Envirothon Study Guide

Ontario Envirothon

FORESTRY

This Study Guide is to be used to help Envirothon teams prepare for the Ontario Envirothon Program.

FORESTS ONTARIO

The Ontario Envirothon Modules assist students and teachers in preparing for the Ontario Envirothon program.

Every year, more than 500,000 students, teachers and families across North America take part in the unique learning experience of Envirothon. The program engages high-school students in learning more about four main areas of the environment—soils, aquatics, wildlife and forests. Students learn in the classroom and through interactive workshops aimed at strengthening scientific knowledge of our natural ecosystems and helping develop foundational skills needed to pursue studies and careers in the environmental sciences.

The program supports students in developing:

- A scientific understanding of natural ecosystems (soils, wildlife, forests, aquatics).
- Practical experience in resource management practices and technologies.
- The ability to apply scientific knowledge and creativity in developing innovative and sustainable solutions to major environmental challenges.
- Stronger communication, collaboration and problem solving skills.

North American Envirothon (NAE), a program of the National Conservation Foundation, partners with 56 provinces and states that coordinate events in which students receive training in essential resource management technologies and practices such as invasive species monitoring, habitat restoration, water and soil analysis, and forest management. Students are then tested on their ability to apply these practices.

Acknowledgements

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Contents

Learning Objectives

Forests provide us with clean air, wildlife habitats and help to prevent soil erosion and improve water quality. They also provide us with over 5,000 products we use in our daily lives. By studying this module, you will understand the physiology and ecology of trees and forests, the steps taken to achieve balance between forest ecology and the forest industry, and the intricacies of managing one of Canada's most renewable resources.

Overall Objectives

Students must be able to…

A. Understand and describe the physiology of trees
B. Understand and describe the various characteristics and processes involved in forest ecology
C. Understand and describe the methods and practices of the forest industry and of sustainable forest management
D. Understand and describe practices involved in the conservation and management of healthy forest ecosystems and forest resources

Specific Objectives

Students must be able to…

A. Understand and describe the physiology of trees

1. Describe the parts of a tree
2. Explain how trees grow, from the process of photosynthesis through branch growth to trunk growth
3. Understand the method and terminology required to utilise a dichotomous tree identification key
4. Know and identify the principle tree species of each of Ontario's forest regions

B. Understand and describe the various characteristics and processes of forest ecology

1. Identify and describe the major forest regions of Ontario and Canada
2. Identify how much of Ontario and Canada's land surface area is forested and describe how much forested land is Crown land and how much is privately owned
3. Understand and illustrate the process and stages of succession
4. Describe the process of photosynthesis and cellular respiration as they relate to the cycling of energy, carbon, and oxygen through abiotic and biotic components of the forest ecosystem

C. Understand and describe the methods and practices of the forest industry and of sustainable forest management

1. Identify the major types of forest products that are produced in Ontario and Canada
2. Identify the types and number of forest-related jobs in Ontario and Canada
3. Identify and describe the various cutting styles and silvicultural principles that are appropriate for and applied to various forestry sites
4. Explain the concepts of even-aged and uneven-aged stands
5. Explain the role wildfire plays in sustainable forest management, including causes, prevention methods, forest destruction, and forest regeneration
6. Describe the economic importance of forest-related industries to provincial, national and international economies
7. Explain how environmental concerns such as water quality, habitat, recreation and aesthetics are incorporated into forest management

D. Understand and describe practices involved in the conservation and management of healthy forest ecosystems and forest resources

1. Examine the historical importance of Ontario's forests, including their value to First Nations Peoples and to the natural environment
2. Identify Ontario's rare, threatened and endangered tree and plant species, as identified by COSEWIC, and explain how and why select species were reduced to those levels
3. Identify and describe the main insects and diseases (both native and non-native) that affect Ontario's forests
4. Understand and describe the effects that climate change has on forest ecology
5. Interpret a variety of laws, agreements, treaties, etc. that govern Ontario's forest resources and ecosystems
6. Identify a variety of major stakeholders and agencies, including Federal, Provincial and Municipal government bodies, that provide oversight of forest resources in Ontario

Application/Analysis

Students must be able to…

1. Identify common Ontario tree species by leaf type, branching, bark, buds scales, twigs, site type, etc. using a dichotomous key, field guide or index
2. Identify harmful forest insects and evidence of their presence in a forest
3. Collect and interpret data using the following forestry equipment:
   - Dot planimeter/ grid
   - Tree calipers (dbh)
   - Compass
   - Prism
   - Caliper tape
   - Increment borer/ tree cookie
   - Stereo viewer (map reading)
4. Illustrate the classification of a variety of trees and plants by identifying similar and different characteristics
5. Explain the forest management cycle and each of its component parts: planning, harvesting, site preparation, regeneration, tending and protection
6. Consider the impact of certification on sustainable forest management (using the Sustainable Forestry Initiative, Forest Stewardship Council, and the Programme for the Endorsement of Forest Certification as examples)
7. Analyse issues related to environmental sustainability and the impact of technology on the forest ecosystem

Evaluation/Synthesis

Students must be able to…

1. Critique the perspectives of various stakeholders (industry, environment, government) as they relate to forest issues
2. Summarise the history of a tree by looking at growth rings (periods of drought, faster growth, scarring)
3. Recommend a management plan (or no plan) for a forested area
4. Construct the history of a forest site (e.g. has the site been harvested? What style of cutting was used? What stage of succession is the site currently experiencing?)
5. Address current forestry issues from different perspectives (clear-cut vs. old growth, prescribed burns in protected areas, pesticide use, etc)

Tools & Apps

The following tools are recommended resources that can help you better prepare for the Envirothon program.

Envirothon Guides

Winter Tree Key - https://www.forestsontario.ca/en/resource/winter-tree-key

Guide to Trees - https://envirothon.org/wp-content/uploads/2019/10/physiology_of_trees.pdf

Training Video - https://www.youtube.com/watch?v=OTXlySouuHA

Interactive Websites and Apps

Tree Bee
https://treebee.ca/

Tree Bee Pocket Guide
https://treebee.ca/wp-content/uploads/2016/05/FO_TB_8.5x11_FOLD-OUT_4WEB.pdf

Focus on Forests
http://www.forestsontario.ca/education/programs/focus-on-forests/

Ontario Tree Atlas
https://www.ontario.ca/environment-and-energy/tree-atlas

Trees in Canada
http://tidcf.nrcan.gc.ca/en/trees

LeafSnap
http://leafsnap.com/

2.0 Physiology of Trees

2.1 What is a tree?

A tree is a woody plant that typically has a single stem or trunk with branches.

The **crown** of a tree is composed of flowers, **branches**, **twigs** and **leaves** or needles. The crown plays an important role in photosynthesis by using the leaves to capture light. The leaves are the manufacturers of food for the trees. The **trunk** of the tree is the main stem and it supports the branches as well as transports food and water throughout the tree. The outer **bark** of the trunk protects the tree from injury. The **roots** act as anchors for the tree, in addition to absorbing nutrients and water from the soil.

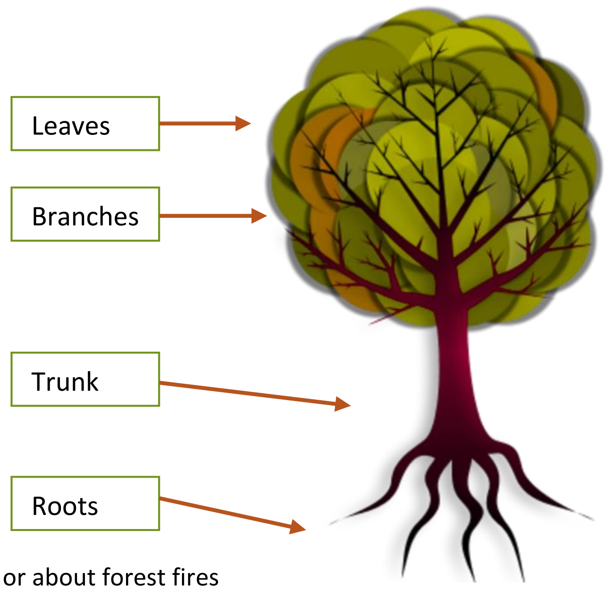


Figure 1. Parts of a tree.

2.2 How a Tree Grows

An old tree can tell you what the weather was like in the spring of 1904 or about forest fires and outbreaks of forest pests that occurred in its life. Trees can do this because each one carries inside of it a detailed history of its growth.

In temperate climates trees grows in girth each year by building up a new layer of wood from a thin layer of cells called the **cambium**. The cambium is located just beneath the bark. Each spring, the cells of the cambium divide rapidly and produce a layer of large, thin-walled cells that make up the **springwood**. As the year progresses, the cells divide and grow more slowly as a result the wood tissue produced over the summer is comprised of smaller, thicker-walled, tightly packed cells. These form the **summerwood**. By early winter, cell growth stops altogether. When growth resumes the next spring, a clear boundary line separates the old and new growth. The springwood and summerwood together, sandwiched between boundary lines, represent one year's growth, or an **annual ring**.

A look at the cross section of a mature tree trunk reveals not only the annual rings, but five different layers. The centre of the trunk, called the **heartwood,** is made up of the older, inactive cells that give the trunk its strength. Surrounding the heartwood is a band of younger cells that make up the **sapwood**. It is through these tissues that water is conducted from the roots up the trunk to the branches and leaves. As the older sapwood cells die and become part of the heartwood, more sapwood is produced by the cambium. Besides producing sapwood cells the cambium also gives rise to the layer around it called the inner bark. This region is made up of **phloem** cells, which carry food produced in the leaves to the rest of the living tissue in the tree. The layer around the outside of the trunk is the outer bark. This protective layer is made up of old phloem tissue. As the tree trunk expands, the outer bark splits and cracks, but is constantly replaced by more tissue pushed out from the inner bark.

Table 1. Cellular function of different parts of a tree.

Cell Type	Cellular Function
Cambium	**Meristematic** tissue which undergoes cellular division and produces new xylem, phloem and cambium cells
Xylem	Transports moisture and nutrients to photosynthesis sites (leaves and needles) from the roots through the trunk, branches and twigs
Phloem	Conductive tissue which serves to transport the manufactured glucose from the photosynthesis sites in the leaves/needles down through the twigs, branches and trunk to the roots and out to the growing buds and shoots
Cortex	Large thin-walled cells which are irregularly spaced around the pith layer. These cells are used for the storage of glucose, water and nutrients
Pith	Like the cortex, used for storage. This cell layer disappears due to the compression by the xylem in later stages of growth of the stem

2.2.1 Dendrochronology

The annual rings and layers can be clearly seen in a cross –section of the trunk or stump after a tree is cut down. A slice of wood taken from across the trunk of a tree is called a tree disc or a tree cookie. Studying tree rings in order to learn about the past history of the tree is referred to as **dendrochronology** (from the Greek words *dendros* meaning tree and *chronos* meaning time). The number of rings tells us the age of the tree whereas the thickness of the rings tells us how much growth occurred in a given season; wider rings mean more growth and thinner less. A good dendrochronologist can interpret many stories in the patterns of rings. A series of several narrows rings together, for example, indicates several successive years with little growth. This may have been the result of a severe drought that lowered the water table, an infestation by pests or suppression by shade or crowding from surrounding trees. The actual years in which the poor growth occurred can be discovered simply by counting the number of rings. This tells us how many years ago the growth of the narrow rings took place. The information inferred from the rings can be cross referenced with weather or pest records to confirm the cause of poor growth. Other changes in ring pattern are caused by fire, which leaves blackened scar tissue. Prevailing winds or a fallen neighbouring tree may cause uneven growth, which produces rings that are wider on the side of the tree opposite to the source of pressure. Growth ring analysis is not only useful for reading the past; it is also a valuable tool for monitoring the growth rate of trees and predicting the future size of trees.

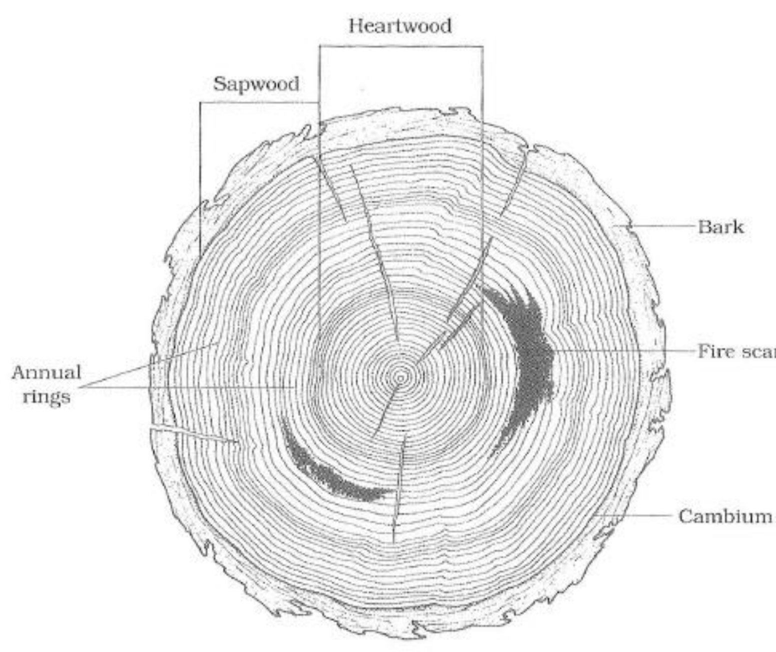


Figure 2. Cross-section of tree trunk showing the various layers of a tree.

The rate of growth of a tree is determined through the interplay of many factors and conditions. These include soil conditions, climatic conditions and wildlife influences. Growth rates are generally measured by monitoring the diameter of a tree. Growth rates may be determined by measuring the change in diameter of a tree over a period of years by comparing measurements. Growth rates may also be determined by measuring the amount of current annual growth (CAG) produced by a tree. CAG is measured from the terminal bud of an active stem to the terminal bud scar which delineates the end of the previous year's growth (Figure 3). However the most accurate measure of growth rate is to examine the annual ring configuration.

2.3 From Seed to Tree

How does a small seed become a 30m tall tree? In the competitive world of the forest, the vast majority of seeds do not produce mature trees. Only the fortunate few that land on suitable ground, get enough exposure to sunlight and water, and avoid being consumed or damaged by animals, will eventually grow up to become trees. Look at the trees on your streets and in your local park. Every tree has a different size and shape which is determined by the rate and pattern in which new cells are added each year.

You can think of tree growth in two ways. First, the trunks grow outwards and upwards from their tips, carrying their leaves towards the sun. This growth produces extra height and crown spread. Second, the trunk and branches grow thicker and sturdier, allowing them to support the added weight of the larger branches. Despite their variation in appearance, all trees have essentially the same basic structure. They have a central column – the trunk – supporting a framework of branches. The branches in turn bear leaves. Anchoring the tree in the ground is a network of roots, which spread and grow thicker in proportion to the growth of the tree above the ground.

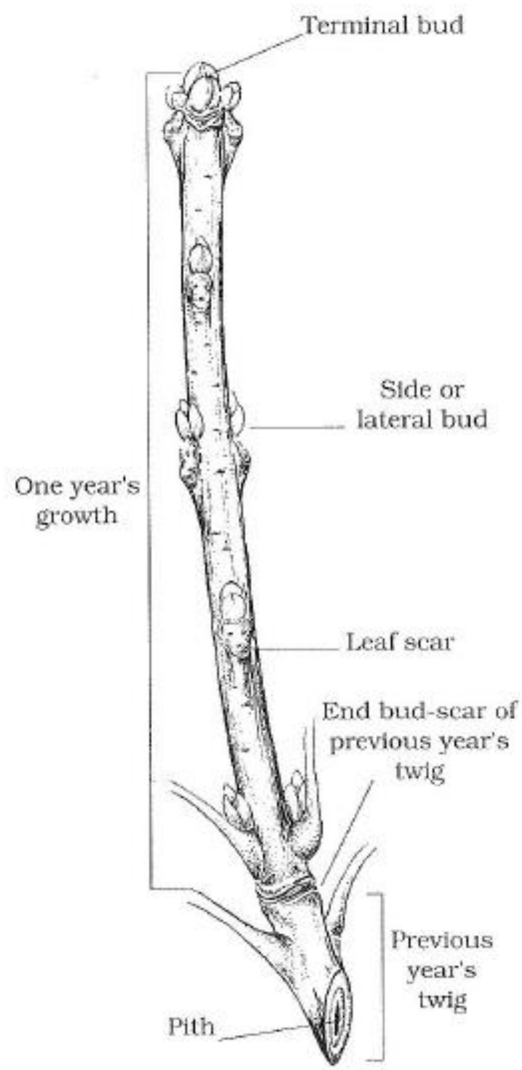


Figure 3. How a twig grows (Focus on Forests, 1987).

In a mature tree, most of the cells of the trunk, **roots** and branches are dead or inactive. The growth of new tissue takes place at only a few points on the tree, by the division of specialized cells. These active growing areas are located at the tips of branches and roots and in a thin layer just inside the bark. If you look at a branch on a deciduous tree during the winter when the leaves are gone, you can see **terminal buds** at the very ends of the twigs. These are the points from which the next spring's growth will take place. Twigs also have side or **lateral buds**, from which side branches develop. Buds are formed in the summer and fall and remain dormant over winter. Dormancy is broken when suitable growing conditions return in the spring.

If you look further back along a twig, you will come to a ring of thickened bark. This scar tissue marks the place where the terminal bud grew the previous year and is called the **terminal bud scar**. The distance between the scar and the new terminal bud is reflects amount of growth that took place in one year. Knowing this, you can find the age of several branches on a given tree. As the main trunk of the tree grows taller, it also grows thicker. Its structure can be thought of as an extremely elongated cone shape. The base of the trunk, being the oldest part, is slightly thicker than the rest of the trunk. You can visualize this growth pattern by inverting and stacking a number of paper cups on one another. Each cup in the column represents a year's growth. The narrow bottom of each cup (pointing upwards in the column) represents the terminal bud. Each year's growth fits tightly around the previous year's and increases the height of the tree. As discussed earlier, while the growth in height comes from the terminal buds, the growth in girth comes from a thin layer of cells called the cambium, found between the inner bark and the wood of the trunk and branches. In the paper cup model, the cambium is represented by the outside surface of the cups.

Besides its branches, roots and leaves, a mature tree grows one other important structure – the **flower** (or **cone**, in the case of conifers). These are the reproductive structures from which the seeds are produced. Seeds are produced when pollen from the male flower lands on the female flower and develops into a seed. Seed production does not always occur annually for trees. It is dependent on the biological characteristics of the species, as well as external conditions including weather, insects, disease and predation by birds and mammals. Intervals between good crop years follow a pattern and this is referred to as **periodicity**. Watching a tree to determine the potential of seed production is referred to as **seed forecasting**. By watching trees and knowing the years in which trees let out high quantity and quality of seeds, it helps to more effectively plan seed collection to plan for future tree planting.

Fast-growing species may mature and produce seeds after as little as 5-10 year's growth, while other species take 30 to 40 years to mature. A certain size is needed before flowering takes place, and suppressed trees may not flower even at an age of 50 to 100 years or more. With the growth of flowers, fruit, and seeds, the life cycle of the tree comes full circle.

2.4 Height and Shape

The growth rate and the ultimate height and shape of a tree are governed partly by the growing conditions of its environment, but also by its genes. In optimal conditions different species reach different maximum heights. The tallest species of trees are the coastal redwoods, which grow on the west coast of California and Oregon and reach heights of up to 112m. A tree can continue to grow for as long as it lives, so its ultimate height depends on its growth rate and its longevity. Long-lived species, like the sugar maple and white pine, tend to be taller, while short-lived species, like the poplar and white birch, are shorter. The shape of a tree depends on many factors, such as the amount of space it has to grow in, the amount of sunshine and moisture it receives, the relative growth rate of its terminal and lateral branches, and any damage it receives from such factors as lightning, fires, prevailing winds, snow, ice, animals, and disease.

While great height and a large crown give a tree more exposure to sunlight, they also make the branches more vulnerable to damage from severe winds or heavy snow. To balance the spread of its branches, a tree tends to grow deeper roots to anchor it firmly against toppling by storms. In general, the crowns of trees growing in Ontario take on two basic forms: **conical** and **round**. In conical forms – such as the familiar 'Christmas tree' – the terminal bud grows much faster than the lateral branches. The resulting conical form helps the tree shed snow and ice, and its compact shape resists wind pressure. For this reason, the conical form is most common in trees growing farther north. In the milder, moister conditions of southern Ontario, the predominant form is that of the spreading, more rounded crown, typical of oaks and maples.

2.5 Photosynthesis

The energy that allows a tree to grow and carry out all its associated functions ultimately comes from the sun. The conversion process, which allows a tree to utilize solar energy and convert it into chemical energy, is called **photosynthesis**. Photosynthesis may be summarized as:

$$6CO_2 + 12\ H_2O + 640\ \text{kcal} = C_6H_{12}0_6 + 6O_2 + 6H_20$$

It involves the addition of carbon dioxide (CO2) from the atmosphere, water (H20) from the soil and sunlight (energy) to produce glucose ($C_6H_{12}0_6$), oxygen (O_2) and water (H_2O). Unlike humans, plants actually breathe in carbon dioxide, and produce oxygen.

Energy from the sun is absorbed by proteins that contain green **chlorophyll** pigments that are held within chloroplasts within the leaves. This is where photosynthesis takes place. Chlorophyll grabs the sunlight and starts the process of photosynthesis. The leaf is a complex structure filled with many different parts that all play a role in photosynthesis. Leaf surfaces differ between deciduous and coniferous trees. Coniferous trees have sunken stomata and smaller surface area that help reduce water loss.

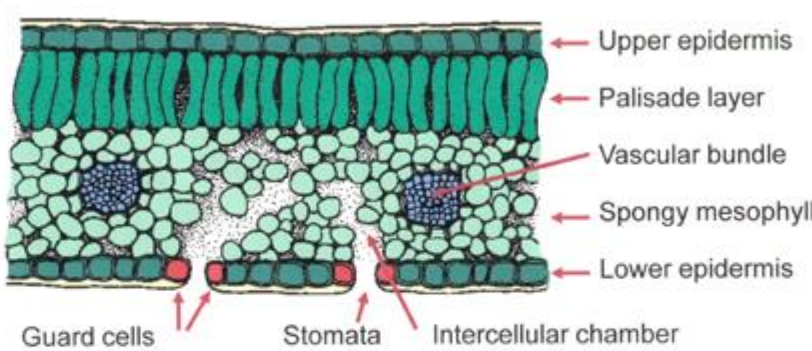


Figure 4. Leaf cross section (Colorado State University Extension 2014)

Table 2. Parts of a leaf and their function.

Leaf Part	Function
Stoma (stomata)	Opening that allows for gas exchange and some water
Guard cells	Open and close stomata
Epidermis	Outer layer of tissues
Palisade	Layer of tissues filled with chloroplasts
Chloroplast	Structures in leaves that contain chlorophyll – green pigment that captures energy in light and begins transformation of energy into sugars
Cuticle	Waxy protective outer layer that prevents water loss
Spongy mesophyll	Layer of tissues that facilitates movement of oxygen, carbon dioxide, and water vapour
Vascular bundle	Xylem and phloem tissues (leaf veins)

3.0 Forest Ecology

3.1 Forest Regions

A **forest region** is defined as a major geographic belt or zone characterized by a broad uniformity in physiography and in the composition of dominant tree species. Different forest regions exist because of differences in soil types, topography, climate and precipitation. Canada has 8 forest regions, each geographically characterized by dominant species and stand types of vegetation.

Figure 5. Forested areas in Canada (Natural Resources Canada, 2015).

Table 3: Forest regions of Canada

Forest Region	Location	Characteristic tree species
Acadian	Maritimes	Red spruce, balsam fir, yellow birch
Boreal	Northern Canada	White spruce, black spruce, balsam fir, jack pine, white birch, trembling aspen, tamarack, willow
Carolinian (Deciduous)	Southwest Ontario	Beech, maple, black walnut, hickory, oak
Coast	British Columbia	Western red cedar, western hemlock, sitka spruce, douglas-fir
Columbia	British Columbia	Western red cedar, western hemlock, douglas-fir
Great Lakes-St. Lawrence	Central Canada	Red pine, eastern white pine, eastern hemlock, yellow birch, maple, oak
Montane	British Columbia and Alberta	Douglas-fir, lodgepole pine, ponderosa pine, trembling aspen
Subalpine	British Columbia and Alberta	Engelmann spruce, subalpine fir, lodgepole pine

3.1.1 Forest Regions in Ontario

Ontario is home to 4 forest regions: Hudson Bay Lowlands, Boreal Forest, Great Lakes-St. Lawrence Forest and Deciduous Forest (Ministry of Natural Resources and Forestry, 2014).

Hudson Bay Lowlands
(Boreal Barrens)

There are 26 million hectares in the Hudson Bay Lowland region. This area is made up of both trees and open muskeg, and thousands of small lakes and ponds. This forest type, with high latitude conditions and clay soils, is generally made up of stunted tamarack and black spruce growing along river banks and other well-drained areas. The Hudson Bay Lowlands are greatly affected by the cold northern climate, and contain all of Ontario's tundra. This area contains 20% of Ontario's forests.

This region is home to woodland caribou, polar bears, arctic fox, and arctic hare. During the summer, millions of migratory birds nest here such as Canada geese, snow geese and other waterfowl.

Figure 6. Forest regions of Ontario (Ministry of Natural Resources and Forestry, 2015).

Boreal Forest

This region is the largest in Ontario, with an area of 50 million hectares containing approximately 59% of Ontario's forests. Here there is a mix of coniferous and deciduous trees, including white and black spruce, tamarack, balsam fir, jack pine, white birch and trembling aspen. These forests also contain hundreds of other plant species including ferns, mosses, fungi, shrubs and herbs. The terrain ranges from lowland peat bogs to deep fertile upland soils to bedrock which is covered by thin layer of soil and moss. Geologically speaking, this region is quite new. Until about 13,000 years ago, glaciers covered most of Canada - it wasn't until about 5,000 years ago that the Boreal forest was firmly established in northern Canada. Today, the forest is home to a variety of wildlife including moose, black bear, a multitude of song birds, wolves, otter, beaver and marten.

Great Lakes St. Lawrence Region

Containing 20% of Ontario's forests, the Great Lakes-St. Lawrence forest encompasses the area along the St. Lawrence River across central Ontario to Lake Huron and west of Lake Superior along the border with Minnesota. This region acts as a transitional zone between the predominately coniferous boreal forest and southerly deciduous forests. Commonly seen in this region are coniferous trees such as eastern white pine, red pine, eastern hemlock and white cedar mix with deciduous broad-leaved species, such as yellow birch, sugar and red maples, basswood and red oak. Species more common in the boreal forest including white and black spruce, jack pine, aspen and white birch can also be found here. Wildlife in this area includes white-tailed deer, moose, black bear, wolves, pileated woodpeckers, various migratory birds, beaver, muskrat, otter and variety of fish and insects.

Deciduous Forest

Ontario's deciduous forest lies along the northern shores of Lake Erie and Lake Ontario and the southeastern shore of Lake Huron. It is the northern most extension of the large deciduous forest of the northeastern United States. Many of the trees found here are at the northern limit of their range. American beech and sugar maple dominate this forest region; basswood and red maple are also common. Other tree species found in this region include black walnut, sycamore, butternut, magnolia, black gum and white oak.

Although this region contains only 1% of Ontario's forests, biodiversity is high and includes a variety of rare mammals, birds, plants, reptiles and insects. Examples include sassafras and tulip trees, southern flying squirrels and the blue racer; in fact 40% of Ontario's rare plants can only be found in this region.

3.2 Forest Structure

Forest structure describes the physical components and layers of a forest. Forests can have a complex structure with trees of all ages and sizes. Below are various structural components you may find in an **old growth** forest (LandOwner Resource Centre, 1999). Many of these components you may also find in other types of forests.

1. **Supercanopy Trees** – tall trees that poke through the canopy; important resting and nesting sites for birds
2. **Canopy Trees**– mature trees that form a continuous layer that shades layers below
3. **Understorey Trees** – small trees beneath the canopy; growth rate limited by lack of sunlight
4. **Shrubs and Saplings** – grow in the shade of canopy trees and in open areas
5. **Decaying Wood** – decaying trees and branches provide habitat for small mammals, fungi, invertebrates and vegetation; as wood decays it returns nutrients back to the forest soil
6. **Ground Cover**– covering the forest floor are fungi, mosses, bacteria, ferns, shrubs and tree seedlings
7. **Organic Litter**– leaves, dead wood and small branches decompose to return nutrients to the soil; helps retain soil moisture
8. **Cavity Trees** - living or dead trees with holes that mammals and birds using for nesting or denning, feeding and escaping; includes primary (make cavities) and secondary (use already made cavities) cavity users
9. **Snags** – standing dead trees used for habitat
10. **Pits and Mounds** – formed when large trees are uprooted; roots and soil are pulled from the ground and provide conditions for some tree species to regenerate

3.3 Succession

Fire, along with disease, insect infestation, and weather (i.e. snow, ice, wind, and lightning) are major environmental disturbances that alter ecosystems. Destructive as they may seem, they leave in their wake space for new plants to grow. A gradual and complex series of changes (both biotic and abiotic) called **succession** must occur to re-establish the forest.

Succession is the directional change in vegetation resulting from the interactions between the living and the non-living factors of the environment. New plants germinate, grow, and reproduce to successfully inhabit the vacant ecological niche. As the plants increase in size and in number, competition and environmental change begin to change the ecosystem. A new series of plants germinate, grow, and reproduce to repeat the cycle of change. The rate of change becomes more gradual with time until the system stabilizes. This is the final stage of succession in the ecosystem and is called the **climax**. However, it must be emphasized that forests are complex, dynamic communities that are continually evolving at varying rates. Even a climax community is constantly undergoing changes. At any time in the series of changes from the beginning to the climax, a new disturbance may interrupt the series and create a new beginning.

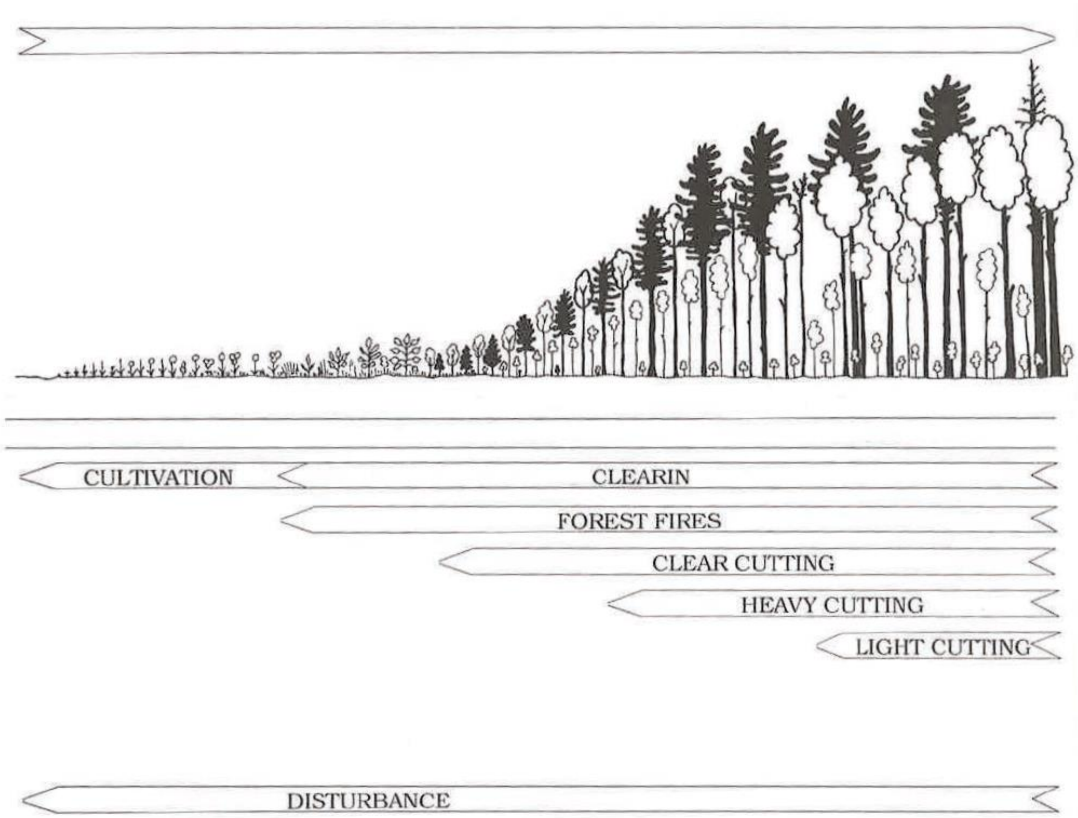


Figure 7.Stages of succession (Focus on Forests, 1987).

There are two major forms of succession: **primary succession** and **secondary succession**. Primary succession begins on bare areas that did not previously support vegetative growth. These may be areas of water, sand, or rock. Primary succession begins with soil building. Soils develop from primitive plants called colonizers reacting with the rock over long periods of time to eventually provide bits of soil that, in time, will support larger vegetation. With the accumulation of soil, new plants germinate, grow, and reproduce to begin the stages of a new succession. Secondary succession occurs in areas in which vegetation does grow, but which have been altered by such external forces as fire, logging, and land clearing. New plants germinate, grow, and reproduce to begin the cycle to the forest stage.

An area containing trees of the same age or close to the same age (10 to 20 years difference) is called an **even-aged stand**. Even-aged stands begin as a result of reforestation of a clear–cut area or an area depleted by disease, insect damage or fire. Usually, even-aged stands are dominated by a single species, although there could be other species present. As a result, they are very susceptible to attacks by insects or disease. If the area contains trees of many ages it is called an **uneven–aged stand**. Because of the diversity of tree species common in uneven– aged stands, a variety of other plants and animals are often present. As a result, diseases and insect pests that threaten the trees may be present but are not usually widespread.

3.3.1 Tolerance

Tolerance is a measure of how much shade and competition a tree species can survive. Differences in tolerance allow plant species to exploit the varying environmental conditions created by different disturbances. **Tolerant** species are able to survive in the shade beneath a forest canopy, even for decades. When an opening in the canopy appears, that tree will thrive and grow to fill the gap. **Mid-tolerant** species need some sunlight throughout their lives to germinate, grow and develop. **Intolerant** species need full sunlight to survive. In areas with full sunlight, intolerant species outcompete more tolerant species.

Table 4. Tolerance of native Ontario tree species (MNRF, 2004).

Intolerant	Mid-tolerant	Tolerant
Black Cherry Red pine	Basswood Red oak Yellow birch White pine White spruce	Eastern hemlock Northern white cedar Beech Sugar maple

4.0 Managing Ontario's Forest Resources

4.1 Ontario's Land Use

66% of Ontario or about 71 million hectares – almost 174 million acres – is forested. Almost 90 % of Ontario's forests are owned by the province (**crownland**). Of that area, some 44 %, or about 27.8 million hectares, is classified as production forest – that is, forest managed for a full range of benefits, including timber production. Private landowners, Federal and First Nations together own 13 % of Ontario's forests. In total, Ontario's forested area is equal to the land masses of Germany, Italy and the Netherlands combined (Ministry of Natural Resources and Forestry, 2014).

Ontario's forests are home to a multitude of plants and animals. The province home to more than 3,200 different species of plants, 160 species of fish, 80 different species of amphibians and reptiles, 400 species of birds, and 85 species of mammals.

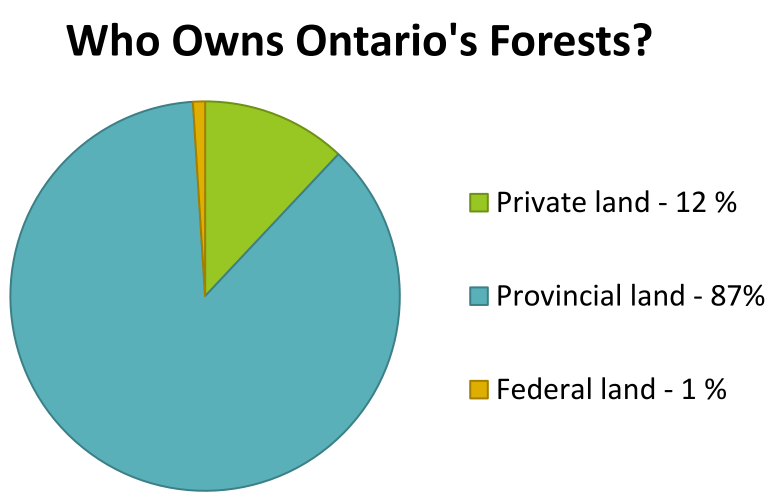


Figure 8. Forest ownership in Ontario.

4.2 Crown Forest

Crown forest refers to land owned by the public. These forest resources are managed by the government, specifically the Ministry of Natural Resources and Forestry. The government grants licences to use the forested land, but companies or individuals must abide by regulations under the **Crown Forest Sustainability Act (CFSA)**.

The CFSA is the governing legislation for forest management on Crown land in Ontario with the goal of managing forests for 'large healthy diverse forests for now and in the future'. The Act specifies the guiding principle - forests will be managed to emulate **natural disturbance patterns**.

87% of forested lands in Ontario are provincially owned and known as Crown lands. Ontario's Crown Forest Sustainability Act (1994) covers all aspects of forest management, including planning, operations and **silviculture**, timber measurement and forest information systems. All forest policies and management practices on these lands must conform to the Policy Framework for Sustainable Forests, which covers **harvesting** and **regeneration**, the management of old-growth forests and the protection and conservation of **non-timber values**.

4.3 Private Forest Land

Private landowners have a right to manage their properties to their own objectives. The government encourages sustainable forest practices on private land by providing incentives through programs such as the Managed Forest Tax Incentive Program (MFTIP) or the Conservation Land Tax Incentive Program (CLTIP).

- *MFTIP* – landowners pay 25% of the municipal tax rate; must prepare and follow a 10-year Managed Forest Plan that details how you will manage the forest; eligibility requirements apply
- *CLTIP* – 100% tax exemption for land that has important natural heritage features; evaluated and identified by the MNRF as provincially important land; commit to protecting the designated portion of the property

The **Ministry of Natural Resources and Forestry (MNRF)** also encourages landowners to become good stewards by preparing a stewardship plan. The stewardship plan helps landowners become more familiar with their property, determine the objectives of the property, and ensure the long-term management direction. This stewardship plan is often the first step when applying for the MFTIP mentioned above.

Municipalities also play a role on private land, with some having **forest conservation bylaws** (also known as tree cutting bylaws) which influence the harvest of timber on private land. They are intended to prevent the overharvest of forest resources. They also recognize landowners' rights to make decisions regarding the management of their forests. Not all municipalities within Ontario have these bylaws, and it is dependent on the tier of the municipality.

4.4 Aboriginal Rights

Aboriginal rights and treaty rights are recognized and protected by the Canadian constitution under section35 of the Constitution Act, 1982. This includes the Aboriginal right to harvest timber for personal use from Crown land. Aboriginal rights are practices, customs or traditions which were integral to the distinctive pre-contact culture of an Aboriginal society. Thus, if an Aboriginal group can demonstrate that historically wood was an integral part of their society in providing shelter, transportation, fuel or tools for example, then they may exercise their Aboriginal right to harvest timber. However, this right does not have a commercial dimension to it (Adkins and Isaac, 2007).

4.5 Parks and Protected Areas

As part of Ontario's balanced ecological approach to managing our forests, the province has set aside significant areas of productive forest land as parks and protected areas. Logging, mining and hydro-electric development are, for the most part, excluded in these areas.

Finding the appropriate balance between areas set aside for parks and areas available for commercial forest management can be challenging. To address this issue, representatives of the forest industry, the environmental community, and the government signed the Ontario Forest Accord in 1999. This ground-breaking agreement created a process for setting aside more parks and protected areas in the future and promoting studies on ways to increase forest productivity. Since 1999, about 10,800,000 hectares have been added to Ontario's system of parks and protected areas, including national parks. This is equivalent to around 10% of the province (MNRF, 2015).

4.6 Forest Management

Forest management involves not only producing the required amount of raw material on a sustainable basis, but also maintaining the many other values of the forest – such as wildlife habitat, water and soil resources, and recreational opportunities. This is what is known as **integrated resource management** – taking into account the many different forest values when planning for a specific area. Management decisions must be based not only on knowledge of forestry, but on ecological and social values as well.

When thinking about the removal of trees from a forest and balancing this against other uses, it is important to understand the reason for harvesting trees. Each of us uses the products which trees and their parts are manufactured into including newspaper, paper bags, furniture, sports equipment, broom handles, and telephone poles, as well as less obvious forest products such as paints and polishes (from turpentine), plastics (from lignin), adhesives (from bark), cosmetics, clothing, and sugar and syrup (from sap). Balancing the needs of society, with the needs of the environment is critical in sustainable forest management.

4.6.1 Forest Management Plans

The Crown forest in Ontario is divided into **forest management units (FMU)**. Most of these units are managed by individual forest companies under a Sustainable Forest Licences (SFL). Before any forestry activities can take place in a management unit, there must be an approved **forest management plan** in place. The company that holds the SFL is responsible for carrying out the activities of forest management planning, harvest, access road construction, forest renewal and maintenance, monitoring and reporting. They have to abide by the rules of the Crown Forest Sustainability Act (CFSA) and Ministry of Natural Resources and Forestry (MNRF) approvals.

A forest management plan is prepared for a ten-year period for each forest management unit in the province. A plan is prepared in an open and consultative fashion by a **Registered Professional Forester** with the assistance of a planning team and a local citizens committee, as well as with input from Aboriginal communities, stakeholders and interested members of the public. A forest management plan is not approved until the MNR Regional Director is satisfied that the plan provides for the sustainability of the forest and all identified concerns have been considered.

4.6.2 Plan Timelines

A 10 year forest management plan is prepared in two phases.

- Phase I: Long-term management direction that provides for the sustainability of the forest with regard for plant and animal life, water, soil, air and social and economic values, including recreation. It remains in effect for the 10 year period. As well, there is detailed planning of operations for the first five-year term of the plan. The Phase I planning process normally occurs in the last three years of the current plan.

- Phase II: Detailed planning of operations for the second five year term (i.e., years 6 to 10) occurs during the last two years of the first five-year term.

Forest management plans are renewed every 10 years. It generally takes 36 to 39 months to prepare a forest management plan (Phase I) and about 16 to 20 months for the detailed planning of operations for the second five year term (Phase II). These planning processes provide formal opportunities for public input at key stages in the development of the plan.

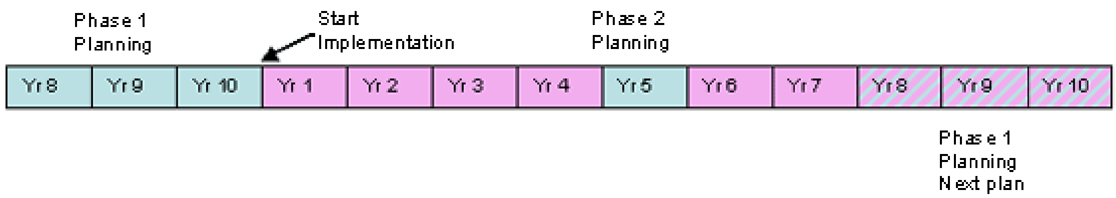


Figure 9. The timeline for preparation of a forest management plan (Ministry of Natural Resources, 2013).

4.6.3 Consultation

Public consultation is a key component of Ontario's forest management planning process. It provides an opportunity for representatives of local stakeholder and interest groups, general public and Aboriginal communities to participate on a **local citizens committee** to assist the planning team with the preparation of a forest management plan. The local citizens committee represents a range and balance of local interests, and ensures that these interests are communicated to the planning team. The local citizens committee may nominate a member to be a member of the planning team. Public consultation also includes a formal public consultation process where notices are posted to allow people to review and comment.

4.6.4 Aboriginal Involvement

The Ontario government is committed to increasing social benefits and economic opportunities for Aboriginal peoples and as such has provided for specific opportunities for Aboriginal communities to be involved during the development of a forest management plan. For example, an opportunity is provided for a representative of an Aboriginal community to participate on the planning team. As a member of the planning team, the representative will be involved with ongoing decisions on how the forest is to be managed. In addition, each community is provided with an opportunity to work with the Ministry of Natural Resources and Forestry and the plan author to develop a customized consultation approach. This approach is intended to describe how the community wishes to be involved in the planning process and how the community's interests will be considered in the production and implementation of the forest management plan.

The planning process also requires the identification and protection of Aboriginal values, involvement of communities in the development of prescriptions to protect those values, and opportunities to participate in the development and review of an Aboriginal Background Information Report and a Report on the Protection of Identified Aboriginal Values.

4.7 Steps of Forest Management

The goal of a management plan is to balance the harvesting and regeneration of trees in such a way as to provide a sustainable yield of raw material over time, while taking into account the many ecological and recreational values of the forest. New growth must balance all depletion due to fire, insects, disease, wind, and flooding as well as harvesting. In this way, the overall productive forest area is maintained. Forested area is like money in a bank. The aim of the forest manager, like that of a good investor, is to live off the interest – or new wood added each year – without depleting the capital. Many factors are at work in managing our forests, and forest managers are not always able to achieve every goal.

Forest management involves six key steps; planning, harvesting, site preparation, regeneration, tending, and protection.

a) **Planning:** The first and most important step is planning. Forest management plans are prepared by a planning team that includes foresters, wildlife biologists, land use planners, Aboriginal communities, and other professionals. Members of the public are also invited to provide their views on how the forest should be managed. To write a forest management plan, the forester must know the type of forest as well as the users of the area. The final plan must take into account and balance all forest values. Foresters collect important information by taking a forest inventory that includes determining if a stand is even-aged or uneven-aged, the species present, average age and diameter, volume of wood and type of soil and other vegetation.

b) **Harvesting:** Having identified the type of forest and having decided on the harvesting method to use, the next step is to calculate the area from which wood can be harvested on a regular basis. The manager must also plan to regenerate the same amount of forest area that is to be harvested. The sustainable level of harvest, termed the Available Harvest Area, is determined locally by the planning team as part of the development of a sustainable management strategy. The Available Harvest Area represents the maximum area that can be harvested during the ten-year period of the forest management plan. The method of harvesting chosen is based on several factors, for more information see Section 4.8.

Age and time are two factors to be considered when calculating the area for timber harvest. The trees in a forest are continually growing. When the trees have reached the desired size for the use intended, the forest is mature. The number of years for the forest or tree to reach maturity is called the **rotation period**.

c) **Site Preparation:** After a forest stand is harvested, the site is prepared in some way for planting seeds or seedlings. The equipment used during harvesting may provide enough soil disturbances to stimulate growth. At other times, mechanical or chemical site preparation or prescribed burning is required to provide good seed beds or planting spots. Controlled or prescribed burns help to clear slash and other vegetation and release their nutrients into the soil as well as destroy disease or insects, and even assist the germination of some seeds.

d) **Regeneration:** Forest regeneration occurs by natural or artificial regeneration. Natural regeneration may occur from seeds or roots/stumps sprouting after harvest. **Crop trees** may be selected and maintained to help improve the success of natural regeneration. Artificial regeneration is achieved through planting or seeding, which accelerates the processes of nature and to controls the species and quality of the trees in the new forest. The choice of regeneration will depend on species and site.

e) **Tending and Protecting:** While the new forest is becoming established, some tending may be required to help ensure survival and promote good growth and form. Tending activities include removing competing vegetation, thinning the trees to avoid overcrowding, herbicide spraying, and sometimes fertilizing. Generally, after 10 to 15 years, the replanted area is **free to grow**, although it must constantly be protected from damage by fire, insects, and disease. Once the trees have reached maturity, they are harvested and the cycle begins again.

4.7.1 Adaptive Management

As the plan is implemented, MNRF and the forest industry routinely monitor and assess the effectiveness of forest operations. This is known as **adaptive management**. This ensures that the forest management plan is being followed, that reports on the results of management activities are produced, and that the effectiveness of management decisions are assessed. The results of the monitoring program are used to make any necessary adjustments to the long-term management direction and the planning of operations in the next plan or phase. The on-going process of adaptive management is critical for improving the decisions made in forest management planning.

4.8 Harvesting Methods

The harvesting methods chosen are based off of emulating natural disturbance patterns. By emulating natural disturbance patterns, the assumption is that if similar forest conditions are produced that biodiversity will be maintained.

There are three main harvesting methods used in Ontario. The **clear cut** method involves removing all or most of the trees in an area in one operation. This method is widely used in the even-aged Boreal forests of northern Ontario, where large scale disturbances such as forest fires and insect infestations occur. In very large cutovers, individual and clumps of trees are preserved for soil and water conservation and for wildlife habitat.

Shelterwood cutting involves leaving individual trees or groups of trees or alternating strips standing to provide seed and cover conditions for natural or artificial regeneration. This method aims to mimic ground fires, windstorms and insect infestations. This method is most commonly used in even-aged management within the Boreal and Great Lakes-St.Lawrence forest regions.

In uneven-aged stands, the **selection** method is used to harvest mature or defective trees. The goal is to emulate the disturbance associated with the death of single or small groups of trees. Harvesting is done every 10 to 40 years, maintaining the uneven-aged structure. This method is most commonly used in the Great Lakes-St. Lawrence forest region. Younger trees are left with optimum spacing, which increases their growth rate. The selection method can also be used to promote the regeneration of superior trees, and the spread of desired species. Although this technique works well in small areas, it is costly on larger forests because trees must be selected and marked, and the volume of wood taken on each cut is relatively small. Again, there is also a risk of damage to remaining trees and to regeneration on each harvest. Selection cuts are done with a chain saw and skidders. In some areas, horse-drawn logging is still used in winter.

Once the method of harvesting is determined, the forest manager must calculate how much wood can be harvested on a regular basis. It is important that the area of forest harvested is no greater than the area returned to forest through regeneration. The trees in a forest are continually growing, but at the age when they have reached the desired size for harvest, they are said to be mature. The length of time taken before newly planted seedlings will reach this age of maturity is the rotation period.

4.8.1 Tree Marking

Tree marking involves the careful selection of trees for harvest or those to be left based on tree size, health, quality, biodiversity concerns and wildlife habitat. Tree marking is practiced in Crown forests and forests of central and southern Ontario. The goal of tree marking is to create a healthy forest. Tree marking is used when you are partially removing the forest such as single-tree or group selection and uniform shelterwood.

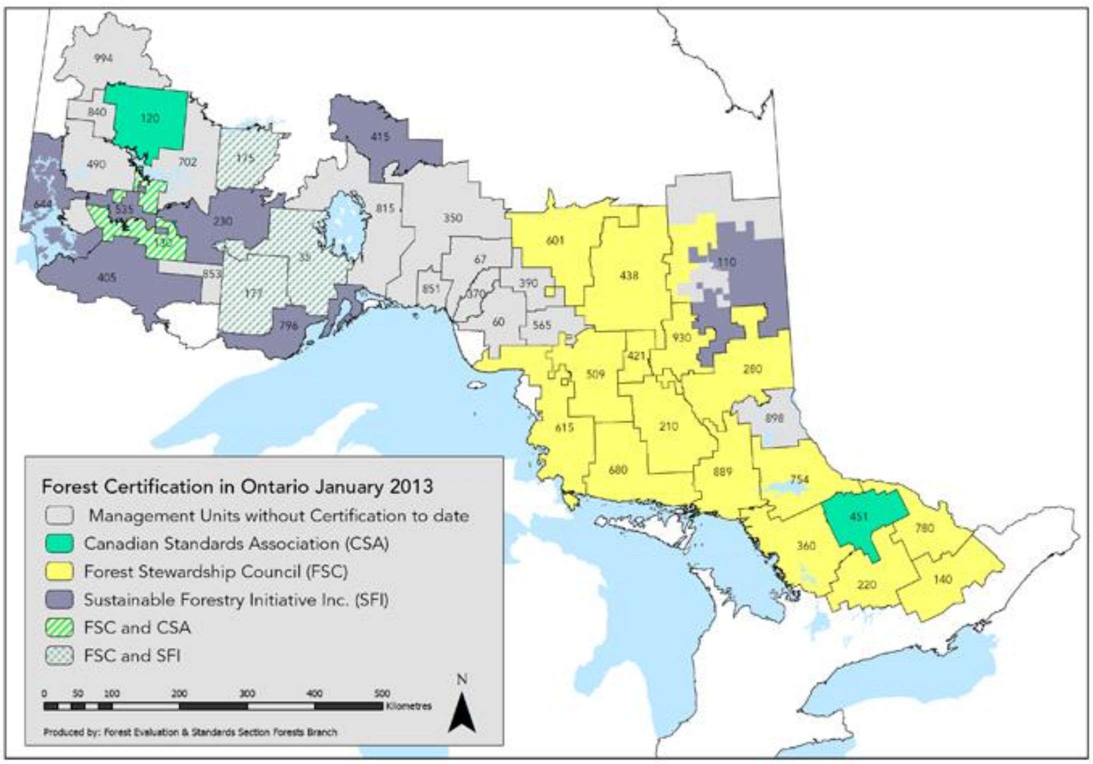
Tree markers go through training that educates them on how to identify tree species, to understand site and land features, to recognize tree defects and indicators, to understand stocking levels, to understand the commercial values of species and products, and to recognize wildlife habitat, biodiversity and other ecosystem values. Tree markers are routinely monitored and evaluated to ensure that they are meeting the standards of wildlife conservation and forest health.

4.9 Forest Certification

Forest certification is a tool for forestry organizations to certify that their practices are sustainable, as determined by a standard. The standards are independently audited by organizations that are not government or forest companies, and the standards have been developed according to environmental, economic and social values. In Ontario, companies are encouraged to seek certification by third party organizations. Each certification scheme has different guidelines that companies must follow in order to remain certified.

Three main standards are currently recognized in Ontario:

- Forest Stewardship Council
- Sustainable Forestry Initiative
- Canadian Standards Association



Source: Ontario Ministry of Natural Resources and Forestry

4.10 The State of Canada's Forests

Every year Canada publishes a *State of the Forests Annual Report*. The report provides up to date information including forest facts, contributions of the forest sector to the overall economy, and amount of forest damaged by insects or fire that year.

For the most up to date information please visit:http://www.nrcan.gc.ca/forests/report/16496 (Canada, Natural Resources Canada, Canadian Forest Service, 2015).

5.0 Measuring the Forest

There are a variety of measurements that you can take in the forest including diameter, height, age, or volume. A forest **inventory** is the systematic collection of data to assist with planning, evaluation, harvesting, management decisions and analysis. This may include collecting information on tree species present, the quality or condition of the stand and an estimate of the volume of wood.

A forest **stand** is a community of trees possessing sufficient uniformity in composition, age, arrangement or condition to be distinguishable from the forest or other growth on adjoining area, thus forming a silvicultural or management entity. Each forest stand can be distinguished or separated from other stands based on differences in species composition, age, height, stocking, site class and health or condition.

5.1 Sampling

When measuring the forest, small sample sizes are taken rather than measuring every single tree within a stand. The task of measuring every tree would be physically impossible and extremely time consuming, resulting in data that does not reflect the current state of the forest at the time of completion. Rather than measure each tree within a stand, a portion of the stand (sample unit) is sampled. The information collected on the sampled area is then expanded to reflect the entire the stand.

5.1.1 Species Composition

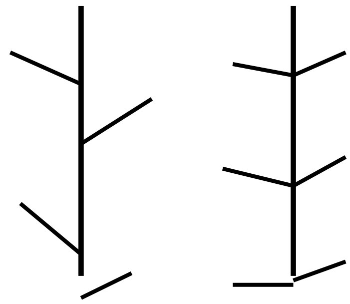
Species composition is important in determining which forest management strategies will be employed. The diversity of species will depend on the forest region (as discussed in section 3.0) which is in turn is influenced by climate, precipitation, and soil types.

Trees are identified using a dichotomous tree. This tool contains a series of choices (or questions) that lead the user to the correct species. Trees may be classified into two broad categories: **deciduous** and **evergreen (or coniferous)**. Evergreens have leaves that remain on the tree for two or more seasons. In Ontario, the seeds of evergreens are contained in cones and the wood is soft and resinous (hence the term "**softwood**").In contrast, deciduous trees usually bear broad leaves that are shed each autumn. However, not all deciduous trees have broad leaves. Tamarack is a deciduous tree with needle-like leaves that are shed each autumn. The wood of deciduous trees is generally harder than wood of evergreens (hence the term "**hardwood**").

Trees can be distinguished with many different features including their leaves. The shape of a leaf, the kind of **leaf margin**, the **leaf type** (i.e. simple or compound), and the **arrangement** of the leaves on the twig are all important factors in tree identification.

Alternate

(oak, poplar, cherry)

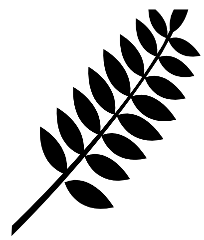


Opposite

(maple, ash)

Figure 11. Twig arrangement is used to help identify tree species.

Simple – a leaf that is not divided into parts (e.g. oak, maple, birch)



Compound – contains numerous leaflets joined to a single stem (e.g. ash, walnut)

Figure 12. Simple and compound leaves

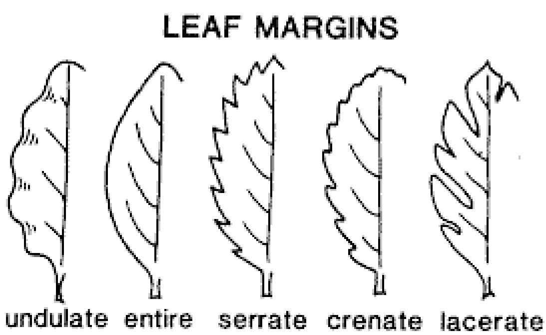


Figure 13. Leaf margins are used to distinguish different tree species (State of Washington, n.d.).

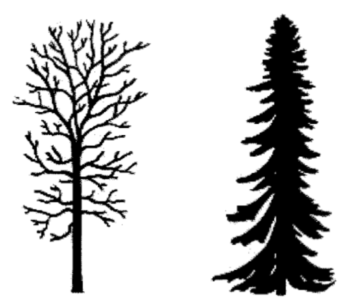


Figure 14. Tree silhouettes are often used to help distinguish different species.

Tree bark can be differentiated according to colour, texture, hardness, and bark patterns. Probably the easiest tree to identify by its bark is the white birch. The creamy white bark peels easily into large sheets, revealing the pinkish-orange inner bark underneath. Sugar maples have dark grey bark that forms long, irregular vertical ridges (called **fissures**). Beech trees have thin, smooth bluish-grey bark. Evergreen bark is full of resin, a substance that sticks to hands and clothing. The bark of most evergreens changes colour and thickens as the tree ages. As the tree matures, the bark becomes dark grayish-brown and develops long fissures.

During the winter, twigs and buds can be used to identify trees. As with leaves, it is important to notice how the buds are arranged on the twig (opposite, alternate or whorled). Note also the size, colour, stickiness, and hairiness of the buds.

General shape or outline (**silhouette**) of a tree may also be used to differentiate between species. Pine trees generally have branches at right angles to their trunks. In sheltered areas, their overall shape is oval. This shape can be contorted by the prevailing winds, often giving a bent and sculpted look (this is especially noticeable in the white pine).The shape of a balsam fir tree, however, is almost symmetrical. Firs have branches that tend to bend downward and tapered trunks that give an overall steeple appearance to the silhouette. The silhouettes of deciduous trees can be equally distinctive in summer or winter. Weeping willows have dropping branches. In direct contrast are the poplars with their tall slim outline. Oaks tend to have short sturdy trunks with a few large branches. Maples also have a few large branches but have larger spreading limbs that support wide, full crowns.

5.1.2 Age

Understanding the age and history of the stand which you are inventorying can help to determine what management steps need to be taken. Every year a tree puts on a new layer of growth. By looking at a cross-section of the tree, you can easily count the rings to determine its age. An **increment borer** is a tool that drills a small hole into a living tree, and is able to remove a section of wood tissue with minimal damage to the tree.

Figure 15.An increment borer is used to determine the age and history of a tree (Forests Ontario, 2013).

5.1.3 Diameter at Breast Height (D.B.H.)

A tree's diameter is measured at a point termed 'breast height' (B.H.), or '**diameter at breast height**' (D.B.H.). The main reasons for measuring at this height are that it is accessible and easy to reach, it is mostly consistent worldwide, and helps to avoid the swelling found at a tree's base.

- the intent or objective is to obtain a fair diameter that represents the tree's volume
- the diameter at breast height includes the bark
- DBH is measured 130 cm (1.3m) above the ground (or 1.4m in the US)

One should become familiar with the point on one's body which is 130cm high as it will make it simpler to find the right level at which to make the tree diameter measurement. If a tree is not a perfect circle, measure the diameter through the largest and smallest dimensions, at right angles, and then average the two.

Diameter tape is the more precise method over callipers or diameter curve. A diameter tape has two sides, one side measures the circumference of the tree, the other has been divided by **π** to give the diameter. Diameter tape is used to measure trees that are too large for the calipers.

Figure 16.A clinometer is used to measure tree height (Forests Ontario).

5.1.4 Tree Height

Tree height is the measurement from the base of the tree to the tip of the highest branch. Height can be measured using instruments called **hypsometers**. While these tools help give an estimate of the height, it is very difficult to be completely accurate given many variables including the angle you are measuring the height, distance to tree, or the variability in topography.

One of the most common tools to measure height is the **clinometer**. The clinometer uses distance and angles to measure the height. By looking through the clinometer, you can match the measuring piece with the top of the tree. The clinometer measures the angle from the eye to the top of the tree, and then the horizontal distance to the tree at eye level using a measuring tape. If the base of the tree is below eye level, then the height of the tree below eye level is added to the height above eye level. Depending on the clinometers, the direct measurement of the height may be given, or a percentage may also be given.

You can also determine the height of a tree using the proportional method, and this method requires only simple math and a ruler.

Determining Tree Height

- **Step 1.** Does an eyeball estimate first. The tree appears to be ______ metres tall.
- **Step 2.** Have one of your friends stand at the base of the tree to be measured.
- **Step 3.** Now walk away from the tree to a point at which a ruler (e.g. 30 cm) held at arm's length "fits" the tree. This means that the top and bottom of the ruler line up with the top and bottom of the tree. Before moving, look at where your friend measures up on the ruler (e.g. Student's height is 5 cm).
- **Step 4.** To find out how tall the tree is, divide the length of your ruler (i.e. 30 cm) by the height of your friend on the ruler (e.g. 5 cm). So the calculation would look something like this: 30cm / 5cm = 6.
- **Step 5.** Measure your friend's real height and multiply the partner's height by the figure in step 4. For example, if the partner's height was 1.5 m, then the height of the tree would be: 1.5 x 6 = 9 metres.
- **Step 6.** Determine the height of your tree.

Activity taken from Focus on Forests - http://www.forestsontario.ca/wp-content/uploads/2016/02/HeightofaTree.pdf

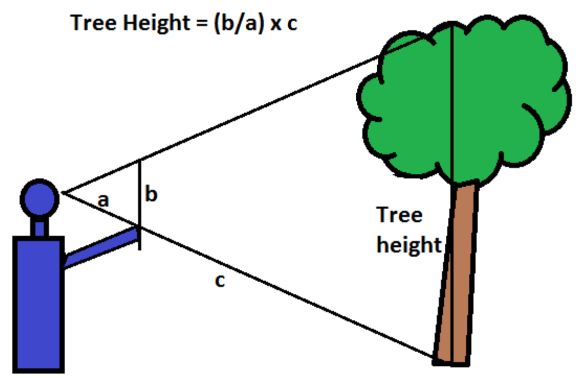


Figure 17. Height is measured using distances and angles.

5.1.5 Basal Area

Basal area is the term used to describe the average amount of area occupied by tree stems in a hectare (Mississippi Wildlife, Fisheries and Parks, n.d). Basal area is closely related to volume, and helps to determine the future development of the forest. Basal area is measured using a tool called a **prism**; one looks through the prism to determine if a tree is factored into the basal area or not. If the offset section of the tree (seen through the prism) touches the tree section outside the prism, then the tree is "in" and is counted – see Figure 18. If you were to add up the surface area of all of the "in" trunks, you would get the basal area for a hectare.

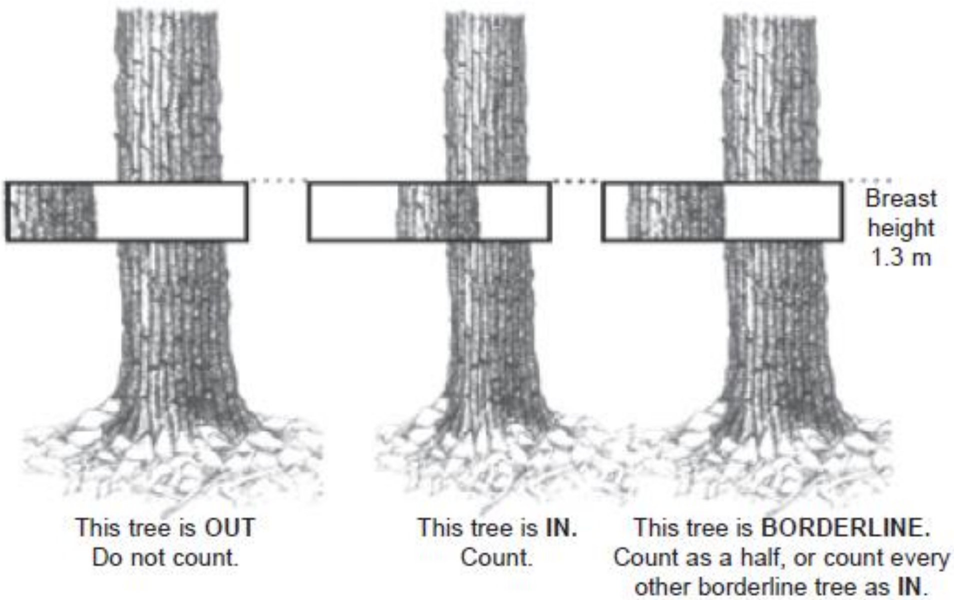


Figure 18. What you might see while looking through a prism (MNRF, 2004).

5.2 LiDAR

LiDAR (light detection and radar) is a technology being used to enhance the quality, accuracy and precision of forest inventory. LiDAR uses the time it takes for the laser emitted to be reflected back to the sensor. It can produce highly accurate models of forest cover, understory vegetation and the ground surface in high three-dimensional detail. LiDAR is often used in conjunction with other inventory methods as described above.

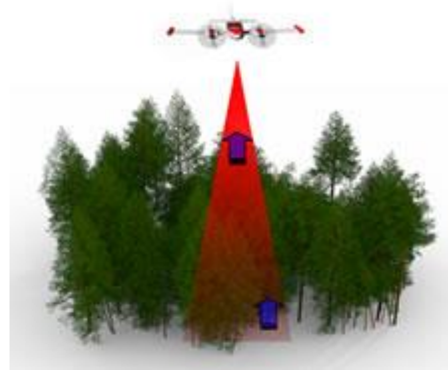


Figure 19. Aerial LiDAR measures the time it takes for a laser to strike an object and return to the source (NRCan 2015).

6.0 Health of our Forests

6.1 Biodiversity

Biological diversity – or **biodiversity** – includes all of the life on Earth and the natural patterns it forms. Biodiversity includes genetic, species and ecosystem diversity. Abiotic components are also part of an ecosystem's biodiversity as they contribute to ecosystem functioning. It is biodiversity that drives many natural processes and functions that are required for the survival of humans. These processes include purification of air and water, recycling of nutrients and fertilization of crops. Without these vital ecosystem services, humans would not be able to survive.

Trees play a crucial role in many ecosystems and are very important to animals as they offer habitat and food sources. Insects, birds and mammals eat the leaves, flowers, fruit, bark and twigs of many trees. Birds and animals use trees for nesting areas. Many animals use trees as a shelter from harsh weather. Other plants have a symbiotic relationship with trees and require their presence for survival. Trees are also very valuable to humans. Trees offer us shade and create beautiful colours for us to enjoy in the fall. Trees provide us with many products such as wood to create furniture, houses and fuel, and materials such as sap and nuts for food and bark for medicines.

Biodiverse forest ecosystems are often healthier because they have higher **redundancy** and **resiliency**. Redundancy occurs when there is more than one species that performs the same or similar vital functions in an ecosystem. High redundancy is beneficial to ecosystems because if one species is removed from the ecosystem there will be another species to perform its function. Resiliency is the ability to recover from, or to resist being affected by a disturbance. Biodiversity plays crucial roles in ecosystem resilience by ensuring ecosystems are capable of reorganizing after a disturbance. Resiliency increases when there is high redundancy within an ecosystem as species are able to replace each other in times of disturbance.

The main threats to forest biodiversity include habitat loss, fragmentation, degradation, invasive alien species and climate change. Many human impacts are creating habitat loss, fragmentation and the degradation of the landscape. The buildings of roads, urban sprawl, recreation, logging and agriculture greatly decrease the number of species. This not only affects forest biodiversity but the biodiversity of all species living with and depending on the trees. With fragmentation, seeds are not able to spread and invasive species are more likely to expand into forest ecosystems and out compete native vegetation. Climate change is also a major threat to forest biodiversity. With temperature changes, trees may not be able to adapt quickly enough.

6.2 Insects and Disease

6.2.1 Insects and Disease

Native insects and disease can cause severe impacts on forest ecosystems through defoliation and mortality. However, these ecosystem changes are not always a negative thing, as it can help to renew forests by removing older trees and allowing younger regenerating trees to thrive. Species can cause outbreaks periodically, and have large scale impacts on healthy forests, and example of this is the native species the spruce budworm, which has periodic outbreaks in the Boreal forest. The outbreaks can be quite large in size, and repetitive years of defoliation can inevitably cause mortality. In addition, mortality of trees leaves behind high quantities of fuel sources that pose issues with wildfires.

6.2.2 Invasive Species

Invasive alien species are plants, mammals, fish, insects, other invertebrates, birds, reptiles, molluscs, microbes, and diseases that are introduced to an area and survive and reproduce, causing harm economically or environmentally within the new area of introduction. Invasive species can have devastating impacts on our native forest ecosystems because they can outcompete **native species**. Invasive species are introduced through a variety of means from importing goods from other countries, ballast water in ships, within wood containers, and through recreation. Their management can be challenging because the impact of the new species is often unknown. Risk analysis and prevention are essential in protecting our environment, economy and society from the impact of invasive species.

Table 5. Common native and non-native pests of Ontario's forests.

Species	Native/Non-native	Impacts
Fall webworm	Native	Insect attacks deciduous trees but rarely causes mortality; defoliation contained to a small area
Eastern tent caterpillar	Native	Insect defoliates deciduous trees; outbreaks can occur but defoliation rarely causes mortality
Dutch Elm disease	Non-native	Fungal disease that causes mortality; disease is spread through bark beetles through travel of spores
Gypsy Moth	Non-native	Insect that defoliates trees and can cause mortality after several years of defoliation
Jack pine budworm	Native	Insect feeds on and can defoliate conifers; Outbreaks are of short duration and rarely cause morality
White pine weevil	Native	Insect girdles stems and causes deformity but trees are not killed
Forest tent caterpillar	Native	Insect attacks deciduous trees; Defoliation may harm trees and branches, but trees are often not killed
Spruce budworm	Native	Insect attacks coniferous trees; Heavy defoliation can cause stunted growth and tree death
Emerald ash borer	Non-native	Insect fees on the inner bark of deciduous trees causing mortality
Butternut canker	Non-native	Fungus infects and kills healthy butternut trees; attacks tree and causes cankers which lead to mortality
White pine blister rust	Non-native	Fungus affects eastern white pine; Colonize needles and move in to twig
Asian long horn beetle	Non-native	Insects bores into trees and feeds, leading to mortality

6.3 Fire Disturbance

Forest fires can be a natural disturbance common to some forest regions within Ontario, a well known example of this is the boreal ecosystem which is dependent on fire to regenerate. In the absence of wildfire, cones may not open to allow seeds to spread and underbrush may not be cleared to allow new seedlings to establish.

Fire is a natural element that can have a significant effect on the health of Ontario's forest lands. Having played a major role in shaping of Ontario's forests for thousands of years, wildfire is a natural force that sustains the cycle of growth in Ontario's forest. Tree species, such as Jack pine, have evolved with fire over thousands of years and require the heat to open their cones and expose mineral soil to allow for the growth of seedlings. Wildlife species also benefit; moose and caribou need open areas like that of a recently burned site in order to move through the forest freely and seek forage. Forest fire protection activities are often carried out when there is a threat to human life, property and natural resources. Some fire protection activities include prescribed burns, where forest fires are created on small and manageable scales, as well as the clearing of underbrush manually using **FireSmart** techniques.

When addressing wildfire in the province's forested lands, the ministry seeks to balance the protection of human values with the positive effects of fire as a management tool, in order to meet silvicultural and ecological objectives. This means the Ontario's wildfire management program will move aggressively to suppress fire in some circumstances, but will manage or use fire in others to achieve ecological objectives, reduce cost and/or hazard to local populations.

6.4 Climate Change

Climate change is expected to have a significant effect on forest ecosystems. Deforestation and land conversion has decreased carbon removal from the earth's atmosphere that forests would have removed through photosynthesis. With an increase of carbon, and more specifically, carbon dioxide (one of the five major greenhouse gases in the earth's atmosphere), more heat is being trapped in the atmosphere instead of being emitted back, thus increasing the atmosphere's temperature and causing 'global warming.' As temperatures in the atmosphere increase, significant changes will occur to the composition of forests. Species that adapt best to new climate conditions and disturbance regimes will succeed and dictate the transformation of forests. In some instances, forests may convert to different land types on their own, such as grasslands. The productivity of forests will vary (either increase or decrease) depending on the rates of tree growth and mortality, as well as the region. Many forested areas will experience decrease in productivity, which may result in habitat loss, or a migration of species (usually northwards, or higher in elevation). Other regions will go through something called 'novel climate', which means that tree species that are already poorly adapted to climate change will experience even more stress. Forest-dependent communities will experience the impact of changes in forest regimes, specifically in timber supply alterations and other forest product (timber and non-timber) values. Both the quantity and quality of desired tree species will be affected, putting many forest-dependent communities at risk. Also, forest operations may be time-limited with the changes in season lengths. Shorter winters mean less time for harvesting operations in Canada. Increased fire activity is also predicted because of climate change effects. Aside from economic losses in forest value, increased fire activity will also influence communities directly and indirectly. It is estimated that annual burned areas will approximately double by the end of the century.

6.5 Changing landscapes

As humans continue to expand our range, we inevitably impact forest ecosystems. Through **deforestation** or **fragmentation**, we are directly impacting the health of the forest and the connectivity of the landscape.

Deforestation is the conversion of forest to non-forest or the complete removal of forest cover. In Canada, the deforestation rate is at 0.02% - among the lowest in the world. Natural disturbances and temporary losses in forest cover are not the same as deforestation. While harvesting does temporarily remove forest cover, sustainable forest management practices in Canada ensure that a future healthy forest will return. This is due to our strength in sustainable forest management that requires regeneration, planning and monitoring. Common reasons for deforestation include urban or industrial development, agriculture, road building and natural resource extraction.

Forest fragmentation occurs when forests are cut down leaving patches of isolated forest habitat. Forest fragmentation happens when forests are removed or converted to another use, or bisected by roads or utility corridors. Within southern Ontario, forests only cover around 20% of the land – ranging from a high of 30% in some areas to a low of 3% in others. Southern Ontario is also home to the highest population, and is the main reason for this large fragmentation. Northern parts of Ontario are more strongly connected as a result of lower human impact.

Forest fragments can still be valuable ecologically when there is a healthy forest interior habitat. A **forest interior** is a sheltered environment away from forest edges and open habitats. The forest interior often is reminiscent of what existed when there was continuous forest in the past. Edge habitats differ from the interior of a fragment. Edge habitats are sunnier, warmer, drier and experience more dramatic environmental changes than the forest interior. The shape of a fragment can have an impact on the amount of forest interior and **edge habitat**. Round and square fragments will have larger forest interior than a long and narrow fragment.

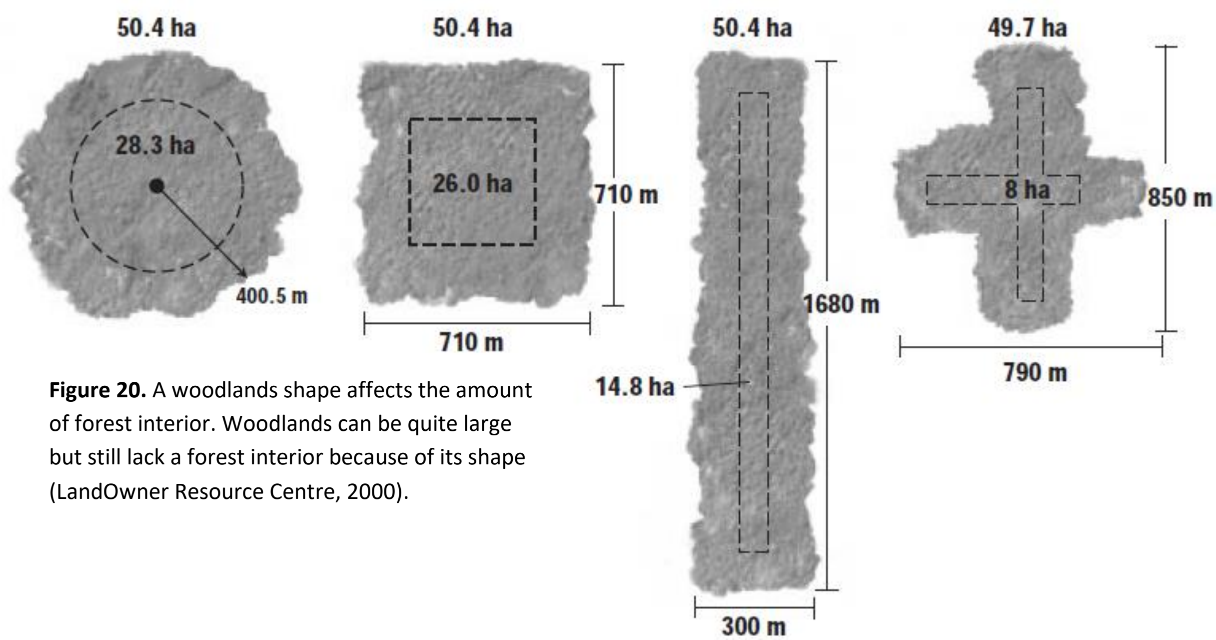


Figure 20. A woodlands shape affects the amount of forest interior. Woodlands can be quite large but still lack a forest interior because of its shape (LandOwner Resource Centre, 2000).

Forest interiors are important habitats for wildlife species, including birds. Some bird species, such as the Acadian flycatcher are in need of large forest areas, and a result of decreasing forest habitat these species are declining in southern Ontario. Alternatively, there are many other bird species that thrive on edge habitat including the common Blue Jay. Ensuring that there is enough edge and interior forest habitat across the landscape is critical for the health of many wildlife species.

7.0 Glossary of Terms

Adaptive management–process of continually improving management policies and practices by learning from the outcome of existing operations.

Annual ring –represent one years growth.

Arrangement –the pattern in which leaves appear on a stem (alternate, opposite or whorled).

Bark– outer layer of tree that provides protection.

Basal area – area of a given section that is occupied by the cross-section of tree trunks and stems at their base.

Biodiversity – the variety and processes of life at all levels, from genes to populations and ecosystems.

Branches–part of the tree which grows from the trunk.

Cambium – the new layer of growth a tree puts on every year.

Chlorophyll – green pigment that captures energy in light and begins the transformation of energy into sugars.

Clear cut – removal of all or most of the trees in an area in one operation.

Conical – form of a tree similar to “Christmas trees”, found in more northern regions where trees need to shed snow and ice and withstand winds.

Coniferous – cone-bearing trees; also known as evergreens.

Climax – final stage of succession.

Clinometer – tool used to measure the height of a tree.

Cone–reproductive structure of coniferous trees where seeds are produced.

Crop trees – trees which are not harvested and left to reseed the forest. Crop trees are generally high value species, have straight stems and are in good health with no sign of dieback, insect infestation or disease.

Crown – the top part of a tree including foliage and branches.

Crown Forest Sustainability Act (CFSA) – governing legislation for forest management on Crown land in Ontario.

Deciduous–trees or shrubs which shed their leaves annually, usually at the end of the growing season.

Deforestation- the conversion of forested land to non-forest or the complete removal of forest cover.

Dendrochronology – study of tree rings to learn about the past.

Diameter at breast height (DBH) – a measurement of the diameter of a tree trunk taken at 1.3m (breast height).

Diameter tape – tool used to measure the diameter of a tree at DBH.

Edge habitat–where two communities or habitats meet, for example at the edge of a forest and a meadow. Edge habitats are attractive to many species as they provide access to multiple food and shelter sources.

Even-aged stand – an area containing trees of the same age or close to same age.

Evergreen –see coniferous.

FireSmart–a program for homeowners, government and industry focused on wild land fire management and prevention.

Fissures – vertical ridges within the bark of a tree.

Flower – reproductive structures of the tree where seeds are produced.

Forest certification–a process whereby forests are assessed by an independent party to verify that they are managed to a defined standard.

Forest conservation bylaw–local legislation which dictates under what circumstances trees may be cut.

Forest interior–refers to the centre of a forest. Commonly defined as the forest area found more than 300 feet from a forest edge.

Forest management plan (FMP) –a plan for the management of a forest area usually for a full rotation cycle: includes objectives and prescribed management activity.

Forest management unit–a discrete forestry planning area.

Forest region – major geographic belt or zone characterized by a broad uniformity in physiography and in composition of dominant tree species.

Fragmentation –the division of habitat into small, isolated pockets.

Free to grow–the growth stage at which regenerating trees have sufficiently outcompeted surrounding vegetation and can be re-entered into the Forest Resource Inventory.

Hardwood – the wood from a deciduous tree.

Harvesting–the cutting and collection of trees.

Heartwood – found at the centre of a tree trunk, comprised of older, inactive cells.

Hypsometer – instrument used to measure tree height.

Increment borer – tool that drills into the trunk of a tree and provides a cross-section which can be used to determine the age of a tree.

Integrated resource management – taking into account the many different values when planning for a specific area.

Intolerant – species that are not able to survive in the shade and need full sunlight.

Invasive alien species – species that are introduced into an area and survive and reproduce, causing harm economically or environmentally in the new area.

Inventory – counting and assessment of a portion of resource to provide information for management.

Lateral buds – where side branches develop.

Leaf type–the basic morphology of a leaf; simple (a single leaf attached to stem) and compound (leaf is comprised of multiple leaflets).

Leaf margin –structure of a leaf edge (i.e. toothed, lobed smooth).

Leaves–the lateral outgrowth from a plant stem, typically flat and green. Primary function is the creation of food through photosynthesis.

Local citizens committee–an advisory committee that represents a wide range of interests and provides advice on the development and implementation of forest management plans.

Meristematic–the tissue in plants containing undifferentiated cells, found in zones where growth takes place.

Mid-tolerant – species that need some sunlight throughout their lives.

Ministry of Natural Resources and Forestry (MNRF) – the government division responsible for the management of Ontario's forest resources.

Native species–a species is defined as native to a given region or ecosystem if its presence in that region is the result of only natural processes, with no human intervention. Every natural organism has its own natural range of distribution in which it is regarded as native.

Natural disturbance patterns – the cycle through which events impact the properties and characteristics of an ecosystem. Natural disturbances include wildfires, insect outbreaks and blowdowns.

Non-timber values–goods or services other than timber which are generated by forests including wildlife habitat, recreational opportunities, medicinal plants and food.

Old growth–a mature, undisturbed forest.

Periodicity - Intervals between good crop years that follow a pattern.

Phloem – cells that move food throughout a tree.

Photosynthesis – the process whereby plants convert sun energy into chemical energy.

Primary succession – the first stage of succession. Occurs on bare areas that did not previously support vegetative growth.

Prism – tool used to measure basal area.

Redundancy – when more than one species performs the same or similar vital functions in an ecosystem.

Regeneration–the act of replacing tree cover after the existing stand or forest has been removed.

Registered Professional Forester–a professional designation for foresters.

Resiliency – the ability to recover from, or resist being affected by a disturbance.

Roots- a part of the body of a plant that develops at the base and grows downward into the soil, anchoring the plant and absorbing nutrients and moisture.

Rotation period – number of years for the forest or tree to reach maturity.

Round – shape of tree often found in milder and moisture conditions.

Sapwood – younger cells surrounding the heartwood and where water and nutrients are conducted.

Secondary succession – follows primary succession. Occurs on areas where vegetation does grow but have been altered by external forces.

Seed forecasting– watching a tree to determine the potential yield of seed production.

Selection – harvesting method used when one or small groups of trees are removed.

Shelterwood– harvesting method where individual trees or groups are retained in alternative strips to provide seed and cover leading to the establishment of a new generation of seedlings.

Silhouette–the shape of the outline of a tree.

Silviculture–the art and science of controlling the establishment, growth, composition, and quality of forest vegetation for the full range of forest resource objectives including timber values, wildlife, water, recreation, aesthetics or any combination of the aforementioned.

Softwood- the wood from a coniferous tree.

Springwood–the softer, porous portion of an annual ring of wood that develops during the first half of the growing period. Characterized by large, thin walled cells and a light colour.

Stand – a community of trees possessing sufficient uniformity in composition, age, arrangement or condition that are distinguishable from an adjoining area.

Succession – gradual and complex series of predictable changes in an ecosystem.

Summerwood–the harder, less porous portion of an annual ring of wood that develops late in the growing season. Characterized by compact, thick walled cells and a darker colour.

Terminal buds – points from which the next Spring's growth will take place.

Terminal bud scar – scar tissue that marks the place where the terminal bud grew the previous year.

Tolerance – a measure of how much shade and competition a tree species can survive.

Tolerant – species that are able to survive in the shade.

Tree marking – the careful selection of trees for harvest or to be retained for other values.

Trunk – central column of a tree that supports a framework of branches.

Twig(s) – slender wood shoot growing from a branch of stem of a tree of shrub.

Uneven-aged stand – an area containing trees of many ages.

APPENDIX A -REFERENCES

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