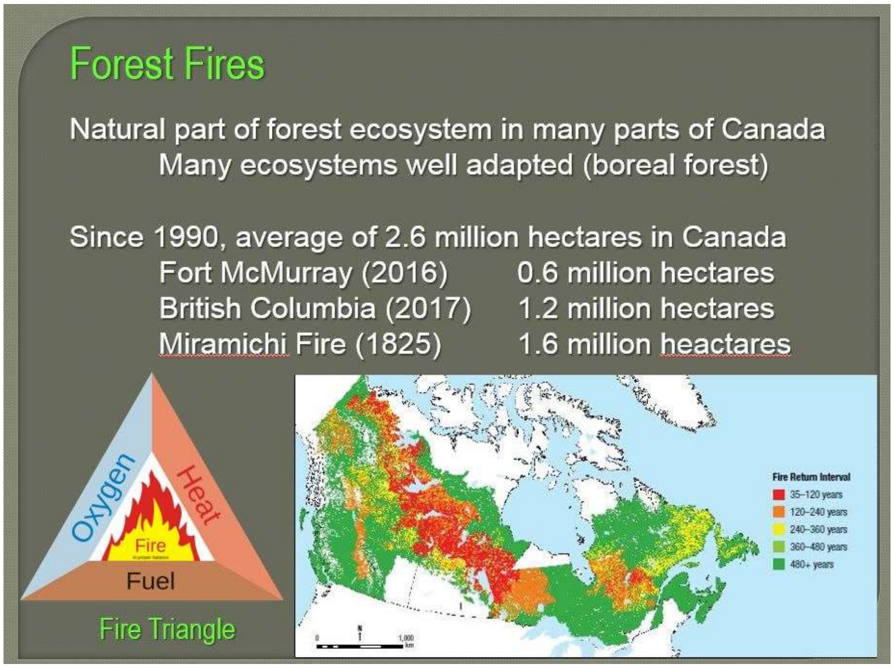
- Lightning-caused fires often occur in remote areas where human life, property and timber values are not threatened. Fire suppression in these areas may therefore be intentionally limited, leaving fire to play its natural role.
- Several lightning fires can be ignited simultaneously, leaving agencies with difficult decisions about where to send available firefighting crews and equipment.

Humans cause slightly more than half of all wildland fires in Canada, typically in populated forest and grassland areas. Because of where these fires occur, they are usually spotted early and can be reached quickly by firefighting crews. Still, the threat they pose to human safety and property makes them a major concern for firefighting crews.

Forest Fires in New Brunswick

The Great Miramichi Fire of 1825 is the biggest fire ever recorded in New Brunswick and one of the largest ever to occur in North America. It is reported to have burned 1.6 million hectares or about 20 percent of the province.

In recent years Canada has experienced other large forest fires. The Fort McMurray fire in 2016 burned 600,000 hectares and in 2017, fires in British Columbia alone totaled 1.6 million hectares. Climate change and insect infestations may result in more frequent and severe forest fires in the future.



Forest Fires

Natural part of forest ecosystem in many parts of Canada
    Many ecosystems well adapted (boreal forest)

Since 1990, average of 2.6 million hectares in Canada

Fort McMurray (2016)	0.6 million hectares
British Columbia (2017)	1.2 million hectares
Miramichi Fire (1825)	1.6 million heactares

Source: G.R. Morrison.

2023 NCF-Envirothon New Brunswick

Forestry Study Resources

Key Topic 3—Forest Management

12. Describe silvicultural treatments for reforestation, stand improvement, and stand regeneration.

13. Explain how management strategies differ between even and uneven aged stands.

14. Identify common silvicultural practices used in New Brunswick forests and their associated management goals.

15. Apply silvicultural practices to make recommendations based on management goals in the field.

Study Resources

Resource Title	Source	Located on
History of Forestry in New Brunswick	Excerpts from: *Bill Parenteau. Looking Backward, Looking Ahead: History and Future of the New Brunswick Forest Industries. Acadiensis, 2013.* and *Provincial archives of New Brunswick. Province of New Brunswick, 1998-2022*	Pages 48 - 51
New Brunswick's Forests at a Glance	*Management of New Brunswick 's Crown Forest. Department of Natural Resources, Province of New Brunswick (page 2), 2003*	Page 52
Forest Management in New Brunswick	*Bernard Daigle, 2022*	Pages 53 - 63
Even-Aged and Uneven-Aged Management	*Province of British Columbia, Excerpt from Silvicultural Handbook for British Columbia, British Columbia Ministry of Forests, 2003*	Pages 64 - 66

Study Resources begin on the next page! ➡

History of Forestry in New Brunswick

The profound relationship between New Brunswickers and their forest heritage began many centuries ago. Early aboriginal inhabitants relied on the forest for food, clothing, and shelter. They developed spiritual traditions based on trees and gathered woodland plants for medicine. European settlers used wood to make everything from barrels and furniture to buckets and sewer pipes. Trees were burned as fuelwood, charcoal, and fertilizer production.

Forestry is the largest industry in New Brunswick today. It has been our economic mainstay since the early 1800s. The history of forestry in New Brunswick came of age in the late 17th century and can be broken down into several distinct periods:

Trade in great ship masts and spars (1760–1800)

The first, shortest, and least disruptive phase in the New Brunswick forest industries – the trade in great ship masts and spars for the British Navy – was a product of environmental conditions and the political conflict in the 1770s caused by the American Revolution.

From a production standpoint, mast making was an uncomplicated industry that involved felling trees and floating them to a harbour where they could be loaded for transatlantic shipment. However, the industry was limited by the need for enormous white pine trees that were straight and free of defects. Large masts could exceed 30 meters in length with a diameter of 75 cm at the small end. They required trees that measured 45 meters in height and 2 meters in diameter at the stump. Masts were moved by teams of oxen in winter and usually cut within sight of a body of water that was deep enough to float a 30-meter stick of wood weighing several tons. It was a highly selective industry that was, on the one hand, wasteful and prone to rapid resource depletion. However, it did not impose a significant drain on the forest reserves of the colony.

Mast making reached its peak during the 1790s and 1800s when New Brunswick produced up to 3,000 masts per year, a substantial proportion of the total shipped from the loyal British North American colonies.

Coming of age (1800–1900)

During the nineteenth century, trees were used to build bridges and make railway ties, but the primary purpose was to build houses and clear tracts of land for agriculture. Farmers used wood from trees to make harrows, tool grips and handles, and toys for their children. Fishermen used wood to build boats and make oars and shipping containers. In the home, fir and spruce were used for making pails, basins, salt boxes, and butter churns, while cedar was often used for containers that did not come in contact with food.

The forests were also an important source of added annual income. It was commonplace and indeed expected that men would go work in the lumber camps in October and not return until the following spring.

Figure 1. This photo shows loggers working in a camp in winter. This log building was typical of those found in lumber camps. (Photo credit: Provincial archives of New Brunswick).

The disappearance of ice from the rivers and streams in April heralded the end of the tree felling season and the beginning of the log drive. The logs were thrown into the water and, if possible, assembled into timber rafts to be taken to a port or to a shipyard or sawmill.

Figure 2. The log drive consisted in sending the logs floating downriver, sometimes aided by drivers who kept everything moving in the right direction. Driving was hazardous work, given the ever-present risk of toppling into the icy water. (Photo credit: Provincial archives of New Brunswick).

Sawmilling was a much more appropriate industry for facilitating the transition of New Brunswick from a resource frontier to a settled colony. The value added in manufacturing lumber made the cost of transportation across the Atlantic a smaller proportion of the overall cost of production. By mid-century, there were 640 sawmills in the province.

New Brunswick's extensive river system gave loggers easy access to the interior with its rich stands of pine, spruce, and hemlock. Sawmills churned out square-cut timber for domestic and overseas consumption. At mid-century, forest products accounted for more than 80 per cent of the province's total exports. Most of the product was shipped to Britain, but New Brunswick shipbuilders also consumed their share.

From the early 1800s, sailboat construction was a major occupation in many places around New Brunswick. Several other types of boats were also built in the province during that time. They included fishing boats and freighters. Boat building was one of New Brunswick's leading industries in the 19th century.

Figure 3. The photo shows builders at work in the interior of a boat. In the mid-19th century, shipbuilding was going full steam in New Brunswick. Each ship was built to its own specifications, depending on its intended use: hauling large cargos over the seas, speeding across the Atlantic, or carrying passengers. (Photo credit: Provincial archives of New Brunswick).

Yet despite the improved infrastructure and apparently unlimited forest resources, New Brunswick's timber trade began to decrease. After 1880, foreign tariffs, world recessions, competition from Pacific Coast logging, and the demise of wooden shipbuilding took their toll. The province also experienced a growing shortage of large and accessible trees, caused by years of wasteful cutting practices.

Pulp and paper mills (1990–present)

Pulp mills first appeared in New Brunswick in the late 1800s and grew more numerous after 1900. By 1930, the pulp and paper industry surpassed the lumber industry in terms of its economic output. Although several large pulp mills have closed in recent years (UPM Kymmene in Miramichi in 2004 and Smurfit-Stone Container Corporation and in Bathurst in 2005), their economic output remains greater than wood products and manufacturing combined (which includes sawmills). Products produced from softwood trees in temperate forests, such as those in New Brunswick, have a long fibre length that make it very desirable because it gives strength to the products that are produced.

Pulp and paper mills created large numbers of jobs: first for building the mill and then actual production work, as well as all the logging and transportation jobs. The raw materials sought after were small softwood trees such as balsam fir and spruce. Paper mills played a major role in the 20th-century economy of New Brunswick.

The laws of supply and demand eventually caught up with the pulp and paper industry. The advent of computers, which decreased the need for paper and newsprint, coupled with less expensive pulp from South America produced from fast-growing species, decreased the demand for pulp products from New Brunswick.

Today, the wood used to feed the pulp mills consists mainly of sawmill residues (wood chips and sawdust). Pulp mills are an important part of the supply chain as they provide sawmills with a market for their wood residues.

What does the future hold?

New Brunswick's forest industry faces many challenges in the coming years. Our forests are an incredibly valuable resource that provide economic, social, and cultural benefits. One advantage of forests is that they are a renewable resource that, when managed sustainably, will continue to provide benefits to society.

Society needs forest products. We need lumber to build our homes and wood fibre is used to produce products that we use on a daily basis. The Coronavirus pandemic in 2020 illustrated the need for everyday products such as toilet paper and paper towels. More importantly, the use of wood fibre in the production of masks, gowns, swabs, etc. used by health care workers demonstrated the importance of wood products.

Finding new uses for our forest is important and the forest industry in New Brunswick has already started to explore new and innovative uses for our forest products. An excellent example is two hardwood pulp and fibre mills owned by the Aditya Birla Group and located in Nackawic and in Atholville, two forest-dependant communities. The mills produce high content dissolving pulp or specialty cellulose for the manufacturing of natural-based, viscose staple fibre, used to make rayon in the apparel and home textile industry.

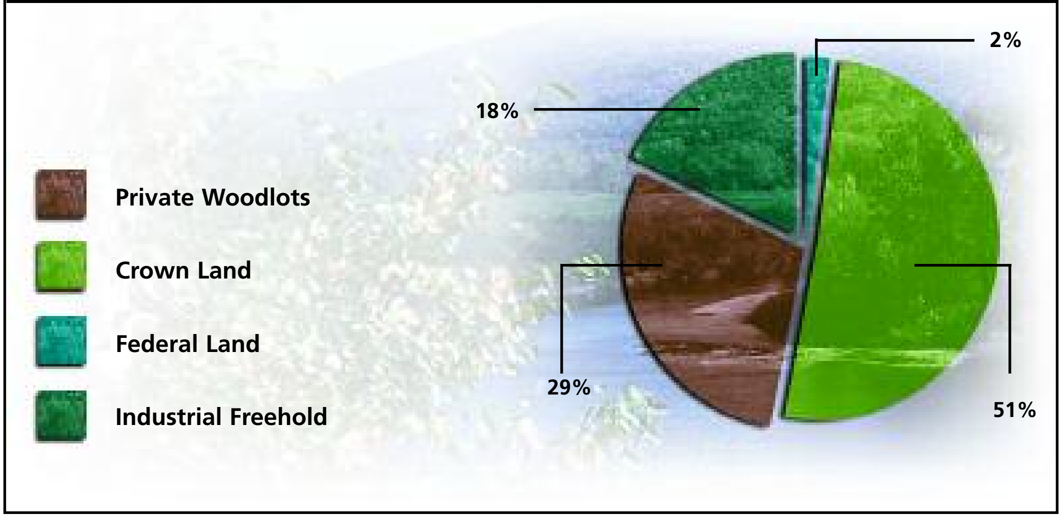
Our history has demonstrated that how we use our forests changes over time. In order to remain competitive and satisfy the needs of society, our forests must continue to provide important forests products such as lumber, pulp, and paper. More importantly, the forest must continue to provide ecological and societal functions such as clean water, clean air, and a place for recreation and spiritual fulfilment.

New Brunswick
Forests at a Glance

Who Owns New Brunswick Forests?

Crown forests represent about 50 per cent of the forested lands in New Brunswick.

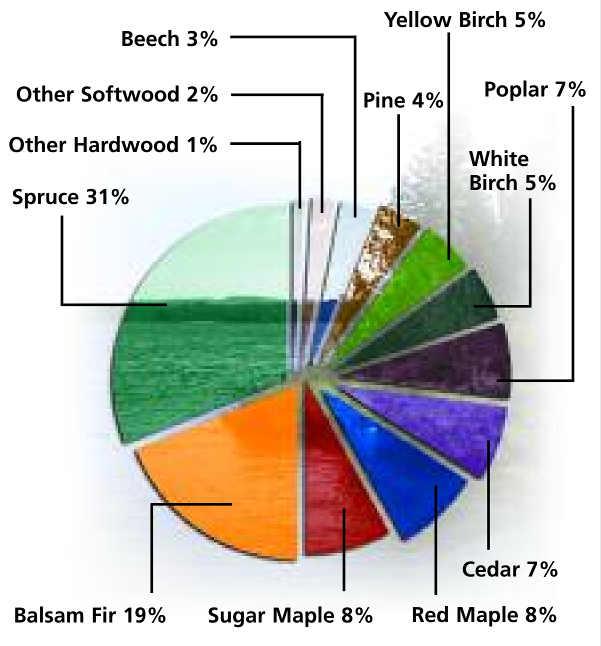
Distribution of Productive Forest Land in NB by Ownership



Tree Species of New Brunswick Forests

New Brunswick straddles an ecological transition zone between boreal coniferous forests to the north and deciduous forests to the south. The province's geographic position combined with its variable topography, soils and climate have produced a remarkable diversity of vegetation, including 39 species of native trees.

What Kind of Trees grow in New Brunswick?



Forest management in New Brunswick

A typical silviculture system (BC Ministry of Forests)

A silviculture system covers all management activities related to growing forests — from early planning through harvesting, replanting, and tending the new forest. Forest managers consider a variety of ecological, economic, and social factors when choosing a silviculture system. Each silviculture system is named after the cutting method with which the regeneration is established. The silvicultural systems most commonly used in Canada are the clearcut, the shelterwood, and the single tree selection systems.

The clearcut and shelterwood systems are used to manage even-aged forests, which are defined by relatively small age differences between individual trees. The selection system is used to manage uneven-aged stands, which means the forest has trees in various stages of development. It is appropriate for species that thrive in shade.

Silviculture can be defined as the art and science of controlling the establishment, growth, composition, health, and quality of forest vegetation to meet forest objectives.

A silvicultural system is a series of planned and scheduled treatments with the objective of:

- Harvesting trees,
- Establishing one or several species on a site,
- Improving wood quality of trees in a stand using a variety of stand improvement techniques,
- Creating or improving wildlife habitat,
- Etc.

Reforestation

All provincial and territorial lands that are harvested for commercial timber in Canada must be regenerated either naturally or by planting or seeding. Each province and territory has its own regeneration standards and regulations, addressing such areas as species composition, density and stocking level, and the distribution of various forest types across the landscape.

The benefits of natural regeneration include the need for minimal human assistance and generally lower costs than for artificial regeneration. However, planting and seeding provides more control over what grows, so they are often used to ensure that provincial and territorial regeneration standards and forest management objectives are met. More than half of Canada's harvested areas are regenerated through planting and seeding activities.

In New Brunswick, about one third of the harvested area on Crown land is planted. In many ways, a forest plantation is similar to an agricultural crop. In order to ensure a successful plantation, the forest manager should:

Use good quality seed – New Brunswick has a long history of genetic tree improvement for reforestation. In 1976, the New Brunswick Tree Improvement Council was established to coordinate tree improvement efforts of government and industrial agencies and to facilitate the free exchange of genetic material and information. Early in the program, plus-trees (trees having superior, form, size, growth and insect and disease resistance) were selected and seed and cuttings was collected to establish seed orchards. Over the years, the best trees were selected, and pollen was collected and used to fertilize flowers of other selected trees. Seed from these crossed trees were planted to establish new orchards.

Today, seed used for growing tree seedlings in New Brunswick comes from second- and third-generation seed orchard trees. Seedlings grown from improved seed are faster growing and of higher quality than naturally grown seedlings.

Seedlings grown at the Kingsclear Forest Nursery, near Fredericton. (Photo credit: Natural Resources Canada)

Plant high quality seedlings – Most of the planting stock used in forestry comes from forest nurseries, and this stock is produced in large quantities. Seedlings used in forest plantations are small (especially when compared to ornamental trees or trees for urban planting).

Tree seedlings are usually grown inside nurseries under controlled conditions. Forest nurseries with greenhouse culture are best for areas with colder climates and short growing seasons. With controlled environmental conditions, it is possible to accelerate the growth of plants and, if required, have more than one crop each year.

Today, almost all the planting stock used for reforestation in New Brunswick is grown in containers.

Ensure good site preparation to provide good planting sites – Areas that have been cutover often have considerable slash – branches, tree tops, and other harvest debris that pose obstacles to tree planters. Many forested areas also have a thick organic layer that can easily dry up during summer causing the seedling to dry out and die. For trees to survive, their roots must penetrate the mineral soil. In order to ensure good planting conditions and survival of planted seedlings, harvested areas usually undergo a site preparation treatment before planting.

Forestry worker planting containerized seedlings in a cutover. (Photo credit: Doug Pitt)

Many different types of equipment can be used to prepare an area for planting. Regardless of the equipment used, the objective is to create as many suitable planting spots as possible. Suitability for planting means easy access for planters and sufficient suitable microsites for seedling survival and growth. These microsites generally have adequate drainage, a mixture of mineral soil and humus, and minimal weed competition.

Choose the right species for the site – White and black spruce are the most commonly planted species in New Brunswick with Norway spruce, red spruce, jack pine, and white pine also planted but in lesser quantities. Hardwood species are not planted for reforestation in New Brunswick mainly because of the risk of browsing by deer and moose. Choosing the right species for the right site is critical, as each species is best adapted to the site conditions.

Tend the planted trees so that they can grow free of competition – Planted trees are small and can be easily overtopped by competing vegetation such as grasses, ferns, shrubs, and low-quality hardwood. In order to ensure their continued growth, a plantation tending is often needed. Plantation tending can be done chemically with an herbicide or mechanically using a brush saw.

Chemical release of planted trees using herbicide (left) and mechanical release using brush saw (right). (Photos credits: Doug Pitt (left) and NBDNR (right))

Pre-commercial thinning

Because the trees have not yet reached a size where they are commercially marketable for timber, this treatment is called pre-commercial thinning (PCT). Thinning can be carried out in stands of natural or planted trees that are of similar age and size.

Some of the best growing sites exhibit the densest thickets of trees. It is not unusual for some softwood thickets to contain over 30,000 trees per hectare. This silviculture treatment can be compared to thinning carrots in a garden and allows the best crop trees to obtain more sunlight, growing space, water, and nutrients.

Trees receive the most benefit from PCT when they are less than 20 years old, and softwoods are 2-6 metres tall and hardwoods are 6-9 metres in height.

PCT is usually carried out with a clearing saw, also called a spacing saw or brush saw, which enables the user to avoid the back strain and danger associated with a chain saw. Softwood trees are usually spaced to 1.8 m to 2.4 m between trees (1,500 to 3,000 trees per hectare).

Choice of crop trees is ultimately up to the landowner but higher-value trees such as spruce are often chosen over balsam fir, tamarack, and poplar.

Silviculture worker doing pre-commercial thinning in young softwood stand.

Shade tolerant hardwoods such as sugar maple, yellow birch and white ash are commonly chosen over red maple, trembling aspen, and white birch. Hardwoods are usually spaced 2.4 m to 3.0 m between trees. Each PCT is unique, as tree size, species composition, density and ground conditions differ on each site.

Increased diameter growth resulting from precommercial thinning.

Commercial thinning


Commercial thinning in a softwood stand

The main difference between a commercial thinning and a pre-commercial thinning (PCT) is the size of the trees. A commercial thinning is generally done as trees are moving from a juvenile to a mature stage of growth whereas a PCT is done when the trees are still in the juvenile stage. Hardwood, softwood, and mixedwood stands can all benefit from a commercial thinning.

Commercial thinning is usually carried out when the stand has reached a point where too many trees are competing for nutrients and light. When left to grow naturally, trees that have poor access to light and nutrients will slow in growth and may eventually die.

The objectives of a commercial thinning include:

- improve the growth of residual trees
- recover wood that would otherwise be lost to mortality
- improve stand composition
- improve the quality of the stand by removing dead, diseased, and deformed trees

While the need to carry out a PCT is based primarily on density, the criteria for commercial thinning is based on basal area and density. Different stocking charts are used depending on the species and site productivity.

Sustainable forest management

Sustainable forest management means ensuring that forests provide a broad range of goods and services over the long term. Forest managers plan for harvest levels that will not affect the long-term sustainability of the forest resource. To determine the yearly level of harvest allowed, governments estimate the wood supply, which is the maximum volume of wood that can be harvested sustainably. Both the estimated wood supply and the volume of wood harvested fluctuate in response to a wide range of ecological, social, and economic factors. Changes in wood supply are largely a result of adjustments in provincial forest management objectives. Comparing the amount of timber actually harvested to the estimated sustainable wood supply is one way to track forest management.

Annual allowable cut (AAC)

The annual allowable cut (AAC) is the amount of wood (volume) that can be harvested each year without affecting the sustainability of the wood supply. The AAC is measured in cubic meters or cords (English system) of wood and is based on what the forest is able to grow.

The AAC can vary over time depending on what is happening to the forest. Certain factors or activities can increase the AAC while others may cause a reduction. Following are examples of how AAC can increase or decrease over time.

- Better forest inventory data (can increase or decrease AAC)
- Area available for harvest (can increase or decrease AAC)
- Insects and diseases (reduction in AAC)
- Forest fires (reduction in AAC)
- Silviculture (increase in AAC)
- Age class structure of forest (can increase or decrease AAC)

In New Brunswick, about 1.3 % of the forest is harvested every year.

Stumpage

Stumpage is the price paid to the landowner or government for the right to cut trees in a given location. To determine stumpage value, the area to be harvested is assessed and appraised through processes aimed at finding the volume of timber it contains.

Stumpage can be paid by cubic meter, weight or area harvested (hectare). The amount paid is influenced by the type and quality of the wood, market conditions, accessibility (roads, proximity to the mill) and many other factors.

Even aged and uneven aged management

What Is a Silvicultural System?

A silvicultural system is a planned program of silvicultural treatments designed to achieve specific stand structure characteristics to meet site objectives during the whole life of a stand. This program of treatments integrates specific harvesting, regeneration, and stand tending methods to achieve a predictable yield of benefits from the stand over time. The naming of the silvicultural systems is based on the principal method of regeneration and desired age structure.

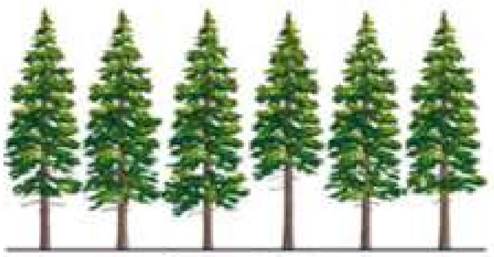
Silvicultural systems on most sites have been designed to maximize the production of timber crops. Non-timber objectives, such as avalanche control and wildlife production, have been less common. Recently, ecological considerations and resource objectives have increased. A silvicultural system generally has the following basic goals:

- Provides for the availability of many forest resources (not just timber) through spatial and temporal distribution.
- Produces planned harvests of forest products over the long term.
- Accommodates biological/ecological and economic concerns to ensure sustainability of resources.
- Provides for regeneration and planned seral stage development.
- Effectively uses growing space and productivity to produce desired goods, services, and conditions.
- Meets the landscape- and stand-level goals and objectives of the landowner (including allowing for a variety of future management options).
- Considers and attempts to minimize risks from stand-damaging agents such as insects, disease, and windthrow.

Even-aged and uneven-aged stands

Even-aged stands generally have one age class, although two age classes can be found in some two-layered natural or managed stands. These stands generally have a well-developed canopy and uniform height.

Pure even-aged stands generally have a nearly bell-shaped diameter distribution. This means that most trees are in the average diameter class. However, diameter distributions should be viewed cautiously since diameter can be a poor criterion for age. The smallest trees in natural even-aged stands are generally spindly, with vigour suppressed by the overstorey.



Even-aged stand
(BC Ministry of Forests)

Uneven-aged stands have three or more well-represented and well-defined age classes, differing in height, age, and diameter. Often these classes can be broadly defined as regeneration (perhaps regeneration and sapling), pole, and sawtimber (perhaps small and large sawtimber). In the classic managed form, where diameters are a good approximation for age, distribution of diameters will approach the classic inverted-J form. The objective of such an approach is to promote sustained regular harvests, with short intervals, at the stand level.

Uneven-aged stands have an uneven and highly broken or irregular canopy (often with many gaps). This broken canopy allows for greater light penetration and encourages deeper crowns and greater vertical structure in a stand.

The Clearcut System

The clearcut system manages successive even-aged stands by cutting the entire stand of trees at planned intervals (the rotation) then regenerating and tending a new stand in place of the old.

The clearcut system is the most straightforward and easiest system to use and has been applied around the world. While it has been successful for pure timber management, especially for valuable shade-intolerant species, concern over aesthetics, habitat impacts, and watershed impacts have prompted interest in alternate systems.

A “clearcut” means a silvicultural system that:

a) Removes the entire stand of trees in a single harvesting operation from an area that is:
    i) One hectare or greater in size; and
    ii) At least two tree heights in width, and

b) Is designed to manage the area as an even-aged stand

This definition of clearcut focuses on the size and width of openings. Kimmins (1992) defines clearcutting as harvesting all trees in a single cut from an area of forest large enough so that the “forest influence” is removed from the majority of the harvested area. Forest influence occurs along the edge or ecotone of an opening adjacent to a forest and is an intermediate microclimate between forest openings.

Patch Cut System

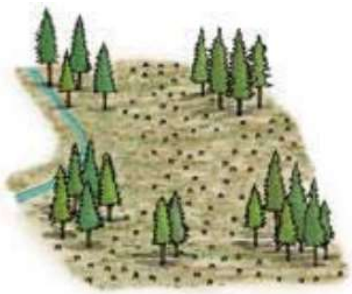
The patch cut system involves removal of all the trees, from an area less than one hectare in size. Each patch cut is managed as a distinct even-aged unit. If an area has several patch cuts, each opening is still managed as a distinct opening. Regeneration is obtained either by artificial or natural regeneration, or a combination of the two.

Seed Tree System

In a seed tree system, the entire cutting unit is managed as it is with clearcut systems except that, for a designated time period, harvesting excludes those trees selected for the purpose of supplying seed. Trees are generally left just to supply seed for the next crop; therefore, the best phenotypes should be selected to try to encourage desirable genetic traits to meet specified management objectives.

In a classic seed tree system natural regeneration is used, although the seed trees may not be relied upon entirely and some planting may occur beneath seed trees, often at reduced stocking levels. It is useful to conduct a stocking survey after three years and use fill planting to fill in any gaps in stocking. Usually, the seed trees are removed in a "removal cut" once regeneration is established, although in practice this is not always the case.

The seed tree system can be uniform, where trees are left more or less uniformly distributed throughout the block or in groups, where trees are left in small groups throughout the cut area.


Group seed tree system


Uniform seed tree system

The Coppice System

The coppice system is defined as an even-aged silvicultural system for which the main regeneration method is vegetative sprouting of either suckers (from the existing root systems of cut trees) or shoots (from cut stumps). This system is usually limited to broadleaved (hardwood) species management.

A good example of a coppice stand originating from sprouting in New Brunswick is trembling aspen regeneration following the harvest of a stand with a trembling aspen component. Trembling aspen roots do not die after the tree is cut but will produce hundreds if not thousands of root sprouts that will quickly occupy the site. As sprouts do not have to develop their own root system, they grow very rapidly often reaching 1–2 meters in height after one year.

Red maple will regenerate through vegetative reproduction from suckers originating from the stump after the tree is cut. As is the case with trembling aspen sprouts, maple suckers will grow very quickly. The number of suckers from a single stump can easily range from 20-30. The wood quality is poorer than trees grown directly from seed.

Although coppicing is an easy method to regenerate a harvested area (providing the area has tree species capable of regenerating from suckers and sprouts), the quality of the wood and the species that are regenerated are not always the preferred species of forest managers.

Shelterwood System

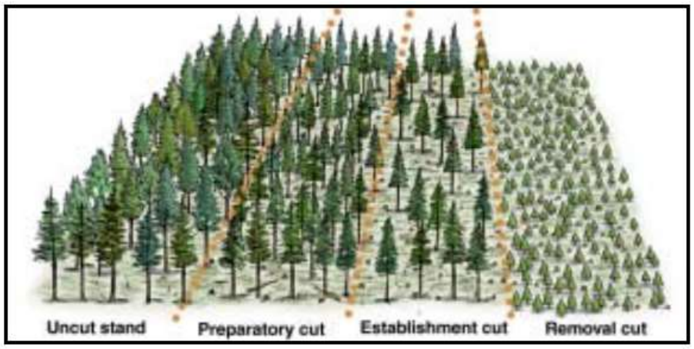
In a shelterwood system, the old stand is removed in a series of cuttings to release existing regeneration or to promote the establishment of a new even-aged stand under the shelter of the old one.

The primary intent of this system is to protect and shelter the developing regeneration. Generally, shelterwood systems aim at natural regeneration, although some planting may occur to diversify the species mix, bolster stocking, and introduce improved seed. The central theme to shelterwoods is that the overstorey leave-trees are left on site to protect the regenerating understorey until the understorey no longer requires the protection. At some point the overstorey starts to inhibit development of the understorey trees through crown expansion and shading. This depends on the density of overstorey trees and the species being managed. The shelterwood trees are removed after the new trees no longer need their protection, so that the new tree can develop uninhibited.

Trees selected as leave-trees in shelterwood systems should be:

1. larger, dominant trees
2. intermediate or tolerant to shade
3. wind firm
4. desirable species
5. desirable physical characteristics

Shelterwood cuts are implemented by using a series of harvesting entries, each with specific objectives. These may or may not include the following depending on stand conditions:



1. Preparatory cuts – A preparatory cut is often the first entry in a stand intended for the shelterwood system. A preparatory cut is very similar to a commercial thinning, as the trees removed are usually the smaller, poorer quality trees in the stand. The objective of the preparatory cut is to begin to open the stand with the objective of improving the vigour of trees that will produce seeds and to make them more wind firm.

2. Establishment cut (regeneration cut) – This cutting, which may be the first cutting in some stands, is intended to provide growing space for the regeneration to establish and to provide shelter for the young developing seedlings.

3 Removal cut – This is the final stage of shelterwood cutting and is carried out once the regeneration is well established. Great care must be taken so as not to damage the existing regeneration as these trees will be the future stand

Variations to the shelterwood system include:

Uniform Shelterwood

Leave trees are left for shelter, more or less uniformly distributed throughout the block.

Group Shelterwood

Patches are opened in the stand such that the surrounding edges of uncut timber shelter the new regeneration. The group size will be increased by one or more cuts until the entire block has had the overstorey removed. This gradual removal of the original overstorey occurs relatively quickly in successive harvesting entries within a normal regeneration period for an even-aged stand (10–25 years). The final groups to be harvested may require artificial regeneration.

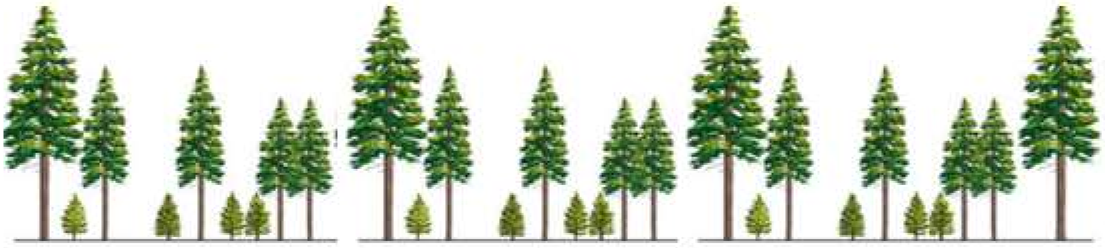
Strip Shelterwood

Initial harvesting occurs in the stand as uniformly spaced linear strips. In future harvesting entries, strips are added beside the initial strips, progressively into the wind, until the entire block is harvested within a normal even-aged regeneration period (10–25 years). Harvesting in each strip may occur gradually and include a preparatory, regeneration, and removal cut, following in sequence. Strips may be oriented to use the side shade from adjacent timber, maximize sunlight penetration, or allow for visual screening from the uncut timbered matrix.

Uneven-aged management system

Also known as the selection system or selection management, the uneven-aged management system removes mature timber either as single scattered individuals or in small groups at relatively short intervals, repeated indefinitely, where an uneven-aged stand is maintained. Regeneration should occur throughout the life of the stand with pulses following harvest entries.

Uneven-aged stands have an uneven and highly broken or irregular canopy (often with many gaps). This broken canopy allows for greater light penetration and encourages deeper crowns and greater vertical structure in a stand. Most stems occur in the smallest age/size class, as regeneration quickly fills the frequent canopy gaps. Because regeneration is initiated in small gaps, more shade-tolerant tree species are generally favoured.



Uneven-aged stands have at least three well-represented and well-defined age classes, differing in height, age, and diameter. Often these classes can be broadly defined as: regeneration (or regeneration and sapling), pole, and mature.
(BC Ministry of Forests)

Uneven-aged management is generally considered to be more difficult than even-aged management since all age classes are mixed together and therefore can be difficult to isolate and quantify. However, uneven-aged management may be an objective for many reasons such as visuals, regeneration of shade-tolerant species, health, soil, habitat, and fire protection.

Under this management regime, trees are removed either as single scattered individuals or in small groups. In order to ensure that a proper age class distribution is maintained, uneven-aged management requires interventions in the stand every 15–20 years. Regeneration should occur throughout the life of the stand with pulses following harvest entries.

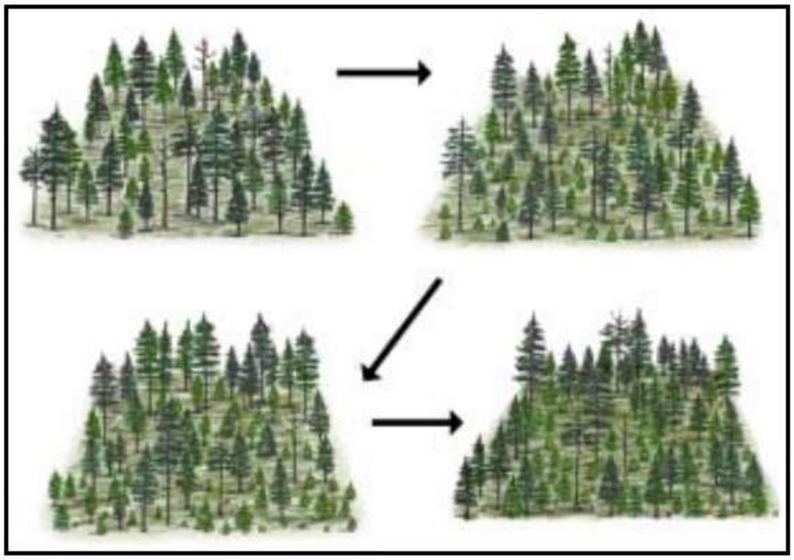
A good example of uneven-aged management is a sugar maple stand managed for the production of maple products. As only mature trees can be tapped for maple products, the owner must maintain trees of all sizes to ensure that as the older trees die, younger ones are there to replace them.

Two main selection systems are used in uneven-age management: single tree selection and group selection.

Single Tree Selection

Single tree selection removes individual trees and small clumps of trees of all size classes, more or less uniformly throughout the stand, to achieve or maintain a balanced, regulated, uneven-aged stand structure. It is easier to apply such a system to a stand that is naturally close to the uneven-aged condition. However, an even-aged stand can be converted to an uneven-aged stand for management under a single tree selection system, although numerous establishment cuttings must be made to bring the stand into a structure where the system can truly be applied.

Once the uneven-aged structure approximates the balanced condition, the single tree selection system generally manages a complex mixture of small even-aged clumps that are thinned over time. In theory, these clumps should be able to yield at least one mature tree of the specified maximum diameter; however, in practice these clumps are often larger.



New regeneration develops in small, scattered openings created in small gaps. Since regeneration is always being recruited and larger mature trees are scattered, or in very small groups, these stands appear quite open, with many gaps. Therefore, the total stand basal area may be somewhat less than that of a fully stocked, mature, even-aged stand on a similar site.

Note: Single tree harvesting is not necessarily single tree selection.

Single tree selection is a term that has been misunderstood and often abused. It has been incorrectly applied to many stands where single trees were only harvested for salvage, highgrading, or general thinning. This has created considerable confusion around the term. Single tree selection manages a stand using regular, predictable sustained harvesting entries in perpetuity by managing towards a balanced (or close to balanced) uneven-aged structure, as described previously.

Single tree selection is much more complex than removing a few large trees from a stand. While highgrading should not be tolerated, one may legitimately harvest just a few large trees. Such a harvesting entry should be labelled an intermediate cut or thinning (e.g., intermediate cut for salvage).

Group Selection

Group selection systems also promote uneven-aged stands with clumps of even-aged trees well distributed throughout the cutting unit. Unlike single tree selection, however, these small even-aged groups are large enough that they can be tracked within the stand.

A 0.25-ha first entry opening in a group selection system

The small gaps or openings are created on short intervals to develop a mosaic of at least three or more age classes throughout the stand. The harvesting entries are light enough so that an uneven-aged structure develops, unlike a group shelterwood.

Groups may be uniformly staggered narrow linear strips (usually 15–50 m wide). Future harvesting strips are added at short regular intervals beside the initial strips, progressively into the wind. Such an approach minimizes windthrow risk.

Harvesting intensity and timing between entries are planned to create an uneven-aged stand with linear clumps of age classes, thus meeting the definition of selection. This differs from its shelterwood counterpart by harvesting the entire area much more slowly over time through harvest entries that remove much less volume.

2023 NCF-Envirothon New Brunswick

Forestry Study Resources

Key Topic 4—Forest Measurements

16. Use an aerial photograph to evaluate a landscape, including map features, distance measurements, and area measurements.

17. Explain the importance of different types of forest measurements and how they can be used to make management decisions.

18. Use common forestry tools to measure tree diameter, height, basal area, density and stocking. (Tools may include diameter tape, calipers, wedge prism, angle gauge, hypsometer, etc.)

Study Resources

Resource Title	Source	Located on
Working with Aerial Photography	*Government of Canada. Concepts of aerial photography. 2016.*	Pages 68 - 69
Tree Measurements	*Maritime College of Forest Technology. Forest Measurements I: Cruising, 2022*	Pages 70 - 72
Basal Area	*Maritime College of Forest Technology. Forest Measurements I: Cruising, 2022*	Page 73
Regeneration Surveys	*Maritime College of Forest Technology. Forest Measurements I: Cruising, 2022*	Page 74

Study Resources begin on the next page! ➡

Working with Aerial Photography

There are a variety of measurements and information that forest managers use to help them decide how forest should be managed.

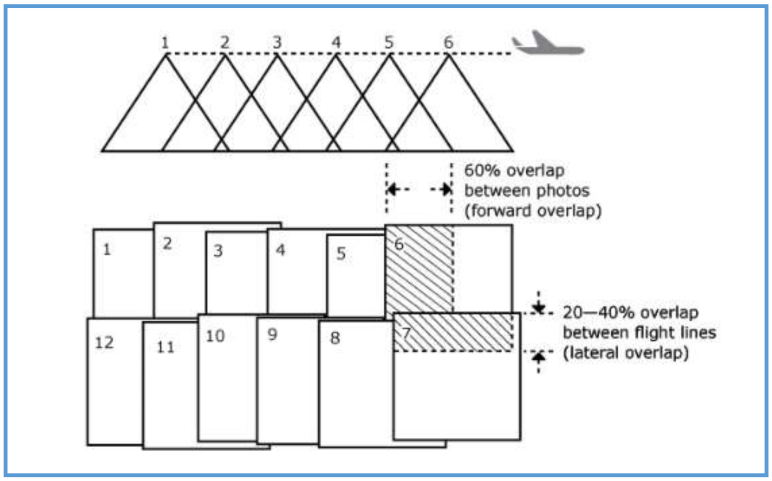
Some basic forest measurements include age, height, diameter, basal area, density, stocking, and volume. Some of these can be obtained directly through measurement (age, height, diameter, density, basal area) while others must be calculated or determined from graphs or charts (volume, stocking).

The most basic unit in forest management is the stand. A stand is a community of trees possessing sufficient uniformity in composition, height, maturity, and health that allows them to be grouped together. A stand can measure anywhere from 0.5 hectare to hundreds of hectares in size. Measuring all the trees in a stand is not practical and therefore sampling is used to determine the characteristics of the stand.

Aerial photographs are a tool that has been used for decades to assist foresters in managing their woodland resources. For the purpose of this discussion, an aerial photograph is a photograph taken from above the ground, usually by a plane. An aerial view of the landscape provides a much clearer image of what the landscape contains. This is extremely useful to foresters who need to understand what is on the landscape and what landscape features need to be considered when planning their activities.

The identification of landscape features is both an art and a science. A good photo interpreter can identify buildings, rivers, lakes, wetlands, power lines, and roads; distinguish between hardwood, softwood and mixedwood stands and measure heights, distances and areas.

A single photograph provides the user with a two-dimensional view of an object. It is not possible to see depth (i.e. three dimensions) using a single photo. In order to see in 3D an object must be viewed from two different angles. Close one eye and look at an object – that object is seen in two dimensions as it is only viewed from a single point of reference. If you open your other eye the object can now be seen in 3D because the object is now viewed from two different points of reference.



Flight lines are flown so that overlap occurs along flight lines (20–40 %) and between photos along a flight line (~ 60 %). This overlap makes seeing in 3D possible when using a stereoscope. (Natural Resources Canada)

In order to view aerial photos in 3D, two photos are needed that show the same object from different perspectives. The image on the right shows how two overlapping photos are used to allow photo interpretation in 3D to take place. A stereoscope is the instrument used to “bring together” the two images and allow the viewer to see in 3D.

Much information can be obtained from an air photo without the use of a stereoscope.

On this photo, you should be able to identify the following:

Roads

Watercourses

Clearcuts

Hardwood (lighter colour)

Softwood (darker colour)

Beaver dams

Wetlands

When looking at a map or air photo north is always “up” unless otherwise indicated. This means when reading text on a map the top of the map will be north. Below is an explanation of the text located at the bottom of the above photo.

DNRE	Department of Natural Resources and Energy
98519 – 63	Flight line and photo number
98-07-27	Date photo was taken
21J-02	Map reference
1:12 500	Scale of photo

The scale of the photo is very useful when determining distances. In this case 1:12 500 means that one unit on the map represents 12 500 units on the ground. For example:

1 cm on the photo is equal to 12 500 cm or 125 meters on the ground

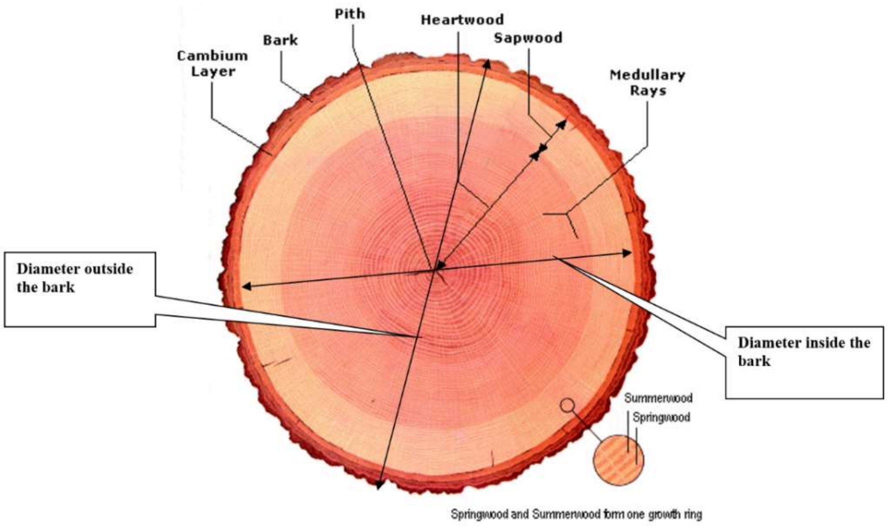
The scale can be used to calculate actual distances and areas.

Tree Measurements

Measuring tree diameter

A diameter is a straight line passing through the center of a circle and meeting at each end of the circumference. Diameter is important because it is one of the measurements that can be measured directly and is used to compute basal area and volume.

It is assumed to be diameter outside the bark (Dob), unless otherwise indicated by Dib (Diameter inside the bark).



Diameter at Breast Height (DBH) is the stem diameter of a tree **1.3** meters above the ground measured from the uphill side of the stem. In the United States, DBH is measured at 4.5 feet.

Why Measure at DBH?

1. It provides a convenient point of measurement
2. It provides a less fatiguing point of measurement
3. It is a uniform point of measurement
4. It has been accepted as a world standard
5. DBH is normally high enough above the ground to avoid erratic taper resulting from root and butt deformities
6. DBH is usually above the snow in the winter, but winter does present a challenge to accurately locate DBH

With the definition of DBH, it would seem the issue of where to measure diameters has been simply solved. However, the first time one heads to the field to measure tree diameters, it is likely that the technologist will run into some trees that pose a challenge to measure at DBH.

Trees can be forked at DBH, below DBH and above DBH. Excessive branching can make it impossible to measure the diameter at DBH. Trees can be diseased or wounded at DBH causing a bulge. Therefore, to measure these trees, rules have been established to determine the correct place to measure DBH on trees with issues that if not accounted for would yield an abnormal diameter and therefore a volume that is incorrect (Figure 1).

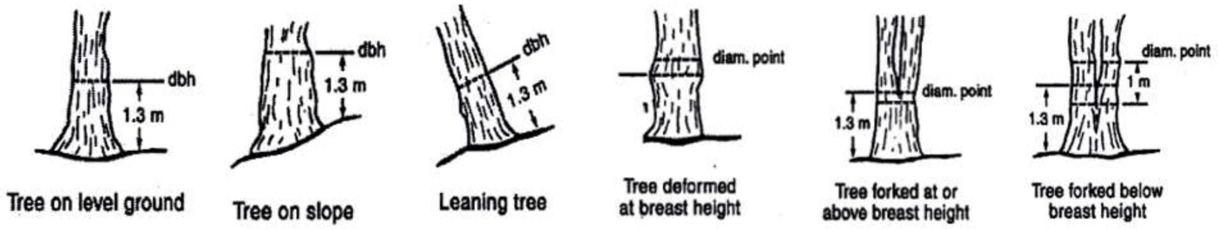


Figure 1. Determining the correct height to measure stem diameter for common tree stem characteristics found in the forest.

Equipment

Instruments used for measuring diameter: Collectively these are called dendrometers.

Calipers

Diameter tapes

Measuring Tree Height

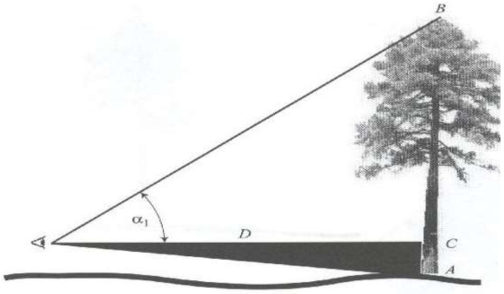
The height of a standing tree is the distance between the mean ground level to the tip of the tree, measured along the axis of the tree. Instruments used for measuring height are called hypsometers. The Suunto is the most common hypsometer used today.

It is a handheld device that is housed in a corrosion-resistant aluminum body. A jewel-bearing assembly supports the scale, which is immersed in a damping liquid inside a sealed capsule. The liquid dampens undue scale movement.

The advantage of this instrument is that it is compact, accurate and relatively inexpensive. The major disadvantage is that the operator must line up the top of the target with one eye while reading the appropriate scale with the other.

How to Measure Tree Heights with a Hypsometer

1. Find a position, at least one treelength away, where the tip and butt are visible.
2. Determine the horizontal distance from the side center of the tree to the nearest 0.1 of a meter.
3. Take a tip reading, lining up the crosshair to the tallest tip on the tree and reading the desired scale reading. This is normally a positive number and the 20 scale is on the left, the 15 scale is either in the middle or on the right. If a percent scale is present, it is on the right side of the scale.
4. Take a reading on the base of the tree using the same scale. Usually this is a negative number.
5. Use the following formula for determining tree height:



$$\textbf{Tree Height} = \frac{\textbf{Horizontal Distance} \times \textbf{Net Reading}}{\textbf{Scale Used}}$$

Note: *If the horizontal distance is the same as the scale used, they cancel each other out in the formula, and therefore the net reading equals the tree height.*

Rule about signs with the hypsometer to determine Net Reading

- Like signs, you must subtract the two readings
- Unlike signs, you must add the two readings to get the net reading

Example:

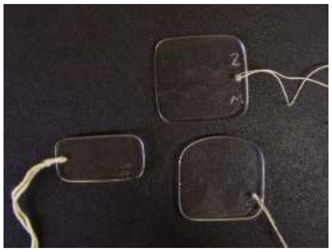
If the tip reading is +16.5 and the base reading is -1.25, then the Net Reading is 16.5 + 1.25 = 17.75.

If the reading at the base was +1.25, then the net reading would be 16.5 - 1.25 = 15.25.

- When using the hypsometer, both eyes must be open; this is a necessity with the Suunto.
- The observer should try to position themself at about the same ground elevation as the base of the tree.
- Leaning trees should be measured at right angles to the lean.

Basal Area

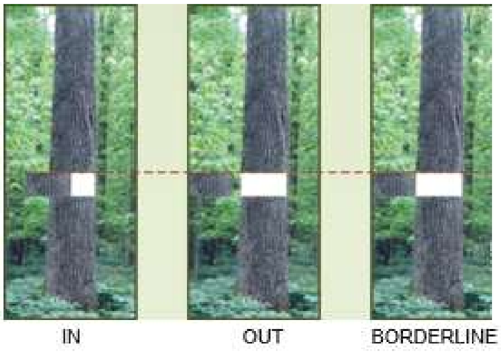
Measuring Basal Area with Wedge Prism



The wedge prism is a wedge-shaped piece of optically ground glass which deflects or displaces rays of light.

How to use a wedge prism

1. On flat ground, the prism is held between the forefinger and thumb, so that the bottom of the prism is parallel to the ground. This means the thick edge is on the side not the bottom or the top.
2. Prisms are held over the plot centre.
3. Looking through the prism with one eye and looking at the tree through the prism at DBH, a section of the tree will appear to be displaced away from the stem (see figure below).
4. If the section that is displaced is within the bole of the original tree, the tree qualifies. Any tree that qualifies is then tallied by species and diameter class.
5. If the section displaced is completely outside the original tree, the tree does not qualify.



6. If the section is displaced so that the side of the displaced section is tangent to the bole of the stem, the tree is borderline. Every second borderline tree is counted.
7. By making a 360° sweep around the plot center all trees that qualify and half the trees that are borderline are counted.
8. On sloping ground, the prism is rotated through a vertical plane so that the angle between the imaginary horizontal plane and the bottom of the prism is equal to the angle of the slope of the ground.
9. Basal area/hectare is calculated by multiplying the average count by the basal area factor of the prism.

Basal area of a single tree is the area of the cut section of the tree if the tree was cut at DBH. It is determined mathematically using following formula. Basal area is expressed most often in m^2 but cm^2 may also be used.

$$\text{Area } m^2 = \frac{\pi R^2}{10000} \quad \text{where} \quad R^2 = \text{Radius of tree (cm)}$$

$$10000 = \text{Constant to change } \mathbf{cm^2} \text{ to } \mathbf{m^2}$$

Example: The basal area of a 24 cm diameter tree is equal to:

$$\text{BA } (m^2) = \underline{3.14 \times 12^2} / 10000 = 0.0452 \, m^2$$

Basal area per hectare is the total surface area occupied by trees on one ha of forest, expressed in m^2/ha.

Regeneration Surveys

Information on regeneration is important in forest management. Regeneration can be monitored in standing timber or in regenerating harvested areas. In silviculture, you will learn many different ways to look at regenerating forests. In cruising, you need to understand what regeneration is, how to sample regeneration and how to express both regeneration stocking and density.

Density is a measure of how many stems per hectare there are in a given area. Density is expressed in stems per hectare.

Stocking refers to how the regeneration is spatially distributed in a given area. It is normally expressed as a percentage of the area that has regeneration present. 50% stocked would mean that 50% of the area has appropriate regeneration and on the other hand, that 50% of the area is not stocked with desired regeneration.

Therefore, someone has to decide what type of species and size of species is desired. Some land holdings are happy with any species of trees, shrubs and ground vegetation.

Other landowners may have very specific species that they will accept and everything else does not count.

Circular plots

Two common sized plots are: 0.0005 ha (1.26 m radius) for stocking plots

and 0.001 ha (1.79 m radius) for density plots.

With each plot size there is an expansion factor, one counts how many trees in the plot and then multiplies the number of trees by the expansion factor to get the stems per hectare. This is easily understood if one understands where the expansion factor comes from in the first place.

Example: A plot size with a 1.79 m radius would have an area of 0.001 ha.
How would you calculate the expansion factor?

The answer is to figure out how many plots of the area will fit in a hectare.
In a hectare there are:

10,000 m². This plot has an area of 0.001 ha or 10m².

Therefore 10,000 m²/10 m² = 1000 (expansion factor)

Therefore, every tree in the plot represents 1000 stems per hectare.

1.26 m plot = 5 m²…10,000 m² divided by 5 m² = 2000 (expansion factor)

3.99 m plot = 50 m² …10,000 m² divided by 50 m² = 200 (expansion factor)

2023 NCF-Envirothon New Brunswick

Forestry Study Resources

Key Topic 5—Forest Health

19. Identify the impacts of climate change on forest composition and productivity.

20. Explain how carbon emissions resulting from deforestation are contributing to climate change.

21. Explain how forests can help mitigate climate change.

22. Identify the main native and non-native pests and diseases in the Acadian Forest Region.

23. Describe the concepts and theories behind the early intervention approach to managing spruce budworm populations that is being tested in Atlantic Canada.

Study Resources

Resource Title	**Source**	**Located on**
Canada’s Forests in a Changing Climate	*The State of Canada’s Forests Annual Report (pages 6-13), Natural Resources Canada, Canadian Forest Service, 2016*	Pages 76 - 83
Forests and Climate Change	*Massachusetts Institute of Technology, 2021*	Pages 84 - 85
Deforestation in Canada – What are the Facts?	*Natural Resources Canada, 2008*	Pages 86 - 87
Projecting the impacts of climate change on the Acadian Forest	*Anthony Taylor, Natural Resources Canada, Canadian Forest Service, 2019*	Pages 88 - 91
Trees insects and diseases of Canada’s forests	*Government of Canada, Natural Resources Canada, 2015*	Pages 92 - 100
A conceptual framework for spruce budworm early intervention	*Natural Resources Canada, Canadian Forest Service, Impact Note No 65, 2021*	Pages 101 - 104

Study Resources begin on the next page! ➡

Canada's forests in a changing climate

The climate is changing and so are Canada's forests. Increased numbers of large fires, greater drought frequency and intensity, shifting patterns of disease and invasive insect outbreaks: all of these trends over the last five decades are impacting Canada's forests and have even resulted at times in loss of jobs and homes in some communities.

How the climate will continue changing is difficult to predict. But because Canada is a northern country, the changes are expected to be greater than the global average. How Canada's forests will respond is also hard to know. However, scientists and other researchers are working to find answers that will reduce these uncertainties.

> If global efforts to address climate change are successful in limiting the world's increase in temperature to 2°C, the increase in Canada is still forecast to average 4°C by 2100.

With the likelihood of new climate conditions, forests are expected to evolve, and in some areas become quite different from what they are now. Species composition, average age, geographic range and growth rates are all likely to change over the coming decades. This makes adaptation by the forest sector – such as planting drought-tolerant species – more important than ever.

At the same time as they are affected by climate change, forests can also be part of mitigating (reducing) it. Trees absorb carbon dioxide (CO_2) from the atmosphere and store it in their trunks, roots, branches and leaves. Increasing the area and growth of forests therefore reduces the amounts of greenhouse gases (GHG) in the atmosphere, helping to slow temperature rise. Using wood products and bioenergy also helps lessen the need for products made with processes that result in high GHG emissions and reduces the use of fossil fuels.

What effect is climate change having on Canada's forests?

Canada's scientists have long been studying how changing climate conditions are affecting the country's forests. Among the most notable impacts observed:

- Milder, drier climatic conditions over the past 50 years are thought to be a major reason for longer fire seasons and the increase in the number of severe forest fires and the size of areas burned.

- In the 2000s, a series of warmer-than-usual winters enabled the mountain pine beetle to flourish and spread across much of central British Columbia. The outbreak killed more than 750 million cubic metres of mature lodgepole pine – a loss of more than 10 years' worth of the province's annual harvest. Researchers report that the beetle, now in north-central Alberta, the Northwest Territories and Saskatchewan (well beyond its natural historical range), may continue spreading east in the coming decades. It has already moved into new tree host species.
- The current spruce budworm outbreak in the Mackenzie River delta in the Northwest Territories is taking place at the highest latitude ever recorded for such an infestation.
- The increase in the rate of premature death of healthy trees in many forest types over the past few decades is likely the result of drought-related or other climate-triggered outbreaks of insects in weakened forests. Drought conditions have also contributed to the death or stunted growth of trees in several parts of Canada, including white spruce in Yukon (from spruce bark beetle infestation) and aspen in Alberta, Saskatchewan and Ontario.

Science points to the changes in the world's climate being the result of greater GHG emissions, including CO_2, from human activities such as heavy reliance on fossil fuels, industrial production processes and global deforestation.

How forests could look in the future

Research on the biological, economic and social implications of climate change for Canada's forests and forest industry is constantly improving our understanding of what the potential changes might be and how they could affect forest habitat and biodiversity, timber supply and communities.

Most areas in Canada, for example, are expected to experience at least a twofold increase in annual area burned by forest fires and a 1.5-fold increase in the number of large fires by the end of the 21st century. This means that the average age of the country's forests is likely to decline in some areas, with increases in the number of young trees regenerating in burned-out areas.

Forest growth rates and the distribution of species may change gradually, too. Climate conditions have already shifted, affecting the distribution of certain tree species in Canada. The rate of climate change is projected to be 10 to 100 times faster than the ability of tree species to migrate. This means that some tree species will benefit (for example, growing faster or spreading more widely), while others will become increasingly stressed, potentially dying out over time.

Such changes pose broader ecological consequences as well, affecting vegetation and wildlife, which would need to adapt or migrate under changing climate and forest habitat conditions.

Given Canada's vast and generally remote forests, measuring, monitoring and tracking the changes in them is challenging. The National Forest Inventory (NFI) is an important tool for tracking or monitoring current and projected changes in the forest. It will also become increasingly important as a means of providing early warning of climate change impacts and tracking ongoing change in our forests.

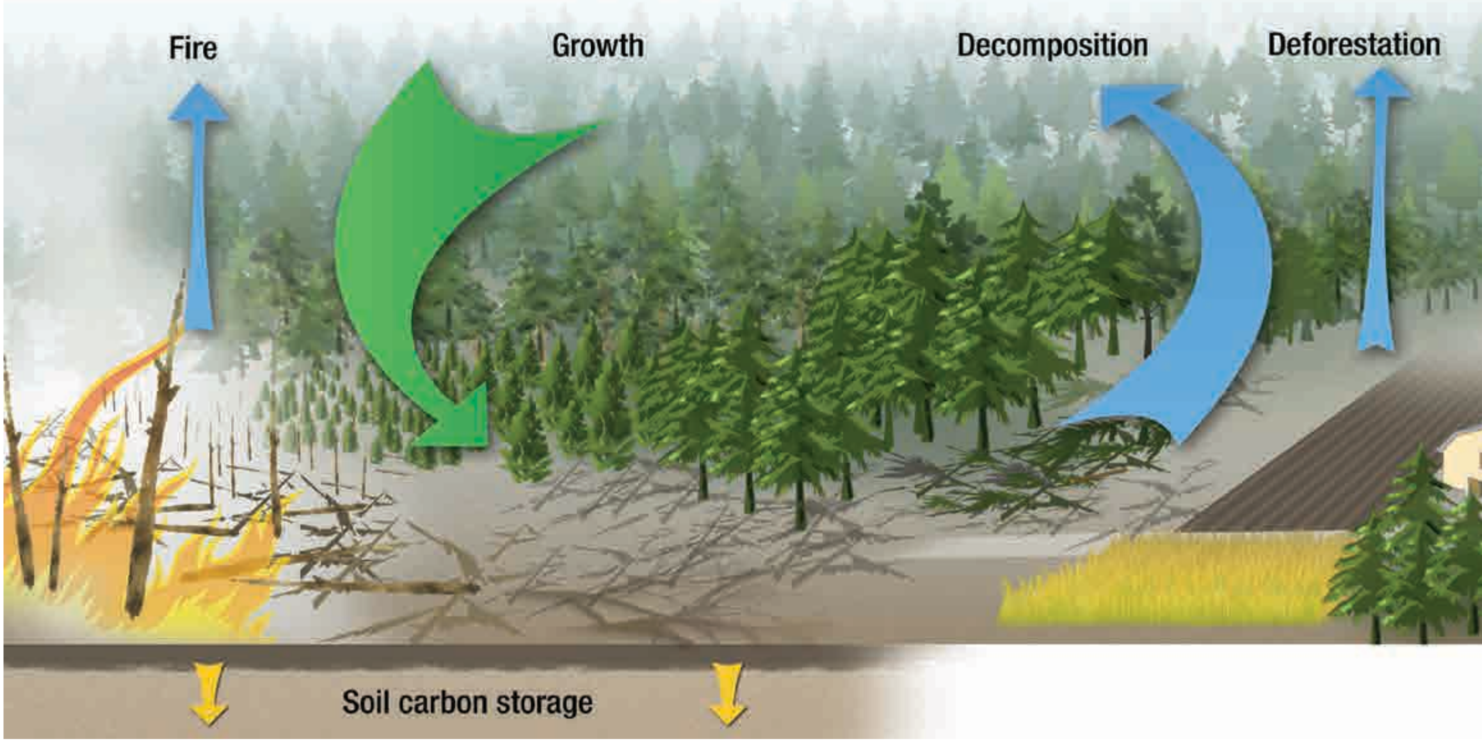
Forest sector adaptation to climate change is needed

Adapting to climate change means adjusting decisions and activities to take into account observed or expected changes in climate. In the forest sector, that means integrating climate change knowledge into sustainable forest management planning and practices to help maintain both ecosystem integrity and the flow of social, economic and environmental benefits. Planting a greater diversity of tree species in a forest, for example, is one way of reducing the forest's vulnerability to future insect infestation or fire risks.

Adaptation measures are specific to a region and forest type and therefore vary widely. What best suits the local environmental and socio-economic needs in a region on the east coast might not offer the best solution on the west coast or in the northern boreal forest. The map on page 12 shows examples of adaptation actions that can be taken.

Adaptation efforts help forest ecosystems, the industry and forest-dependent communities across Canada reduce their vulnerability to the negative effects of climate change.

The role of forests in the carbon cycle



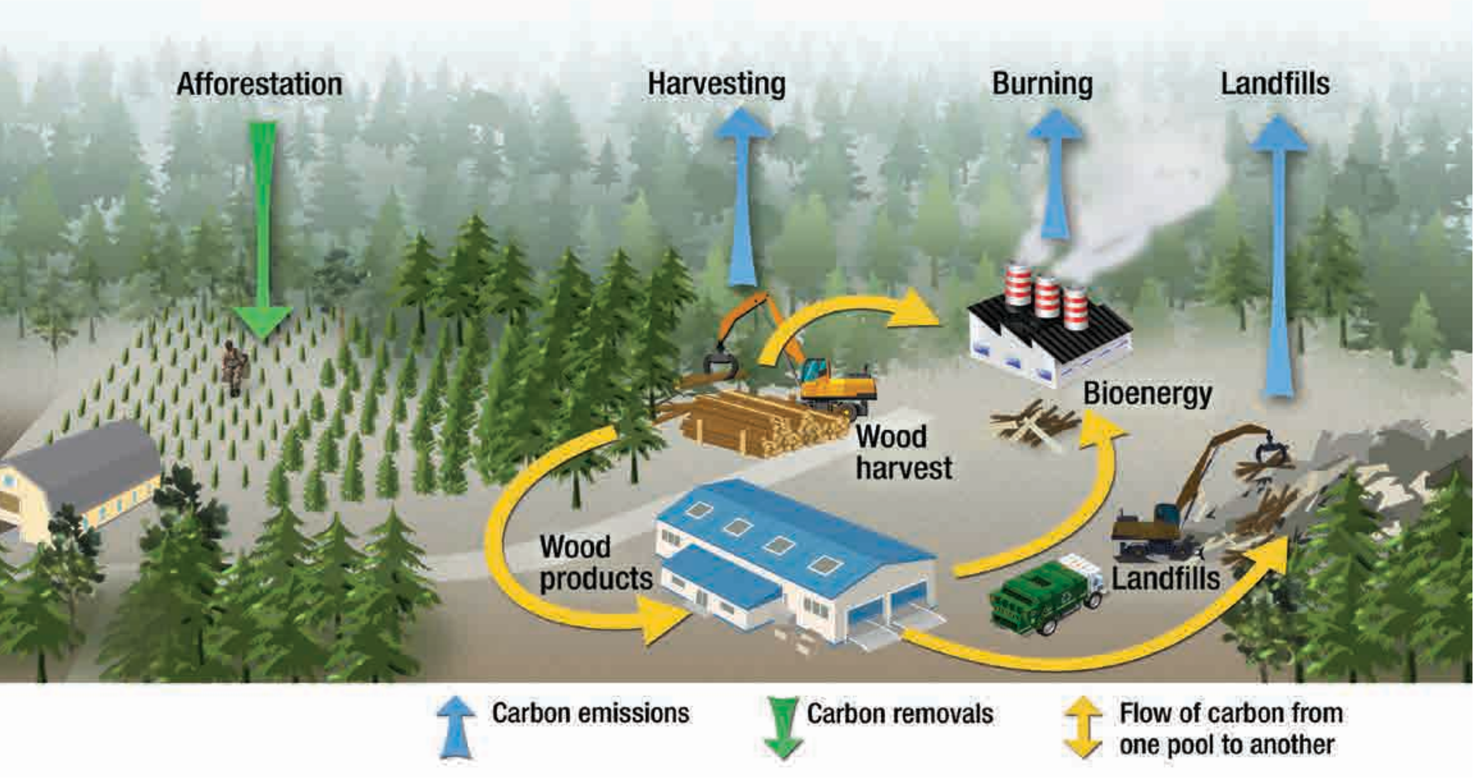
As they grow, forests absorb large amounts of carbon from the atmosphere. Other natural forest processes, such as decomposition and fire, release carbon back into the atmosphere. This dynamic process of absorbing and releasing carbon constantly affects Earth's carbon balance. How humans manage forests and use wood also affects this balance.

Adaptation will also be important to industry and communities as they adjust to the changing forests they rely on. Harvest levels, for instance, may need to be reduced as more-frequent natural disturbances reduce the available timber supply. Forest companies will need to increase their efforts to find innovative ways to use more dead or low-quality wood salvaged from burned areas or areas invaded by insects or disease. Communities located in forested areas are already being encouraged to be “fire smart” by clearing trees and general forest brush (living and dead) from areas between buildings and forest.

Since 2008, the Canadian Council of Forest Ministers (CCFM) has focused on what adaptation means for sustainable forest management. A series of the CCFM’s reports offers forest managers guidance in assessing the vulnerabilities, risks and opportunities associated with climate change. Many forestry organizations are using the reports to inform policies and practices.

Forest Change, a component of the Government of Canada’s adaptation program, was also launched in 2011 to support the forest sector in adapting to climate change. The program provides science-based information and analysis on past trends and future projections of climate change impacts on the forest and the forest sector. And its tools are helping forest managers and others in the sector develop and implement adaptation plans and take action to adjust to the future climate.

The “carbon cycle” is the movement of carbon from land and water through the atmosphere and all living things. Carbon in the atmosphere exists as CO_2*, a GHG. Forests are an important part of the carbon cycle. Trees absorb carbon during photosynthesis and store it in their stems, branches and roots. A large proportion of this stored carbon also ends up in forest soil through natural processes such as annual leaf fall and tree death. Trees release carbon during respiration, when they die and decay, and if they are burned in a forest fire. Forests are considered to be “carbon sinks” when they absorb more carbon than they release; and “carbon sources” when they release more carbon than they absorb.*



Using Canada's forests to help mitigate climate change

At the climate change conference in Paris in December 2015, Canada joined the international community in aiming to achieve near-zero GHG emissions by 2050. Canada has committed to a 30% reduction in its emissions (below 2005 levels) by 2030. Further emission reductions will be needed after that in order to meet the international ambition of keeping the global temperature increase to below 2°C.

Given the current and projected impacts of climate change on Canada's forests, it may seem counterintuitive to think that forests can also be part of the climate change solution. However, the carbon-storing capacity of forests, together with the ability of wood products to replace fossil-fuel-intensive products, can contribute to keeping CO_2 out of the atmosphere. (For more information, see the sustainability indicator on carbon emissions on page 32.)

The ways in which forests are managed (tended, harvested and regenerated) and harvested wood is used can therefore make important contributions to Canada's efforts to meet its climate change commitments. Among the mitigation actions being considered by various jurisdictions are the following:

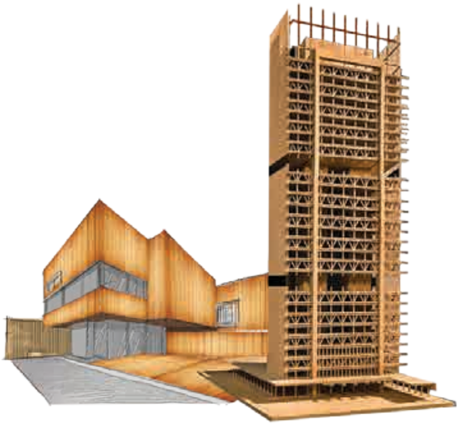
- Increase the overall forest area – Landowners could plant new forests on lands not currently part of the managed forest.

Increase the overall forest area.

- Use sustainable forest management practices that reduce GHG emissions and store carbon – Forest managers could limit on-site burning of harvest waste (such as stumps, bark and branches), using it for bioenergy instead; make more complete use of the material harvested; speed up reforestation after natural disturbances; and increase growth rates in appropriate locations through intensive management.

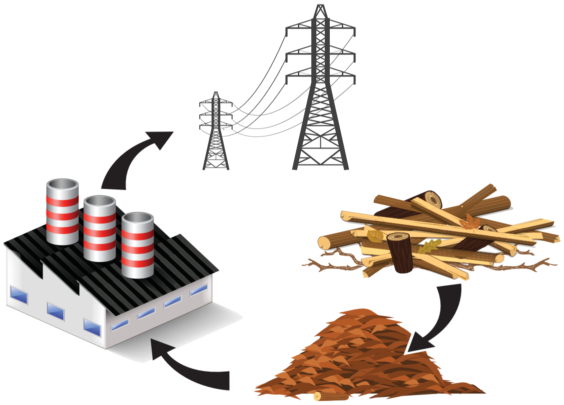
Use sustainable forest management practices that reduce GHG emissions and store carbon.

- Use more wood in construction – Builders could use more wood from sustainably managed forests in non-traditional construction applications in place of other materials whose manufacture, use and disposal involve higher amounts of GHG emissions. The practicality and environmental benefits of using wood in construction are already being demonstrated in ever larger and taller wood buildings. (See "Taking wood buildings to new heights" on page 14.)



Use more wood in construction.

- Use more wood waste for energy and other bioproducts – Industry and individuals could increase the use of waste wood for energy to replace fossil fuels or use bioproducts that replace similar products made from fossil fuels. (See “5 reasons why wood is one of Canada’s most valuable resources” on page 15.)



Use more wood waste for energy and other bioproducts.

Some of the emission-reducing benefits from these activities would be immediate. Other benefits would take more time to achieve. For this reason, the sooner mitigation actions are undertaken, the more they will help Canada meet its GHG emission reduction target for 2030 and its longer-term move to a low-carbon economy.

> The federal government, provinces and territories are working together to develop a pan-Canadian framework for climate change. Launched by the Prime Minister and Premiers in March 2016, the framework aims to develop and implement a plan for how Canada can achieve its 2030 climate change target.

Looking ahead to minimizing future climate change impacts

While there is no certainty about future climate or forest conditions, the impacts of current climate change on forests is evident in more frequent fires, insect and disease outbreaks, and drought. Canada’s scientists are working with others around the world to equip decision-makers at all levels with knowledge and tools to better anticipate the climate challenges ahead.

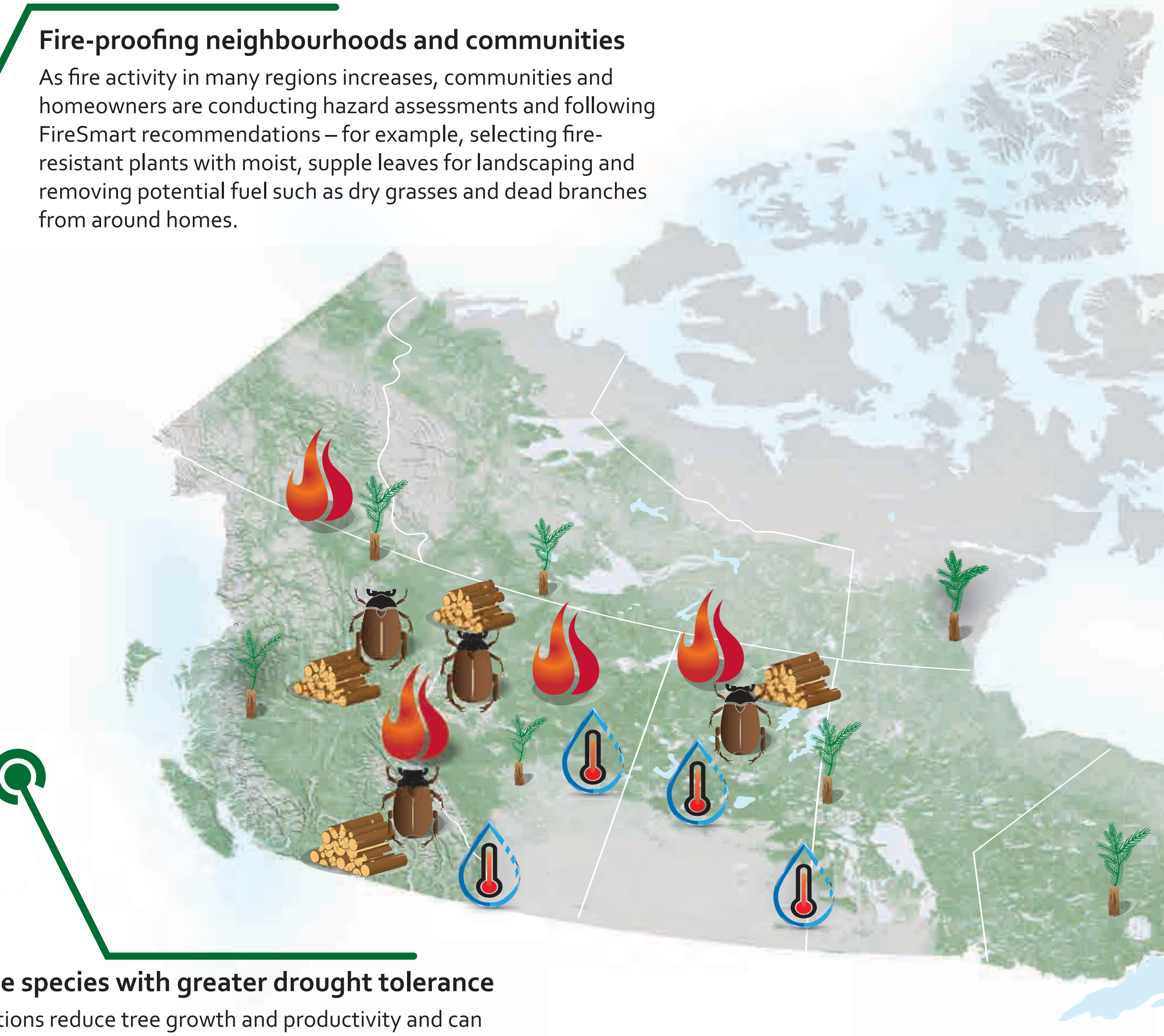
An example is Canada’s carbon monitoring and reporting system. It tracks how emissions are changing and is a useful tool for devising carbon mitigation strategies. Other tools, such as assisted migration and risk assessment guidelines, have also been developed. Forest managers are already using these to adjust their thinking and their management practices to support the long-term sustainability of Canada’s forests. New strategies, tools and practices will continue to emerge as research adds to our knowledge of the complex relationship between forests and climate.

As a biological resource, forests are on the front line in experiencing the effects of the ongoing changes. And as a renewable resource made of carbon, they are part of the climate change solution. For both reasons, helping our forests adapt is critical for maintaining their health and for ensuring that mitigation strategies are successful.

Adapting to climate change in Canada’s forests

Fire-proofing neighbourhoods and communities

As fire activity in many regions increases, communities and homeowners are conducting hazard assessments and following FireSmart recommendations – for example, selecting fire-resistant plants with moist, supple leaves for landscaping and removing potential fuel such as dry grasses and dead branches from around homes.

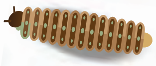


Planting tree species with greater drought tolerance

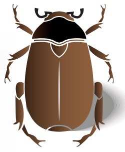
Drought conditions reduce tree growth and productivity and can lead to tree mortality. Researchers are studying plant traits to identify tree species with greater drought tolerance and increased ability to reproduce following drought.

Planting trees from a wider range of seed sources to maintain productivity

A tree planted today will mature in a warmer climate and may not grow as well in that regime. Foresters are therefore planting seedlings from a range of seed sources, favouring species from southern or lower-elevation populations – sources already adapted to warmer conditions.



SPRUCE
BUDWORM



MOUNTAIN PINE
BEETLE

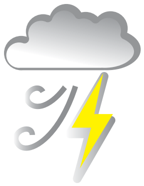
GYPSY MOTH

Adjusting forest harvest schedules to minimize severe insect damage

As the incidence of severe insect infestations increases, foresters can adjust harvest schedules to remove vulnerable stands of trees ahead of pest attacks and harvest insect-damaged trees to maintain overall stand health.

Reducing damage to forests from wind storms

As temperatures warm, the early thaw and delayed freezing of soils provide less support for tree roots, making them more prone to uprooting during spring and fall wind storms in eastern Canada. Silviculture techniques such as varying the size and shape of harvest blocks and leaving patches can help reduce forest vulnerability to wind damage.



Finding ways to use the wood from dead and damaged trees

To offset the effects of damage to forests caused by insect and disease outbreaks, forest companies are salvage-logging and adjusting wood-processing techniques to create new products from dead and lower-quality trees.

Forests and Climate Change

Forests cover about 30% of the Earth's land surface. As forests grow, their trees take in carbon from the air and store it in wood, plant matter, and in the soil. If not for forests, much of this carbon would remain in the atmosphere in the form of carbon dioxide (CO_2), the most important greenhouse gas driving climate change.

Each year since 2000, forests are estimated to have removed an average of 2 billion metric tons of carbon from the atmosphere.[1] This "carbon sink function" of forests is slowing climate change by reducing the rate at which CO_2, mainly from fossil fuel burning, builds up in the atmosphere. Careful forest management can therefore be an important strategy to help address climate change in the future. Healthy forests also provide a host of other benefits, from clean water to habitat for plants and animals that can live nowhere else.

Deforestation, and our options to reverse it

Over the past 8,000 years, humans have cleared up to half of the forests on our planet, mostly to make room for agriculture.[2] Cutting down or burning forests releases the carbon stored in their trees and soil, and prevents them from absorbing more CO_2 in the future. Since 1850, about 30% of all CO_2 emissions have come from deforestation.[3] Deforestation can also have more local climate impacts. Because trees release moisture that cools the air around them, scientists have found that deforestation has led to more intense heat waves in North America and Eurasia.[4]

There are three ways to reverse these losses: afforestation, reforestation, and the natural regeneration of forest ecosystems. Afforestation refers to planting forests where there were none before, or where forests have been missing for a long time—50 years or more. Reforestation is planting trees where forests have been recently cleared. Natural regeneration, on the other hand, does not involve tree-planting.[5] Instead, forest managers help damaged forests regrow by letting trees naturally re-seed, and through techniques like coppicing, in which trees are cut down to stumps so new shoots can grow.

Forests as a climate solution

There is no doubt that these strategies can help remove CO_2 from the atmosphere, but their impact is hard to measure. Even for China, which has done more afforestation and reforestation than the rest of the world combined, there are still large uncertainties about how much carbon these projects are storing.[6]

Looking at China also shows some of the unintended consequences of large-scale tree-planting projects. In the dry northern part of the country, people have planted trees to fight desert expansion. But because the tree species that were planted were ill-suited to a dry climate, this effort has depleted water supplies and degraded soils. In the south of

China, reforestation with monocultures—that is, just one species of tree—has led to loss of biodiversity.[7]

Natural regeneration of forests, on the other hand, has few unintended consequences and large potential to store carbon over the coming decades. If done worldwide, natural regeneration of forests could capture up to 70 billion tons of carbon in plants and soils between now and 2050[8]—an amount equal to around seven years of current industrial emissions. Combining natural regeneration with thoughtful afforestation and reforestation is an important option for combating climate change.

Footnotes

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CANADIAN FOREST SERVICE SCIENCE-POLICY NOTES

Deforestation in Canada—What Are the Facts?

May 2008

The Canadian Forest Service of Natural Resources Canada monitors deforestation to meet international climate change reporting requirements.

Annual deforestation rates are estimated using a combination of satellite and aerial images, land-use records, and field inspections. The results show that although there is some deforestation in Canada, most is driven by sectors of the economy other than forestry, such as agriculture and urban development.

What Is Deforestation?

Deforestation is the permanent removal of forest cover from an area, and the conversion of this previously forested land to other uses. In Canada, clearcutting or other harvesting practices are used as part of sustainable forest management to provide timber for producing paper or wood products. This is not considered deforestation because the area is replanted or allowed to regenerate naturally, renewing the forest cover.

Area deforested for recreational usage (golf course) in Southern Ontario. (Don Leckie, Natural Resources Canada)

Deforestation in Canada—A Snapshot

- Deforestation is not logging—it is the result of clearing trees for a change to a non-forest land use, such as agriculture.
- Deforestation affected less than 0.02% of Canada's forests in 2005.
- Canada's deforestation rate accounts for only 0.4% of global deforestation.
- Solutions are complex, requiring the involvement of many players. Integrated landscape management and other best practices are part of the answer, as is raising public awareness about the issue.

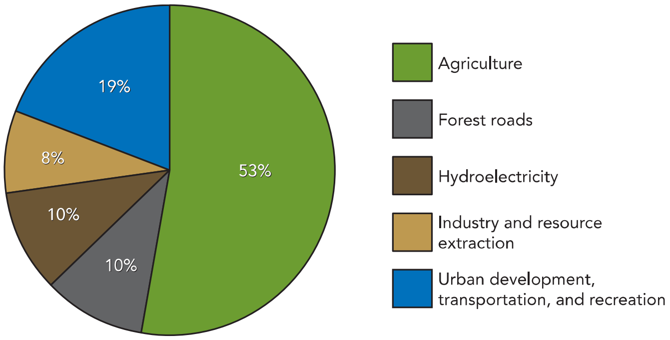
How Much Deforestation Occurs in Canada?

Canada's 402 million ha of forest and other wooded land account for about 10% of the world's forest cover. In 2005, an estimated 56 000 ha were deforested in Canada. Over the past 30 years, except for large hydroelectric projects in the late 1970s and early 1980s, annual deforestation rates have been decreasing. Overall, deforestation affected less than 0.02% of Canada's forests in 2005. A portion of this deforestation is offset by increases in forest area due to afforestation (planting of new areas of forest), estimated at 9400 ha in 2005.

Globally, about 13 million ha of forest are deforested each year—the area of Nova Scotia and New Brunswick combined. Therefore deforestation in Canada represents only approximately 0.4% of global deforestation, far less than Canada's 10% share of the world's forests. Around the world, deforestation is a major issue because it reduces biodiversity, affects water and soil quality, and is an important contributor to climate change. Although the rate of deforestation in Canada is quite low, it still makes sense to try and reduce it where possible.

What Activities Cause Deforestation?

The agriculture sector accounted for just over half of the deforestation in 2005 (see chart), the result of forests having been cleared for pasture or crops. The remainder was caused by urban development, transportation corridors, and recreation (19%); hydroelectric development (10%); the forest sector (10%); and other natural resource extraction industries (8%). About two-thirds of this deforestation occurred in Canada's boreal forest,



Causes of deforestation in Canada for 2005.

mainly in areas in Alberta, Saskatchewan, and Manitoba where the forest borders the Prairies.

How Can We Reduce Deforestation in Canada?

Deforestation in Canada is driven by demand for resource development, economic growth, and the need to build infrastructure. Efforts to reduce deforestation must therefore be balanced against other goals, such as expanding the economy, diversifying economic activities, and supporting community employment.

As a result, finding solutions to reduce deforestation is challenging. There is a range of government policies and regulations that affect development, and these vary by sector and jurisdiction. Policies and regulations generally deal with other environmental, safety, or economic issues—not deforestation. A further challenge is the lack of public awareness about deforestation. Governments and the public have only recently begun to focus on this issue.

Because of increasing awareness, governments and industry are trying to better understand and reduce deforestation in Canada. Recognizing that we need a more comprehensive approach, provincial governments are increasingly using innovative practices such as integrated landscape management (ILM). Integrated landscape management means planning land uses over an entire landscape and encouraging different land users to work together. For instance, ILM has been used in Alberta to coordinate forest clearing with oil sands development, to ensure forest companies harvest timber from sites to be cleared for oil and gas, and to prevent forest clearing for oil and gas development in newly replanted areas. British Columbia has also used ILM to encourage the various industries operating in forests to share roads rather than each building its own.

Area deforested for agricultural purposes near Quyon, Quebec. (Roberta Gal, Natural Resources Canada)

Deforestation and Greenhouse Gas Emissions

The Canadian Forest Service estimates greenhouse gas emissions from deforestation for inclusion in Environment Canada's greenhouse gas National Inventory Report. Those estimates show that, in 2005, deforestation caused less than 3% of the total greenhouse gas emissions in Canada. In comparison, deforestation worldwide results in up to 20% of global human-caused emissions according to the Intergovernmental Panel on Climate Change—most of this is in developing countries. Since Canada's total greenhouse gas emissions are about 2% of global emissions, deforestation in Canada represents a very small proportion of global greenhouse gas emissions.

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ISBN 978-0-662-47858-4
Cat. no. Fo93-1/3-2008E-PDF

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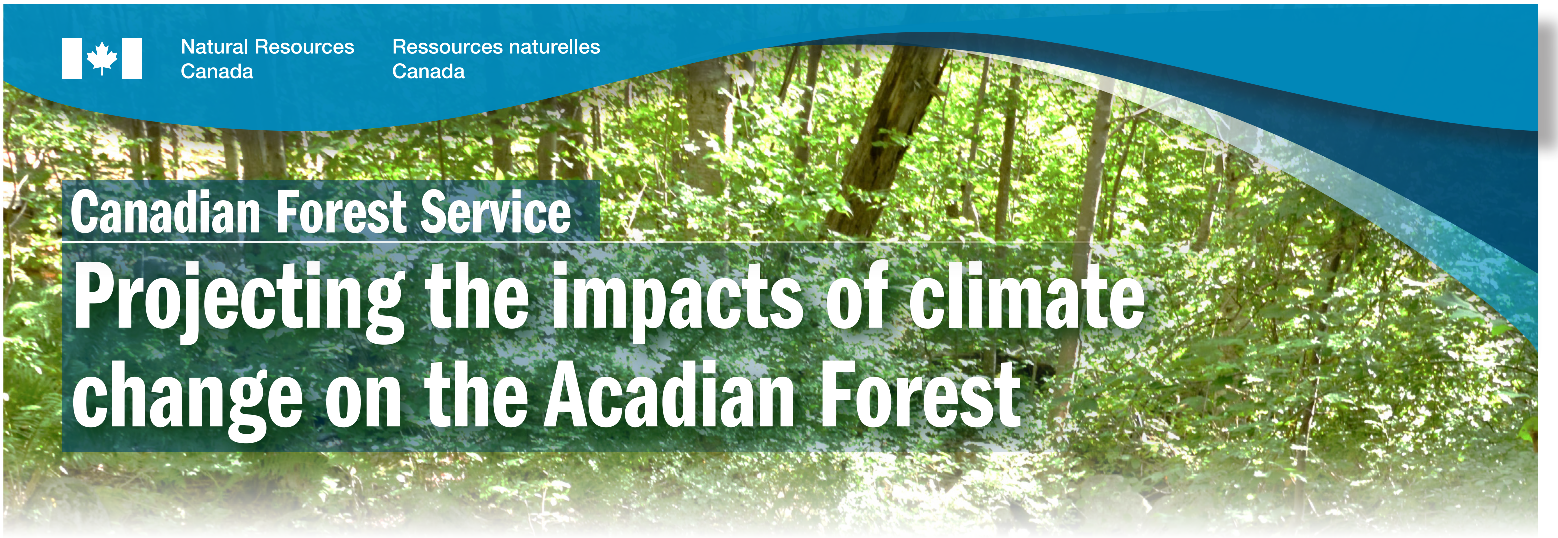


Canadian Forest Service

Projecting the impacts of climate change on the Acadian Forest

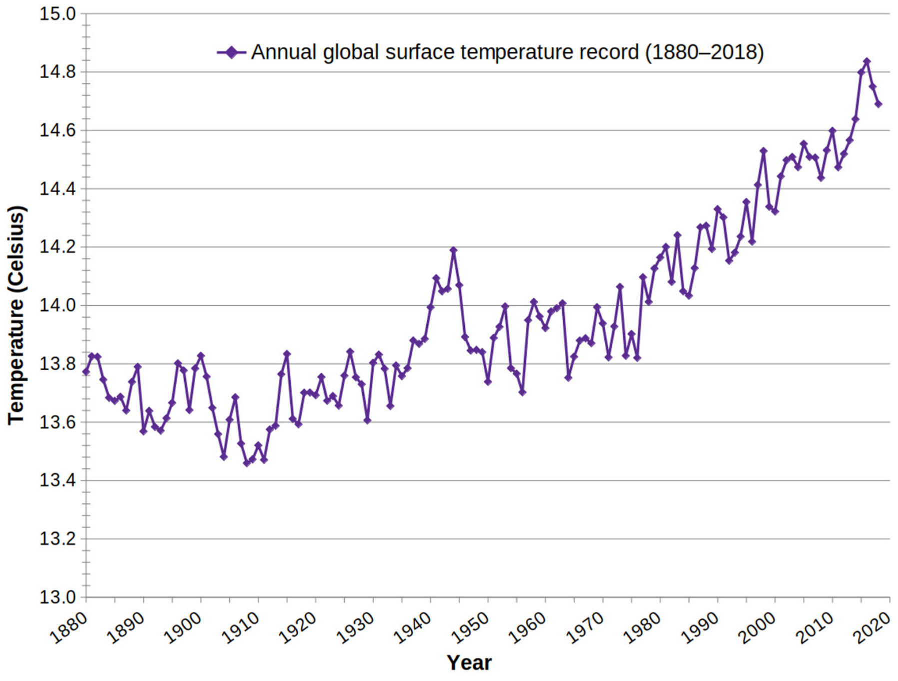
Impact Note No. 63

The Earth's climate is constantly changing and has been doing so for billions of years. Twenty thousand years ago most of Canada was covered with a sheet of ice more than a kilometre thick. As the ice withdrew, life slowly returned to the barren landscape left behind by the retreating glaciers. The fauna and flora (including trees) that are present today are mostly the result of a northward migration that occurred at end of the last ice age. Plant and animal species have different habitat requirements and are constantly seeking the "sweet spot" that will satisfy all of their needs.

Global temperatures have been steadily rising over the last 100 years. Although fluctuations in temperature are a natural phenomenon, most scientists agree that the rate of increase is greater than what would be considered "normal" and that the increase is being driven by the burning of fossil fuels, which is contributing to an increase in the amount of carbon dioxide in the atmosphere.

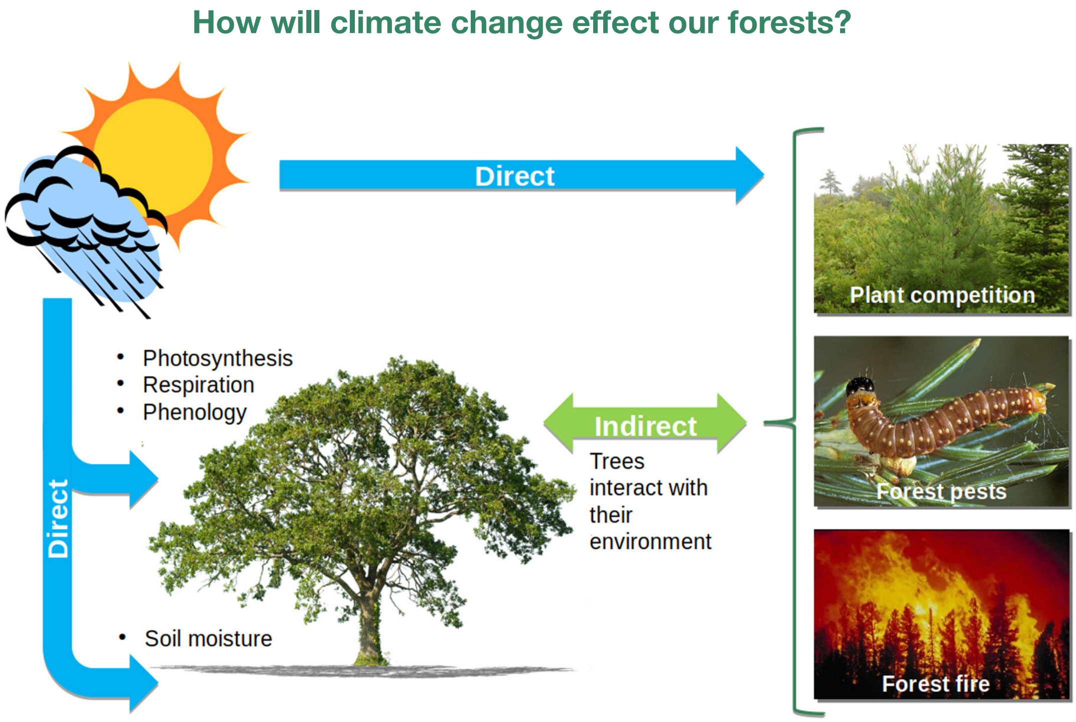
Dr. Anthony Taylor is a research scientist with the Canadian Forest Service at the Atlantic Forestry Centre in Fredericton, New Brunswick. He is part of a team of scientists that is using ecosystem simulation models to project the effect of climate change on the forest. More specifically, Taylor's recent work has focused on understanding and projecting the effects of climate change on the growth and species composition of the Acadian Forest.

Figure 1. Annual global land and ocean temperature (1880–2018)



Source: noaa.gov

Figure 2. Direct and indirect effects of climate change on the Acadian Forest



How climate change will affect the Acadian Forest

Climate change strongly affects the distribution of tree species. Changes in temperature and precipitation directly affect tree phenology, photosynthesis and respiration. Climate also affects forests indirectly through its effects on fire, insects and diseases, severe weather events, soil moisture regimes, and competition for resources.

The best way to address the complexity of these interactions is through forest ecosystem simulation modeling. Models provide a framework that allows researchers to integrate our knowledge of many factors to project how the ecosystem will respond to environmental changes.

To project the impacts of climate change on tree species, we need to know what changes in climate are likely to occur in the future. The United Nations International Panel on Climate Change has adopted four climate change scenarios that describe possible climate futures to the year 2100. The climate scenarios are referred to as "representative concentration pathways" (RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5). They represent different radiative forcing (warming) narratives (i.e. story lines) that humanity may follow depending on our future dependence on fossil fuels and on the level of greenhouse gas emissions. Scientists use these climate scenarios to predict future impacts under different levels of greenhouse gas concentrations.

Taylor used RCP 2.6 and RCP 8.5 and compared his results to our current climate as represented by conditions that existed between 1981 and 2010.

RCP 2.6 assumes that greenhouse gas emissions will peak sometime between 2010 and 2100 and then start to decline. This situation represents a mean annual temperature increase of about 3°C from current conditions in the Acadian Forest region by mid-century, at which time it will start to decline.

RCP 8.5 represents a "business as usual" scenario in which carbon dioxide levels continue to rise unchecked, and the mean annual temperature continues to rise to about 7°C above current conditions by the year 2100.

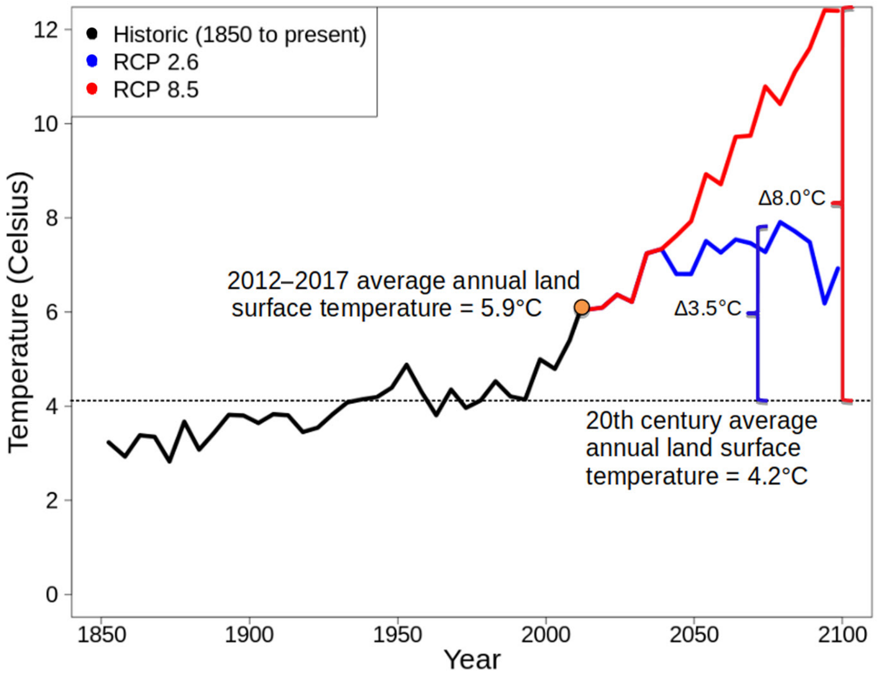
Forest ecological modeling

Various models can be used to project forest change. Some models operate at a very coarse ecological scale. This enables them to model the effects of climate change over very large spatial scales (e.g. nationwide), but at the cost of omitting important biological details about how the forest actually works.

Other models operate at finer ecological resolutions, incorporating many biological processes. This allows them to simulate forest ecosystems more realistically, but this extra detail limits their application to smaller forest areas.

Taylor used PICUS, an individual tree-based, spatially explicit, forest gap model that simulates the establishment, growth and mortality of individual trees on 1-hectare sections of forest area. The PICUS model requires information on many factors that affect the growth and composition of the forest. Those factors include soil (pH, available nitrogen, water holding capacity); climate (temperature, precipitation); tree species (18 most important species); and disturbances (fire, insects, windthrow, harvesting).

Figure 3. Climate change projections for the Maritimes under RCP 2.6 and RCP 8.5



Sources:
Historic data: berkeleyearth.org
Projection data: Natural Resources Canada

Taylor used 988 provincial forest inventory plots that are representative of stand conditions across the Acadian Forest and simulated forest dynamics in these plots under different climate change scenarios using the PICUS model.

What the Acadian Forest will look like in the future

The Acadian Forest region is a mosaic of softwood, hardwood and mixedwood forests. The Acadian Forest consists of tree species that are representative of the conifer-dominated boreal forest to the north and temperate deciduous forest to the south.

Boreal tree species such as balsam fir, black spruce, white spruce, white birch and trembling aspen are at the southern limit of their ranges. Temperate species such as red maple, red oak, American beech, eastern hemlock and eastern white pine are at their northern climatic limits.

Species that exist on the fringes of their home ranges are particularly susceptible to a changing environment. As the climate warms, tree species that characterize the temperate forest will find the conditions more favourable, while cold-adapted species of the boreal forest will find the conditions more challenging.

Species composition

In the short term (years 2011 to 2040), little or no difference in forest composition is projected between the baseline (current climate) and RCPs 2.6 and 8.5. No discernible changes in forest composition were detected under RCP 2.6 over the long-term. However, under RCP 8.5, the relative abundance of warm-adapted temperate tree species gradually begins to increase by mid-century while the cold-adapted boreal tree species (e.g. spruce and fir) decrease. By the end of the century, the abundance of spruce and fir is projected to decrease by 20 to 30% under RCP 8.5.

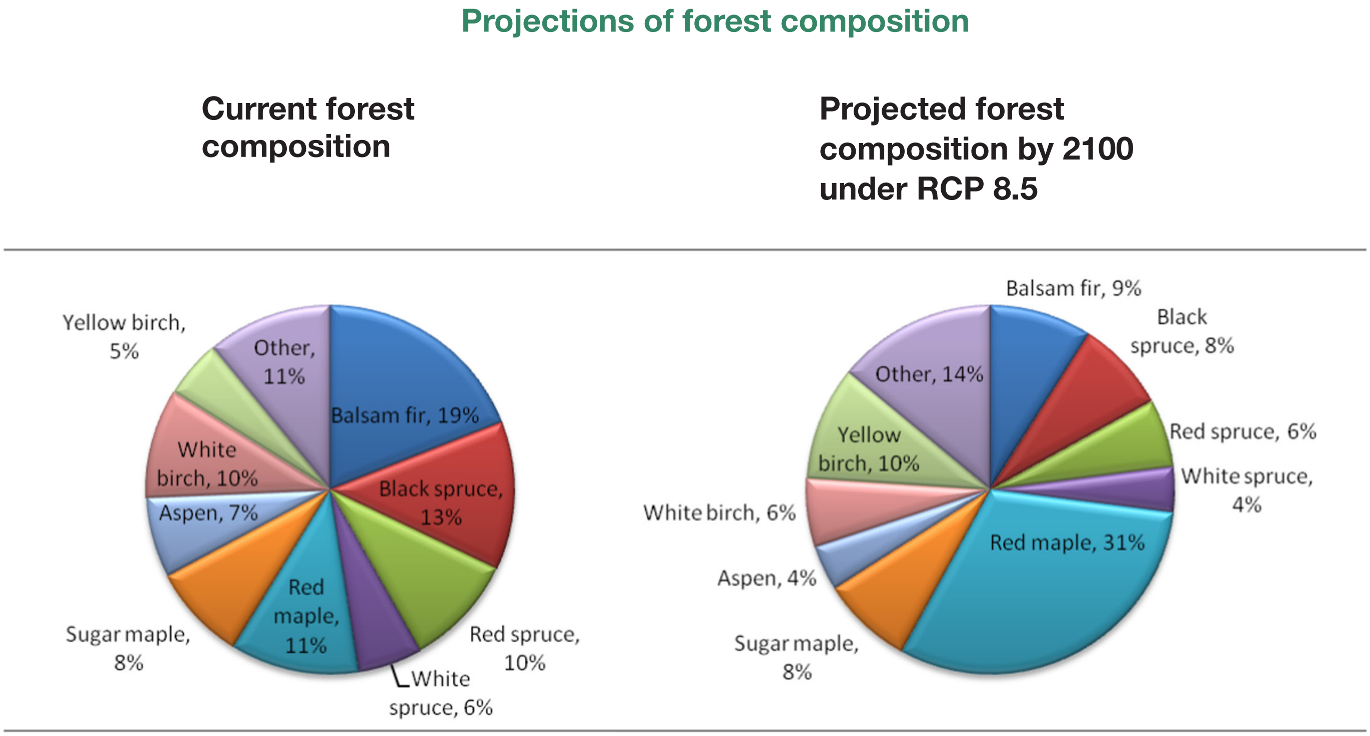
Forest growth

Similar to forest composition, in the short-term (2011 to 2040), little or no difference in forest growth is projected between the baseline and RCPs 2.6 and 8.5. In the long-term, growth rates under RCP 2.6 are slightly lower than baseline, showing a 6% decrease in growth by the year 2100. The greatest difference occurs under RCP 8.5, where a 42% reduction in growth is projected.

The main reason for the loss in productivity is a reduction in growth of the boreal species component of the Acadian Forest. This decrease in growth of boreal species is exacerbated by what Taylor and colleagues are calling a “blocking mechanism.”

What happens is maladapted boreal species are physically blocking the establishment of better-adapted temperate trees by continuing to occupy space. Because the climate is expected to change very rapidly under RCP 8.5, the forest is unable to adapt quickly enough, causing a lag effect. The effect is that there may be a temporary adjustment period for the warm-adapted temperate trees to gradually replace the boreal component.

Figure 4. Projection of forest composition in the Acadian Forest under RCP 2.6 and RCP 8.5



Forest managers need to be aware of the effects that a warming climate may have on our forest, especially under a "business as usual" scenario represented by RCP 8.5. In this scenario, a reduction in valuable boreal species such as balsam fir, black spruce and red spruce will occur and will likely affect forestry in the region.

The forest industry in the Maritimes needs to be aware of these potential changes and consider how best to manage the forests as our climate changes.

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Impact Note No. 63

Cat. No. Fo103-3/63-2019E (Print)
ISBN 978-0-660-29420-9

Cat. No. Fo103-3/63-2019E-PDF (Online)
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Spruce budworm (*Choristoneura fumiferana*)

Spruce budworm is a native species and 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 black spruce.

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 edge 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.

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 continues uninterrupted over several years, some trees will die, while others will continue to 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 on the underside of needles, 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.

Adult moth (top left) and larva (bottom left) and severely defoliated stand of balsam fir (right). Photos on left Thérèse Arcand and right Claude Monnier

Forest tent caterpillar (*Malacosoma disstria*)

The forest tent caterpillar is native to North America and is a serious pest of many hardwood tree species. Outbreaks occur about every 10 years and usually last 2 to 5 years.

Defoliation is caused by the larvae (caterpillars), which begin to feed on the new leaves as soon as they appear in May. Given this insect's voracious appetite and gregarious behaviour, 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 outbreaks, millions of hectares of trees can be completely defoliated, but even severely defoliated trees can recover from short outbreaks relatively well. Trees defoliated for the first time will usually produce another crop of leaves later in the growing season.

In late June, the female deposits between 150 and 250 eggs in a single egg mass on twigs in the upper crown of host trees. Embryos become fully developed larvae before cold weather arrives, but do not emerge from eggs until the following spring.

Several natural factors play a role in regulating forest tent caterpillar populations once outbreaks have developed. Parasitoids and natural predators, such as birds that eat larvae and moths, can often be important forms of natural control.

The most important parasitoid is the large flesh fly (*Sarcophaga aldrichi*), that targets the forest tent caterpillar pupae. Large flesh fly populations increase rapidly after the start of a forest tent caterpillar outbreak and can destroy up to 80% of the pupae within a population.

Adult female moth (left); larvae (centre); egg band on twig (right). Photos Thérèse Arcand)

White pine weevil (*Pissodes strobi*)

Native to North America, the white pine weevil occurs throughout the range of white pine in eastern Canada. Damage is caused mainly by the larvae, which feed under the bark of the tree’s terminal leader. Feeding punctures made by the adult weevils can also damage the leader.

The first symptom of weevil attack is resin oozing from small (0.5-1.0 mm) feeding punctures in the spring. The presence of the insect is easily detected by the drooping, wilted appearance of the current year’s leader, which resembles a shepherd’s crook. The leader is eventually killed. Symptoms are usually noticeable by late June.

Tree mortality due to the white pine weevil is rare. During outbreaks, the combined damage caused by adults and larvae results in reduced growth and usually in the total loss of the previous and current years’ terminal shoots. In white pine with recurring annual damage, wood quality is affected, reducing merchantable timber volume by sometimes up to 60%.

The white pine weevil has only one generation per year, but the adults can live and continue laying eggs for several years. Adults overwinter in the forest litter, and, in early spring, emerge when the temperature rises to 2−4°C. They crawl up the trunks of nearby host trees to the terminal shoot and begin to feed before mating. Weevils also disperse by flying on warm sunny days. The female lays her eggs in feeding cavities in the bark made with her rostrum. After the eggs hatch, in about 10 days, the larvae burrow into the bark, feeding on the cortex (inner bark). At the end of their feeding period, the larvae burrow in the pith or directly under the bark, forming pupal cells lined with strands of wood chips.

Adult white pine weevil (left); larvae in terminal shoot (centre); damage on white pine terminal shoot (right). Photo credits: Thérèse Arcand (top left, bottom left); Jean-Pierre Bérubé (right)

Emerald ash borer (*Agrilus planipennis*)

Native to eastern Asia, the emerald ash borer was first discovered in near Windsor Ontario and Detroit Michigan in 2002. It had likely been present since the early to mid-1900s before it was detected. It has since spread to 35 US states and 5 Canadian provinces.

While the emerald ash borer can fly up to several kilometres, a 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.

Emerald ash borer has killed millions of ash trees and poses a major economic and environmental threat to urban and forested areas. The emerald ash borer 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. Adults emerge in June and July. A few days after mating, female ash borers lay between 60 and 9+0 eggs, one at a time, in bark crevices. After emerging, larvae dig into the bark and begin feeding under the bark creating s-shaped galleries. They hibernate in the bark and pupate in April or May.

Signs and symptoms include:

- 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

Adult (top left), larva (bottom left); galleries (right). Photos D. B. Lyons

Butternut canker (*Ophiognomonia clavigignenti-juglandacearum*)

Butternut (*Juglans cinerea*) is a native tree species of central and eastern North America that is under serious threat from an introduced fungal disease (*Ophiognomonia clavigignenti-juglandacearum*). In Canada, butternut can be found in southern Quebec and Ontario and in New Brunswick. The butternut populations in New Brunswick are considered to be the most genetically diverse and contain some of the last remaining uninfected butternut trees in North America.

The fungus infects butternut trees through buds, leaf scars, insect wounds and other openings in the bark. It is believed that rain splashing can move the fungal spores from infected branches to other branches and that insects and birds may inadvertently carry the spores to the trees. A characteristic sign of infection in a butternut is cankers that leak a blackish fluid from cracks in the bark after a rainfall or in humid weather. These cankers coalesce and eventually girdle the main trunk, killing the tree. Controlling infected trees is not possible. This fungal disease is a fundamental threat to butternut and has caused this species to die out throughout much of its natural range.

In 2005, butternut was listed as Endangered by the Species at Risk Act (SARA) in Canada. A federal recovery strategy was developed for butternut in 2010 and notes that recovery will likely depend on finding canker-resistant trees, conserving genetic material, and instituting a program to restore viable populations.

The work currently being carried out in New Brunswick is a key component of this recovery strategy. The butternut project is using seeds to conserve butternut in the long term. Butternut seed cannot withstand much drying, and because of this, remains viable for only up to two or three years. Although whole seeds cannot be stored, research has shown that part of a butternut seed, the embryo, can be cryogenically preserved for many years in liquid nitrogen (-196°C). The National Tree Seed Centre in the Atlantic Forestry Centre in Fredericton, New Brunswick, has a cryogenic facility that can store close to 50,000 butternut samples.

Butternut canker has been found across the entire geographic range of butternut. It has killed up to 90 percent of the butternut population in some areas of the United States.

Butternut canker damage (lefty and centre); cluster of butternuts (right). Photos: Tannis Beardmore.

Spongy moth (*Lymantria dispar*)

Formerly known as the gypsy moth, the spongy moth was introduced to the United States in 1869 and has become one of the most serious defoliators of hardwoods in North America.

Spongy moth damage is caused exclusively by the caterpillars, which feed on developing leaves in May. Newly hatched larvae are hairy and black and feed by chewing small holes in the surface of the leaves. Older larvae devour entire leaves. The body of the larvae are dark-coloured and hairy, with red and blue spots on the back. Full-grown larvae can be up to 65 mm long.

Another sign of spongy moths is the presence, in late July, of spongy egg masses covered with tan or buff-coloured hairs from the female's abdomen on the trunks and branches of trees or in forest debris near defoliated trees.

During severe outbreaks, trees and shrubs are completely defoliated over large areas. Despite the trees' ability to produce a new crop of leaves over the summer, the damage causes significant growth loss. Understorey shrubs and plants may also be affected.

Mature larvae feed at night and congregate in shady areas during the day, particularly in the litter near the trunks of affected trees. When the tree is completely defoliated, the larvae vacate the tree and migrate in groups in search of new sources of food.

Upon completion of their development, the larvae pupate, often in the same shady areas where they take refuge during the day. The adults emerge in July. The females, which are too heavy to fly, lay up to 1000 eggs per mass, often near the pupation site. The insect overwinters in the egg stage.

Adult female (top left); larva (bottom left); egg masses on tree trunk (right). Photo credits: Thérèse Arcand (top left, bottom left); Pierre Therrien (right)

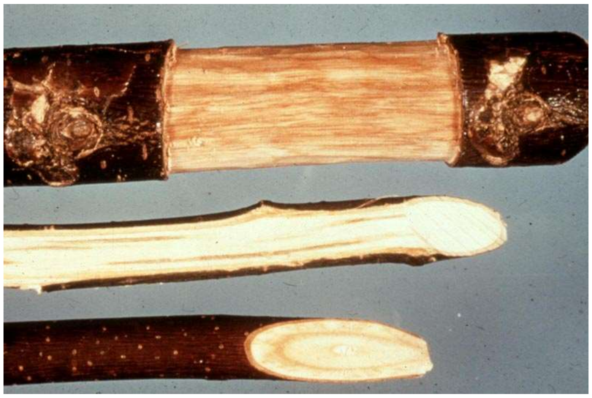
Dutch elm disease (*Ophiostoma ulmi*)

Dutch elm disease was introduced into Canada around 1940.

The fungus causes a vascular wilt that results in browning of the foliage and kills affected trees. Because their sap supply is cut off and fungal toxins poison them, the affected parts of the tree wilt and eventually die; this process can take a few days or a few years.

The fungus develops in the sap-conducting tissues of elm trees, under the bark. The first symptoms of the disease generally appear between mid-June and mid-July. The leaves of affected branches wilt, curl up and dry out, while turning yellowish or brownish, but they usually remain on the tree. If the infection occurs later in the season, premature leaf drop usually follows the wilting. When an infected branch is cut, a ring-shaped brownish vascular discoloration can be seen. The exposed wood beneath the bark has numerous brown streaks.

The disease is transmitted by bark beetles. These insects dig galleries beneath the bark of weakened trees where they can reproduce. Once spring arrives, the bark beetles, which have in the meantime become covered by spores from the causal fungus, migrate toward healthy trees and begin feeding. The beetles thus contaminate new hosts and spread the disease. A new, more aggressive disease, *Ophiostoma novo-ulmi*, has resulted from natural mutation of the former disease. This disease has spread from the American Midwest and replaced the disease introduced in the 1940s.



Brown vascular staining caused by Ophiostoma ulmi in a white elm with Dutch elm disease

Infected elm tree (Photo: Pierre Desrochers)

Brown spruce longhorn beetle (*Tetropium fuscum*)

The brown spruce longhorn beetle is native to Europe, where it can be found from Scandinavia to Turkey. It is also present in Japan and western Siberia.

In March 1999, the brown spruce longhorn beetle, was found in dying red spruce trees in Point Pleasant Park, Halifax, Nova Scotia. The find in Nova Scotia is believed to be the first discovery of this insect in North America.

The adult has a flattened body, 1 to 1.5 cm long. The head and neck area are dark brown to black. The elytra (wing covers) can be tan, brown, or reddish brown and have 2 to 3 longitudinal stripes. The antennae are red-brown and about half of the body length. The legs are dark brown. The larvae is yellow-white, about 14 to 28 mm long, and slightly flattened.

In its native range the brown spruce longhorn beetle is recognized mainly as a secondary forest insect, attacking trees that have already been subjected to other types of insect attack or environmental stresses. During a population outbreak, beetles can attack living, healthy trees. Outbreak levels have the potential to persist for a decade and continually cause damage over extensive tracts of vulnerable conifer forest. In Europe, the brown spruce longhorn beetle often attacks stands of Norway spruce over 50 years of age. Tunnels in the wood as a result of larval feeding reduce timber quality.

Symptoms of attacked trees include:

- streams of resin scattered along the trunk
- holes in the bark about 4 mm across
- networks of feeding tunnels just under the bark, up to 6 mm across;
- tunnels in the wood about 4 cm deep and 6 mm wide. These tunnels appear L-shaped when the wood is cut longitudinally.
- Coarse sawdust may be found in and around tunnels or plugging the exit hole.

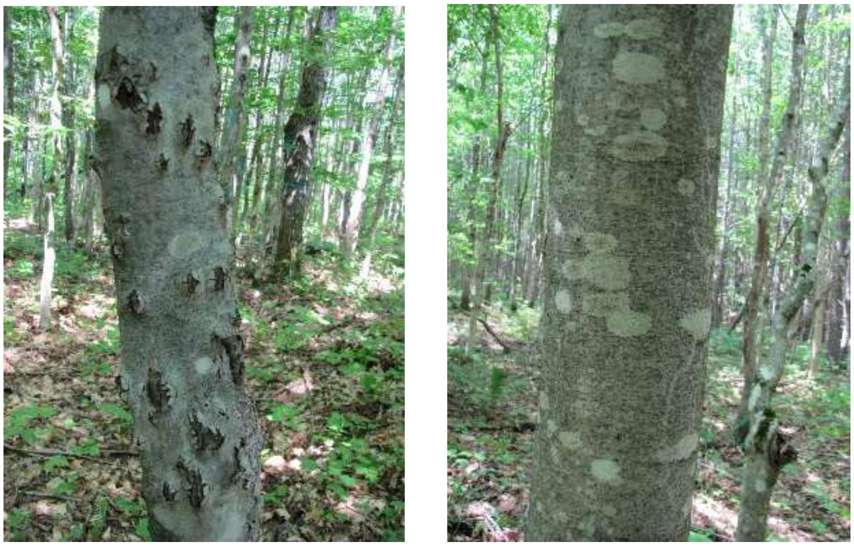
Adult brown spruce longhorn beetle (left); streams of resin along the trunk (centre); larva in wood (right). Photos Jon Sweeney

Beech bark disease (*Neonectria fagiana*)

Beech bark disease results from the combined action of the beech scale insect and a pathogenic fungus, *Nectria coccinea*. Most affected beech end up succumbing to the disease, either directly or as a result of being attacked by other pathogens.

In mid-summer, the female deposits her eggs (asexual reproduction) in the bark fissures. The larva hatches and stays in the same place or migrates to other cracks. In fall, the nymph becomes stationary again and secretes a woolly envelope. This woolly envelope makes the tree look like it is covered with snow. The scale insect overwinters in the bark of the tree. The fungal spores are disseminated by rain splash or by the wind and penetrate into the tree through wounds created by the scale insect. The fungus first causes a depression in the bark of the affected region and cankerous blisters of various sizes also form. On severely affected trees, there are so many cankers that they end up merging.

A beech survey conducted in the mid-2000s found that between 3 and 4 percent of the beech tress in the Acadian Forest region remain free of the disease and appear to be resistant.



American beech infected with beech bark disease (left) and disease-free beech (right).
Photos: Bernard Daigle

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CANADIAN FOREST SERVICE

A conceptual framework for spruce budworm early intervention:

Can outbreaks be stopped?

IMPACT NOTE NO. 65

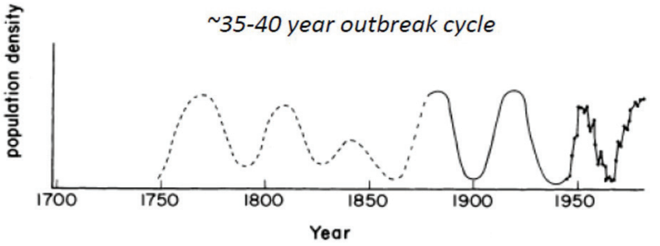
The spruce budworm is a native forest insect that inhabits the spruce-fir forests of northeastern North America. Outbreaks of this insect occur every 30 to 40 years. During this cycle, populations range from being very low (endemic) to very high (epidemic). If left unmanaged, these outbreaks can result in significant growth reduction and mortality of spruce and balsam fir trees.

Previous efforts to protect the forest against spruce budworm were a reaction to an outbreak that was already underway. Insecticide was applied over large areas of forest by aerial spraying after significant defoliation had occurred. This is often referred to as the foliage protection strategy, and its main objective is to keep the trees alive. This reactive approach must be repeated every year until the outbreak ends.

These large-scale foliage protection programs cost governments millions of dollars and generally mitigate only a small fraction of the damage to forests and on the forest industry because the damage has already occurred.

Scientists from Natural Resources Canada's (NRCan) Canadian Forest Service and five Canadian universities are testing a unique approach to managing spruce budworm populations – the early intervention strategy (EIS) for spruce budworm. If successful, the EIS could prevent an outbreak from occurring, with minimal or no defoliation in forests and therefore no impact on the wood supply, the economy, and the ecological services that spruce-fir forests provide.

Changes in spruce budworm density over time. Note that the outbreak peaks occur every 30 to 40 years.



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What causes spruce budworm outbreaks?

The cause of spruce budworm outbreaks has puzzled scientists for decades. Knowing the cause is important for forest managers because it affects how spruce budworm populations are managed during outbreak cycles. The competing theories of outbreak development are oscillatory and double equilibrium.

Oscillatory theory (predator-prey relationship)

The oscillatory theory supposes a predator-prey relationship between the spruce budworm and its natural enemies (i.e. predators, parasites and diseases).

In this theory, natural enemies kill enough spruce budworm to keep populations from growing large enough to cause an outbreak.

However, when the spruce budworm population is small, the population of natural enemies that feed on spruce budworm decreases. When conditions are favourable, this fluctuation can lead to a rapid increase in the spruce budworm population that causes an outbreak over a large area.

If this theory were correct, then a large-scale foliage protection program would be required to minimize the impacts of an outbreak.

The basics of the oscillatory theory are:

- Outbreaks occur over large areas and develop quickly.
- Moth dispersal does not play a strong role in the spread of spruce budworm.
- Regional-scale spruce budworm outbreaks cannot be prevented.
- A traditional foliage protection program is the correct strategy to manage spruce budworm.

Double equilibrium theory (formation of epicentres)

The double equilibrium theory supposes that spruce budworm populations can be at equilibrium at both endemic and epidemic stages.

Canada

In this theory, outbreaks originate in areas where spruce budworm populations are low but are growing to a level at which natural enemies and environmental controls cannot keep populations below outbreak thresholds.

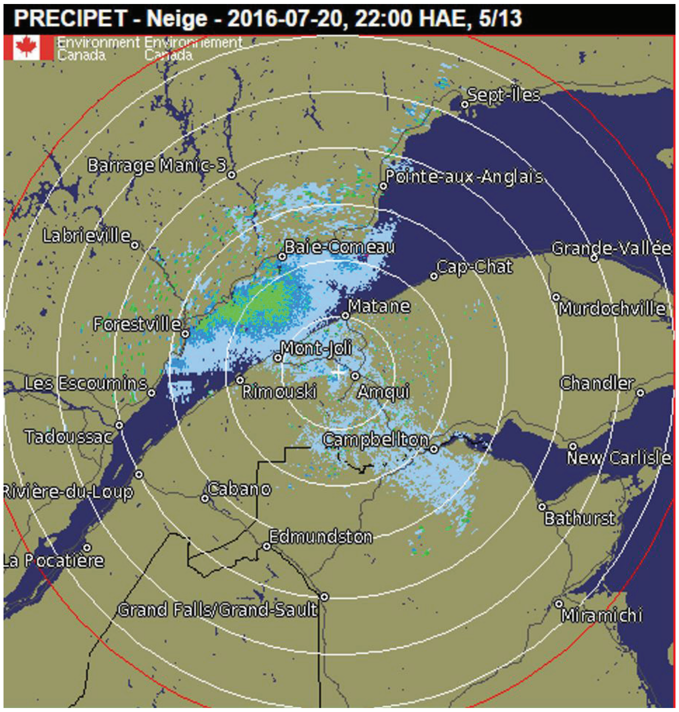
When this happens, spruce budworm populations increase quickly, creating a hotspot from which an outbreak can develop. Spruce budworm moths disperse from those hotspots, adding to existing populations or establishing new hotspots.

If this theory is correct, it may be possible to prevent outbreak spread by proactively suppressing pockets of rising population (i.e. hotspots) along the leading edge of the outbreak. Not only would this prevent populations from establishing and damaging those areas, it would prevent those areas from becoming sources of immigrant moths that would propagate spread.

The basics of the double equilibrium theory are:

- Outbreaks begin in small areas, with rapidly growing populations (hotspots).
- Moth dispersal plays a strong role in outbreak spread.
- Regional-scale budworm outbreaks can be prevented.
- Intervention early in the outbreak cycle is the correct strategy to manage spruce budworm.

A moth dispersal event in July 2016

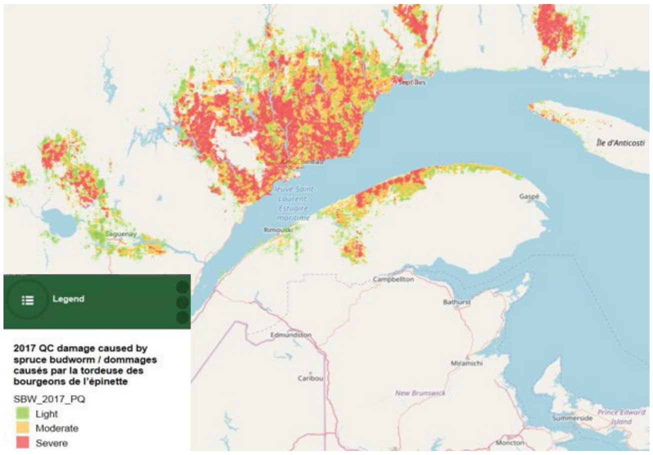


A new outbreak begins

In 2006, a new spruce budworm outbreak started in Quebec. Previous research occurred mostly during the peak and decline of outbreaks. Scientists at NRCan saw an opportunity to study a spruce budworm outbreak early in its cycle.

The research showed that the outbreak might be spreading from areas with high spruce budworm populations and that moth movement was likely contributing to the spread. These observations gave credence to the double equilibrium theory. Scientists theorized that it might be possible to control the spread of a spruce budworm outbreak by treating areas earlier in the cycle – at the leading edge of an outbreak.

Defoliation by spruce budworm in Quebec in 2014



Early intervention strategy

By 2014, the spruce budworm outbreak in Quebec had grown to 4.6 million hectares and was approaching the northern border of New Brunswick. In response to this threat, the Healthy Forest Partnership was formed to study if an early intervention approach could control spruce budworm populations at the leading edge of an outbreak, thereby preventing an outbreak from occurring. The group comprises researchers and representatives from academia, government (provincial and federal), and industry.

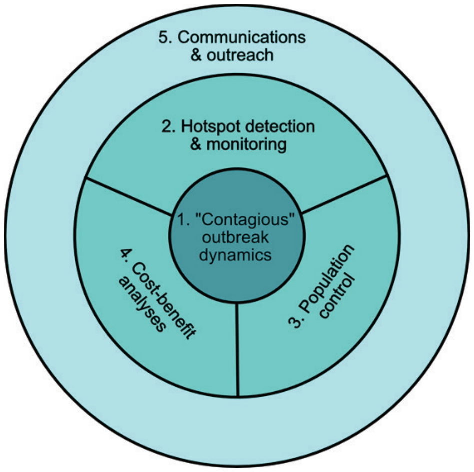
Double equilibrium population dynamics provided the core ecological justification for the early intervention strategy (EIS). EIS management involves applying insecticides on smaller areas or hotspots, that is, areas where populations are still low, but are increasing. The objective is to keep populations low enough to prevent an outbreak from occurring, with minimal or no defoliation to forests.

With smaller geographic areas to treat, the EIS presents forest managers with a lower cost option than a traditional foliage protection program. In addition, the EIS treats the forests before damage occurs, with minimal wood supply and economic losses.

Critical components of a successful EIS treatment are:

- monitoring and prioritizing treatment areas
- population control
- cost-benefit analysis
- communication and outreach

Conceptual framework for the early intervention strategy



Monitoring and prioritizing treatment areas

Intensive monitoring is the backbone of the spruce budworm EIS. Although forest managers and researchers use a variety of methods to assess spruce budworm numbers, sampling overwintering spruce budworm larvae provides the best indication of the number of budworm that will be present the following year. Sampling is the main tool for determining whether a local population needs to be controlled.

The threshold for hotspots is seven overwintering budworm larvae per branch. Once spruce budworm numbers surpass this level, the population is poised to erupt into a full-blown outbreak. Keeping populations below this threshold is the essence of the EIS.

Once hotspots are identified, treatment areas are determined by assessing the risk to the stands in the surrounding areas. Mature balsam fir and spruce stands are more susceptible than mixed wood or pure hardwood stands, and these factors are considered when deciding the area to treat.

Population control

Spruce budworm have a high reproductive capacity, with each female capable of laying an average of 180 eggs. Many natural and environmental factors contribute to mortality and help keep populations low.

Another important factor is mating success. When populations are low, female moths have difficulty finding mates, and reproductive success is affected. As numbers approach the threshold level, mating success improves, and the spruce budworm have a better chance of overcoming the natural controls that help keep populations in check.

The objective of the treatments is not to eradicate spruce budworm but rather to keep numbers below the threshold level and maintain populations at endemic levels. Another objective is to minimize harm to other organisms, including the many natural enemies of the spruce budworm.

Two insecticides (Btk and tebufenozide) are available for use in Atlantic Canada. Btk is a naturally occurring soil bacterium that causes a breakdown in the lining of the insect's gut wall and leads to death. Tebufenozide is a synthetic chemical that mimics a growth hormone found in caterpillars and causes premature moulting, leading to death. Both products are specific to Lepidopteran larvae (caterpillars of butterflies and moths) and are applied by spraying the foliage that the caterpillars eat.

Cost-benefit analysis

The costs and benefits associated with EIS for spruce budworm can be economical, environmental and social.

From a purely economic standpoint, spruce budworm outbreaks cause massive timber supply and economic losses, in part because they cover large areas and cause high tree mortality. Insect outbreaks can also influence local economies through their impact on non-timber forest products and tourism.

Ultimately, the feasibility of an EIS depends on how management costs compare with potential losses from an uncontrolled spruce budworm outbreak. The cost of an uncontrolled spruce budworm outbreak in Atlantic Canada has been estimated to be about $15 billion.

The ecological costs of a spruce budworm outbreak are significant. Dead trees increase the risk of forest fires, increase carbon emissions from the forest, and can affect water quality by increasing the nutrient load and causing stream temperatures to rise. The temperature rise can affect habitat for freshwater fish species such as trout and salmon that prefer cold water. An early intervention approach also has a lower spray footprint, as the treatment areas are substantially smaller than under a traditional foliage protection approach.

Society derives many ecological services from the forest, such as clean drinking water, clean air, recreation, aesthetics and spiritual values. A spruce budworm outbreak and widespread tree mortality put these at risk. In addition, wood supply loss could lead to mill closures and loss of jobs affecting the livelihood of families in resource-dependant communities of Atlantic Canada.

Communication, outreach and engagement

Canadians take a keen interest in their environment. Many remember past outbreaks of spruce budworm and the controversy that accompanied the large-scale insecticide treatment. Regardless of the quality of the science, the ultimate success or failure of an EIS depends on public support. Consequently, the communication and outreach strategy has always been to proactively engage audiences in a transparent manner, using experts as ambassadors.

The EIS includes consulting with government, industry, landowner organizations, Indigenous peoples, provincial and federal parks, and local media. The Healthy Forest Partnership keeps everyone informed about EIS research, treatments and the current spruce budworm outbreak through:

- the partnership website and social media
- presentations to citizens, landowners and communities
- annual general meetings to convene stakeholders
- hundreds of media interviews and meetings

Community scientist program

Public engagement in the EIS is recognized as critical to the success of the EIS. To that end, the Budworm Tracker community scientist program was launched. Each year, community scientists in Atlantic Canada, Quebec, Ontario, and the state of Maine set out budworm traps and contribute valuable information to help scientists plan their EIS. These community scientists contribute valuable research information, are ambassadors of the EIS, and help spread the word to others in their communities.

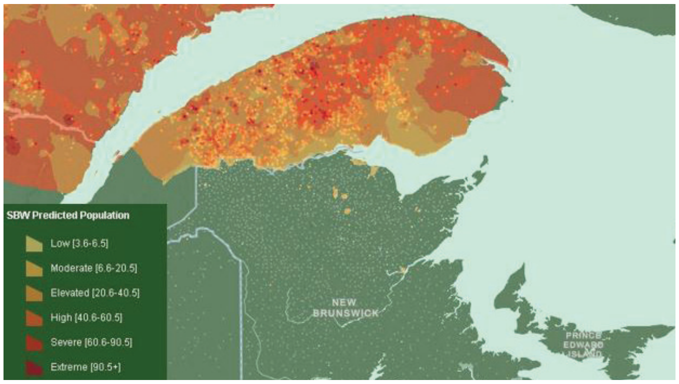
Research and results

The EIS research is yielding valuable information on managing impending spruce budworm outbreaks, and researchers remain cautiously optimistic that the EIS is helping to prevent an outbreak in Atlantic Canada.

New Brunswick has much lower infestation levels than Quebec, and defoliation is minimal because of the EIS, even along the New Brunswick-Quebec border where defoliation is severe on the Quebec side.

Since 2014, no mortality of balsam fir or spruce in New Brunswick that can be attributed to the spruce budworm and only light defoliation levels have been reported in small pockets in northern New Brunswick. However, the risk of an outbreak remains high due to the continuing epidemic in Quebec and from the risk of moth migration into Atlantic Canada. In 2020, Newfoundland and Labrador launched its first EIS treatment, after budworm surveys revealed emerging hotspots or areas that met the threshold for applying the EIS.

Defoliation by spruce budworm in Quebec in 2020



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Impact Note No. 65

Title: A conceptual framework for spruce budworm early intervention: Can outbreaks be stopped?

Cat. No.: Fo103-3/65-2021E-PDF

ISBN: 978-0-660-37736-0

Aussi disponible en français sous le titre : Un cadre conceptuel pour l'intervention précoce contre la tordeuse des bourgeons de l'épinette : Peut-on arrêter les épidémies?