2025 FORESTRY

STUDY RESOURCES

2025 NCF-ENVIROTHON ALBERTA

2025

Forestry

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NCF-Envirothon 2025 Alberta

Forestry Study Resources

Key Topic #1: Plant Biology and Growth

1. Explain the fundamentals of plant biology as they apply to trees and shrubs.
2. Explain the formation and function of different types of tissues found in trees and other plants.
3. . 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
    d. Nutrient use
4. Identify the differences between the following: angiosperm, gymnosperm, deciduous, coniferous, evergreen, hardwood, and softwood.

Study Resources

UNIVERSITY OF GEORGIA
Warnell School of Forestry & Natural Resources

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Know Your Tree Biology

Abbie Judice and Jason Gordon,

University of Georgia Warnell School of Forestry and Natural Resources

Understanding tree biology is critical to providing appropriate tree health care. Many people know the basics of what trees need to survive and thrive—water, sunlight, air, elements—but it is important to know how these factors interact in a whole tree. This publication provides tree biology information for readers who are both new and experienced tree stewards. We start with a brief description of cell growth in trees, followed by descriptions of tree anatomy and physiology. We conclude with comments on the tree's defense system and climate change impacts on tree biology. This information is the basis for improving tree health care with suggestions for further reading at the end of the publication.

CELL GROWTH

Meristems are specific zones of new cell growth in trees. Cells reproduce in the meristem through division and differentiation. Cell division is when one cell copies its genetic material and splits into two exactly alike "daughter" cells after which the process begins again. Only one of the two daughter cells differentiate, developing a structure to fulfill a specific function for the tree (Figure 1).

Meristematic zones are either longitudinally oriented or horizontally oriented. Longitudinally oriented meristems are known as apical meristems. They are found in the shoot tips and root tips of trees and grow length-wise or elongate. Horizontally oriented meristems grow wide and split down the length, thereby increasing the diameter of the tree during each growing season. Sometimes called lateral or secondary meristems, these meristems are located along the exterior of twigs, branchlets, branches, trunks, and roots, and result in increased thickness of these organs.

Summary of Cell Division and Differentiation

1. Cells divide with half devoted to further division and half assigned specific functions needed for a tree to survive.
2. Cells with the same function create tissues.
3. Tissues combine to create organs, such as buds, twigs, leaves, and roots.
4. Organs combine to create the organism – the entire tree (Figure 1).

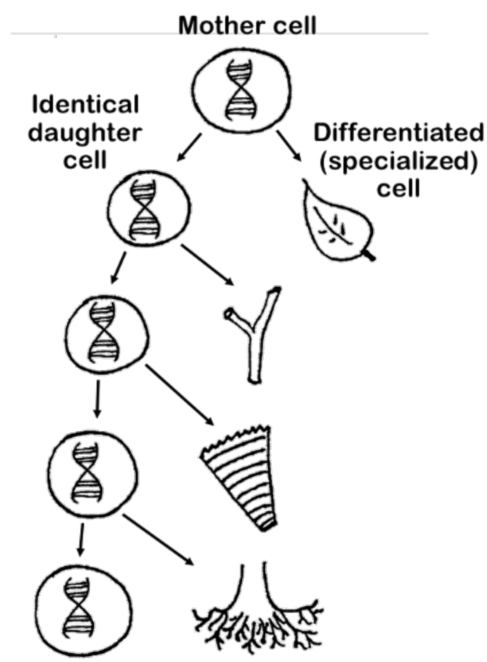

Figure 1: *Simplified diagram of cell division and differentiation.*

ANATOMY AND MORPHOLOGY: COMPONENT PARTS OF A TREE

Wood & Bark

Lateral meristems in a tree are called cambiums and include the vascular cambium and cork cambium. Both cambiums grow laterally and develop layers of different tissues (Figure 2).

The vascular cambium is responsible for development of the inner tree and wood. This area is responsible for transport of water, elements, and sugars that allow a tree to survive and grow. The vascular cambium grows in both interior and exterior directions, creating a series of tissue networks called xylem and phloem. Inside the vascular cambium, xylem tissues are produced in layers and primarily function as the water transport for trees, delivering water from roots to shoots along the length of the trunk and branches. Xylem also assists in supporting the weight of the tree, storing sugars, and defending the tree against decay and disease. On the exterior side of vascular cambium, a vascular tissue called phloem develops in layers much like xylem does in the interior. Like xylem, phloem is responsible for transporting materials. Phloem transports sugars (i.e., carbohydrates) from the shoots to the roots—that is, from the tree crown where leaves use sunlight to create sugars, down to branches, trunk, and roots for use or storage. Xylem is created in a higher quantity than phloem, resulting in the majority of mass and structure of the tree.

The cork cambium is responsible for development of exterior bark layers of a tree, which protects a tree from injury, moderates tree temperature, and mitigates water loss. As trees cannot physically flee environmental threats, cork cambium is an essential part of their defense system. Cork cambium also grows in both an internal and external direction, much like the vascular cambium. On the inside of cork cambium, thin layers of tissue called phelloderm develop alongside aging and inactive phloem. On the outside of cork cambium, phellum tissue develops in layers, aging and dying to create bark or periderm. Periderm is a tree's first line of defense system against pests, decay, and injury (Figure 3).

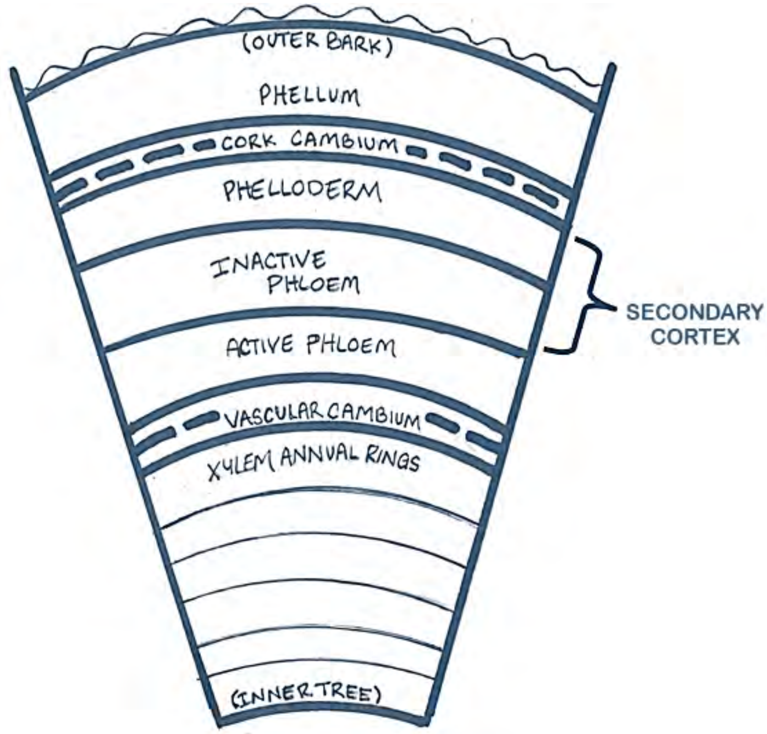

Figure 2: *A simplified diagram of the layers and secondary meristems that make up tree wood and bark. Image modified from Coder 2019.*

Figure 3: *New growth over a wound on a juvenile maple tree.*

Figure 4: ***Roots systems grow laterally, with a majority of roots in the top twelve inches of soil.***

Roots

Roots are especially important to a tree as they provide necessary water and elements that provide life, and they furnish structural support against wind and gravity. Root survival and growth is guided by the availability of water, gravity, oxygen, soil volume, as well as the tree's response to temperature extremes. The space where a tree lives is critical to its long-term health because ninety percent of tree roots are found in the top twelve inches of soil. Root systems grow laterally out from a tree base, searching for water and elements (Figure 4).

Root function can be classified by the size of each root (Figure 5). The three to ten largest roots provide primary structural support for a tree and are located closest to the trunk. The area they encompass is termed "root plate." The next largest roots branching out from the root plate are transport roots. They deliver sugars to developing root tips for further growth and transport water and elements from smaller roots back to the tree trunk and up to leaves. They also provide the framework for the tree's structural stability. Lastly, smallest in size but largest in quantity, are absorbing roots, which are necessary for water and element uptake in a tree. Absorbing roots are less woody than transport and structural roots. They form fan-like horizontal layers in areas of sufficient soil resources.

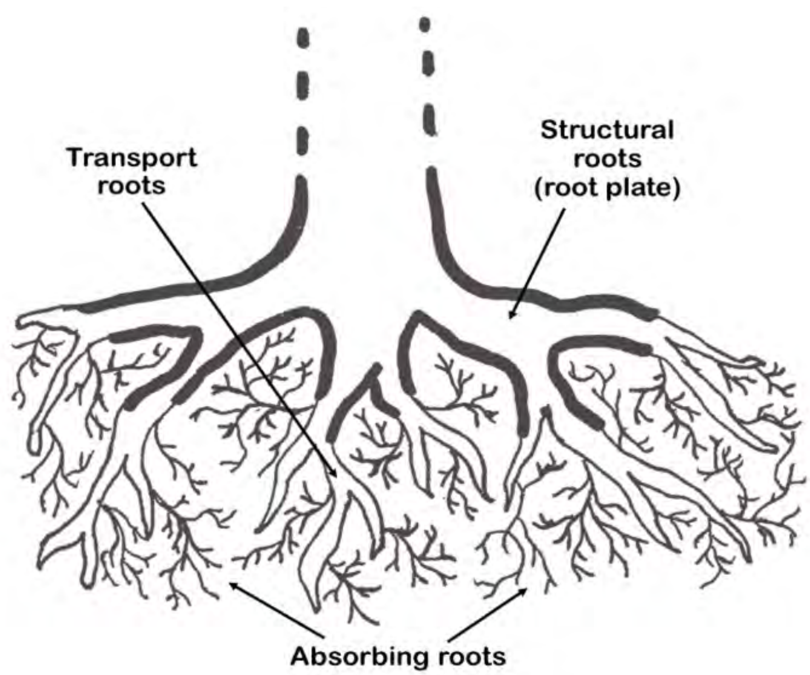

Figure 5: ***Simplified diagram of root function by size.***

Shoots and Buds

Buds are found on branches and twigs and are the elongation growth points of tree crowns. Crowns capture sunlight and carbon dioxide (CO2) to make energy (derived from carbohydrates). The crown also releases water vapor, a process which powers the movement of water from roots to shoots. Buds allow for growth, expansion, and adjustment of tree crowns. Buds may also include reproductive organs like flowers.

Buds are classified according to two different locations on the tree. They occur at the tip of a twig or along the side of a twig. Buds at twig tips are called terminal or apical buds (Figure 6) and regulate the growth of other buds on the same twig using growth regulators (described below). Side buds are found independently along a twig or where a leaf is attached to the twig, an area called the node. Buds along a twig are called axillary or lateral buds (Figure 7) and are typically dormant the first year in deciduous trees until the terminal bud is removed or until it is signaled to create new shoot development (typically caused by unusual weather or a stress factor).

Lateral buds can be preventitious or adventitious. Preventitious buds are formed within a growing season and continue to grow within the tree without creating any new shoot development until signaled by a lateral bud or growth regulator. An adventitious bud forms spontaneously at the time when it is needed, usually because of a tree wound or attack, and creates shoots within the same growing season it was formed. Adventitious buds are an evolutionary adaption to improve a tree's likelihood of survival when experiencing stress.

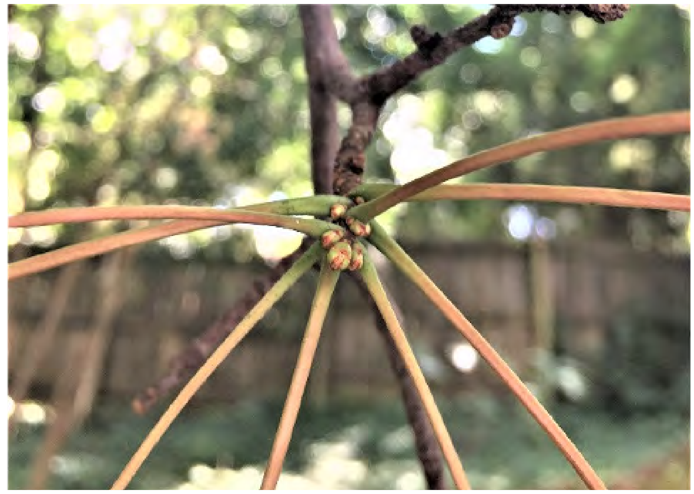

Figure 6: ***Terminal bud on a maple tree.***

Figure 7: ***Lateral buds on a maple tree.***

Twigs, Branches, and Trunk

A shoot is considered a "twig" in its first year of growth, a "branchlet" in its second and third year, and a "branch" starting in its fourth year.

Some significant parts of twigs include (Figure 8):

- lenticels - small porous areas in twig or bark for gas exchange
- nodes - areas where leaves and a corresponding bud arise on a twig
- internodes - the area between two nodes
- leaf scar – a visible area of leaf detachment on a twig
- terminal bud scale – a scar area on the twig signaling the difference between the last growth period and the current growth period, usually appearing as multiple ring-like scars that are closely compacted

Each tree branch is autonomous— a branch creates enough energy (carbohydrates) through photosynthesis to sustain itself entirely. Any extra energy produced is stored in the branch itself or sent to the trunk or roots for further use or storage.

Branches are connected to trunks with reinforced strength (Figure 9). Overlapping xylem tissues forming a zig-zag pattern create a compact connection that ensures stability and hold. The branch bark ridge, which is a line of raised bark because underlying tissues have weaved together, is where the top of a branch and trunk join (known as the area of confluence). Lack of a branch bark ridge is a sign of a weak connection. If a branch grows too upright and is therefore too close to a trunk, it may not grow the proper connection. Instead, the branch and stem grow included bark – bark that does not have tissues woven together – and is therefore susceptible to breaking.

In part, the special strength between a trunk and its branches results from the branch collar, which is where the trunk surrounds the branch base to provide extra support. The area of thickness signaling the trunk transitioning to the branch is called a trunk flange. The branch collar should be avoided when pruning to not affect the overall health of the trunk.

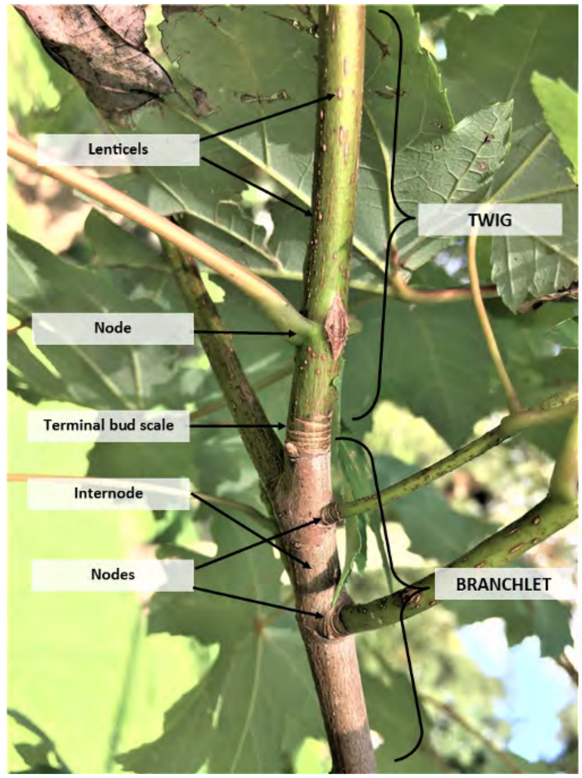

Figure 8: *Young branches on a maple tree.*

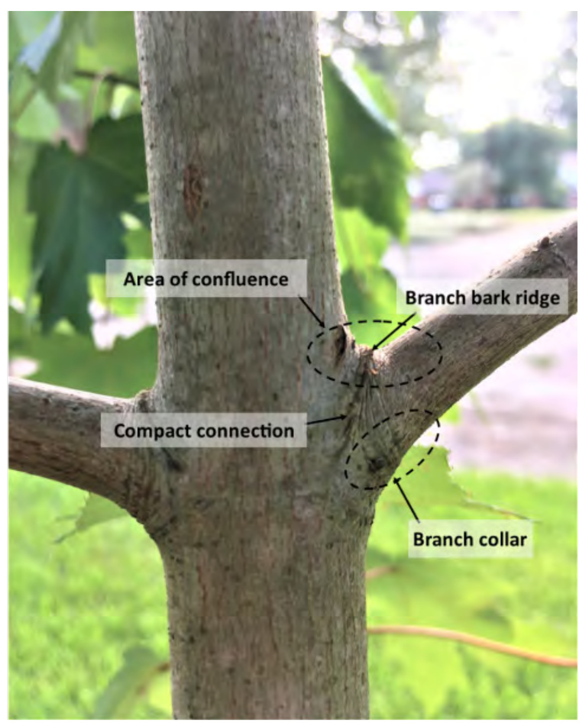

Figure 9: *Strong branch attachment with connected xylem tissues.*

Leaves

Leaves are a tree's primary source of energy production and play an important role in water uptake in the roots. Leaves require a certain amount of sunlight, water, elements, and carbon dioxide to function properly. They are highly adaptable to their surroundings, depending on tree species, and their functions vary across seasons.

Leaves are deciduous, evergreen, or in-between. Deciduous trees (for example, most oaks) lose their leaves annually and are controlled by growth regulators to signal when to function, breakdown, and drop. Evergreen tree leaves (for example, pine needles) last for multiple years. They do not drop based on seasonal changes in weather and continue to absorb light throughout the year. Some trees are semi-evergreen, meaning they keep their leaves past a single growing season, but not over multiple years.

Figure 10.: ***The underside of a maple leaf with veins for transportation of water and elements.***

Leaves use sunlight to energize water and break apart carbon dioxide cells, creating carbon chains in a process called photosynthesis (described below). These carbon chains are the primary energy source used throughout a tree for structural growth, energy storage, and more. Leaves are also involved in water uptake through a process called transpiration (described below). An initial pull of water from inside a leaf into the atmosphere creates tension throughout the tree that continues to pull a connected stream of water through xylem tissues from the branches, trunk, and ultimately the absorbing roots (Figure 10).

Leaves are specially built to interact with water and sunlight. Small pores on the underside of leaves called stomata open and close based on light and environmental conditions to control water loss. Likewise, the cuticle (outer waxy surface layer of leaves) also helps to keep water inside a leaf. Chlorophyll (a green pigment used for photosynthesis) captures sunlight energy needed to build carbon chains, while absorbing harmful levels of sunlight to protect itself.

Flowers, Fruits and Cones

The reproductive units of trees vary based upon genetics and species adaptation. All reproductive units develop within tree buds (meristematic zones), but function differently. Flowers may use seeds or pollen in reproduction processes. Fruits and cones use seeds to disseminate potential offspring (Figure 11). Many of these tree reproductive mechanisms rely on the tree's environment to distribute genetic materials, including animals, wind, water, and other environmental features (Figure 12).

Figure 11: ***The seed capsules of a mature maple tree, called samaras.***

Summary of Tree Parts and Functions

Wood and Bark
- Protect the tree from harm
- Transport carbohydrates and water
- Grow in girth to support weight of tree

Roots
- Elongate in search of best growing conditions
- Provide structural support
- Absorb water
- Uptake essential elements

Shoots and Buds
- Sense and optimize resource allocation
- Adjust for appropriate light capturing environment
- Regulate growth of new twigs and shoots

Twigs, Branches, and Trunk
- Transport water, sugars and essential elements
- Support, stabilize, and govern biomechanics and heat distribution
- Moderate internal water and temperature

Leaves
- Capture light to create energy
- Absorb carbon dioxide to make sugars
- Release water vapor to cool tree and transport

Flowers/Fruits/Cones
- Develop and protect reproductive organs
- Enhance reproductive success

Figure 12: ***A growing tree requires water, sunlight, essential elements, carbon dioxide, and oxygen.***

PHYSIOLOGY: PHOTOSYNTHESIS, RESPIRATION, TRANSPIRATION, ABSORPTION, AND TRANSLOCATION

Carbon chains formed in leaves during photosynthesis become carbohydrates, which can either be used immediately in the area they were created or stored as starch for later use. They can also be combined into transport sugars (sucrose) for delivery to other non-energy-producing parts of the tree, such as the trunk or roots. Starches will eventually be used in combination with specific elements to form some other structural or functional compound (such as amino acids, lignin, or fats that the tree needs to survive). The conditions for ideal photosynthesis rely on appropriate amounts and intensity of sunlight as well as water for the transpiration process (Figure 13).

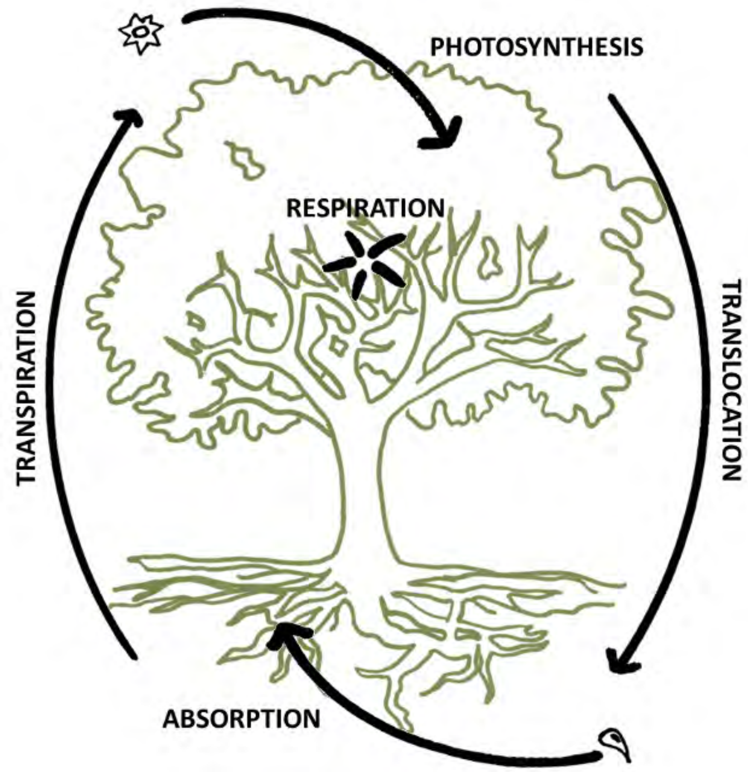

Figure 13: *A simplified diagram of the five physiological processes in a tree – photosynthesis, respiration, transpiration, translocation, and absorption.*

Another process, respiration, is the breaking up and release of energy created during photosynthesis for use in tree biological functions. Unlike photosynthesis, respiration does not happen in any particular area of a tree. The process happens everywhere in the cells. Respiration requires a carbohydrate component and oxygen, and releases water and carbon dioxide once complete. Respiration breaks the bonds of carbon chains and releases units of usable energy. Oxygen is used to pair with the broken carbon and hydrogen elements from carbon chains and release them back into the atmosphere as carbon dioxide and water. Respiration can happen without oxygen, but only for short periods.

Transpiration creates an upward pull of water within trees, from the roots to leaves. Water vapor is released from the wet interior of a leaf into the dry atmosphere via stomata. As water vapor escapes, carbon dioxide is also allowed into the leaves in small quantities, fueling photosynthesis. When stomata are closed (for example, at night) the transpiration pull remaining is strong enough to continue until the stomata open again. Water vapor released through leaves also functions to cool off the tree during the day and is part of the cooling effect of shade. Factors affecting the rate of transpiration include humidity, temperature, and water availability.

Absorption is the uptake of water in roots. Although the movement of water from roots to shoots is powered by the transpirational tension created from leaf water loss, roots have an additional system to keep water moving into a tree to feed transpirational pull. Similar to water vapor moving from the wet inner-leaf environment to a dryer atmosphere, roots rely on mass flow to bring water into the roots. Mass flow consists of water moving from high concentrations (from the soil) to lower concentrations (into the roots). A tree's mineral concentration within the roots also assists in this pull.

Translocation is the movement of transport sugars created by leaves to other areas of the tree via phloem. Following the tree's pattern of moving resources from areas of high concentration to low concentration, carbohydrate components move from source to sink; that is, from where they are created to where they are needed. Translocation itself requires energy to function and growth regulators to map out the patterns of transport.

GROWTH REGULATORS

Growth regulators coordinate and control tree processes, most notably growth and dormancy. They relay messages from roots to shoots and back, giving updates on availability of critical materials like carbohydrates and nitrogen. Primary growth regulators include auxins, cytokinins, abscisic acid (ABA), and gibberellin.

Auxin is primarily produced in shoot tips and flows downward to root tips. Auxin is responsible for developmental functions like cell growth and expansion. Cytokinins are produced at root tips and send their regulation messages to the shoot tips via the xylem water transport system. Cytokinin is responsible for cell division and shoot initiation. Auxin and cytokinins exist in a delicate balance in trees. Small changes in the ratio between the two will signal tree adjustments. Using these growth regulators, roots can communicate to the tree crown when it is lacking water or elements and signal for less growth. Likewise, tree crowns can communicate to the root system that carbohydrate production is low and signal for lower root expansion rates.

ABA is a growth regulator produced during photosynthesis. As it builds up over the active photosynthetic season, it eventually acts as a barrier to auxin growth regulators and signals leaf senescence, or leaf drop. Gibberellin is a growth regulator responsible for sending short, intermediate messages within a tree. It is involved in initiating flowering and branch development.

TREE DEFENSE (CODIT)

Trees are limited by their inability to change location or to heal injuries. Instead, trees use a compartmentalization technique, paired with chemical defenses, to recover after injury or decay (decay is caused by fungus). The model for Compartmentalization of Decay in Trees (CODIT) is described by the creation of four walls to seal off further tissue loss within a tree once wounded (Figure 14). It is important to note that trees do not heal or regenerate cells once an affected area is contained. The compartmentalized area remains empty for the remainder of a tree's life.

Wall 1 resists vertical spread of decay after injury by plugging the top and bottom xylem transport tissues. Wall 2 resists inner spread of a fungus by creating a chemical defense in the next level of annual rings towards the tree core. Wall 3 resists transverse spread through activation of chemical defenses in existing cells extending radially on either side of a wound. These three phases of compartmentalization occur within the first year of a triggered wound or decay and are collectively called the reaction zones.

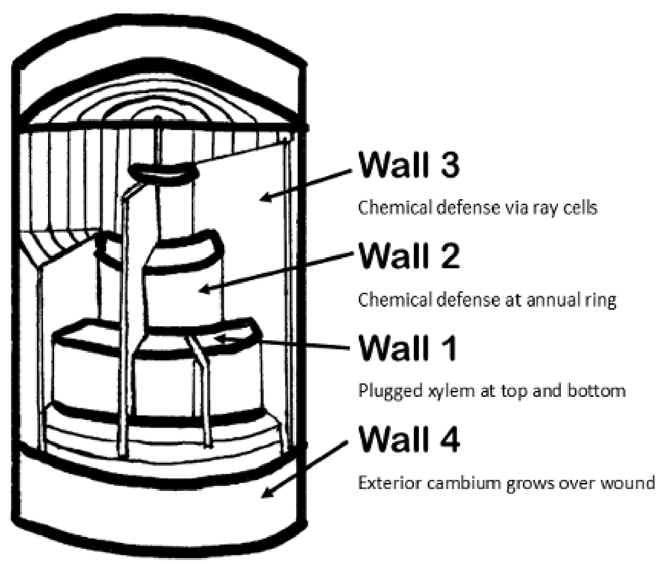

Figure 14: *A simplified depiction of CODIT*

Wall 4 is the final coverage of the wound and is formed with living cambium on the exterior of the tree. This final "growing over" of the affected area protects the tree from outward vulnerability to decay (Figure 15). Wall 4 takes more time to develop than Walls 1-3 and generally occurs a year after the wound has occurred. This wall is called the barrier zone.

Of the four walls in CODIT, Walls 1-3 are most likely to fail, allowing for the interior spread of decay. Wall 4 is chemically strong, but weak structurally and can be susceptible to breakage or cracks.

Figure 15: *CODIT in action, sealing off a pruned limb to protect from decay.*

IMPACTS OF CLIMATE CHANGE ON TREE BIOLOGY

The impacts of climate change on tree biology are complex and continue to be examined by scientists. A changing climate will affect the structure and function of trees in a variety of ways. Changes in temperature, precipitation, weather, and carbon dioxide levels will cause a number of direct and indirect reactions in just five to ten decades. Warming temperatures lengthen the growing season for many trees but will also change the geographic distribution pattern of many species. Changes in precipitation will challenge drought and flood tolerance of many species and disturb habitat suitability for those tree species that cannot handle the stresses. Too much warmth paired with a reduction in water availability will undoubtably effect tree health and development. Increases in carbon dioxide levels pose changes to species geographic distribution, dominance, and biodiversity. Increases in carbon dioxide will drive faster growth in some species, but other changes in environmental conditions, such as drought, will mitigate that potential.

Indirectly, climate change may increase occurrences of many tree disturbances, including pest outbreaks, invasive species, wildfires, severe storms, and more. The negative impacts of climate change greatly compromise a tree's ability to provide ecosystem services, as species adaptation only occurs over the course of thousands of years. Taking into consideration rapid increased in land development, air pollution, and other human impacts, proactive management of trees remains a priority to retain urban and natural forest benefits for future generations.

Figure 16.: *A juvenile stem on a growing maple tree.*

CONCLUSION

This article provided an introduction to tree biology. Understanding tree biology – including anatomy and physiology – is key to taking better care of trees. In turn, healthy trees provide critical benefits to people and other animals. Proper tree health care will only increase in importance as urbanization increases and climates change globally.

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Section 1.1: Tree Anatomy & Functions

What Makes Up a Tree?

Trees are the largest plants on the planet. They provide us with oxygen, help stabilize the soil, and give life to the world's wildlife. Trees are key members of the ecosystem and they are an excellent source of information about the environment. Through the TREE Program, you will get to investigate and find out what stories' trees have to share, specifically looking at trembling aspen trees. For now, we start by looking at what trees are composed of. They can be divided into three main parts: the roots, the trunk, and the canopy.

- Roots - Refers to all the tree parts below ground although roots can occasionally be above ground. Roots spread throughout the ground to anchor the tree in place and to gather water and nutrients. Roots also serve to store food for the tree throughout the winter. With some species, such as trembling aspen, trees reproduce through their roots, creating what are known as clone trees.
- Trunk - Refers to the large column(s) of wood above ground but below the canopy. The trunk supports and elevates the canopy, as well as transports water and nutrients throughout the tree.
- Canopy - Refers to the leaves and branches of the tree. The canopy positions the leaves in full view of the sun, allowing for photosynthesis, transpiration, and hormone production in the tree.

What Makes Up Tree Roots on the Cellular Level?

Tree roots are not only the anchor for the tree but essential in providing the tree with life. They soak up the necessary nutrients and water from the soil, feeding the growth cycle of the tree. Tree roots are composed of a complex and intertwined network of cells with two main types of structures: root hairs and lateral roots.

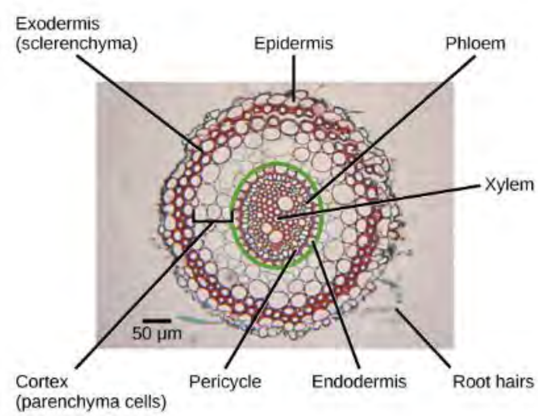

Figure 1 shows a cross-section of the cellular structure of roots. Image by CNX OpenStax.

Root hairs are a small outgrowth stemming off the lateral roots. Root hairs are continually being created and typically last 2-3 weeks before they die off and their nutrients are taken up by the roots. Root hairs provide a lot of surface area to absorb water and nutrients into the root. Lateral roots are the other main root structure and are much bigger than the root hairs. The lateral roots contain larger amounts of tissue, called vascular tissue, to transport nutrients and water throughout the tree.

When roots are cross sectioned, we can see that they have five main types of cells: the epidermis, the exodermis, the cortex, the endodermis, and the vascular tissue (as shown in the Figure). The term tissue in this context refers to when cells are bundled together.

Types of Tree Root Tissue

- Epidermis - The epidermis is the outermost tissue that is a physical barrier providing protection, insulation, as well as moisture and gas control. The epidermis also absorbs some nutrients and water. As the epidermis wears away and dies off, it is continually replaced by cells from the exodermis.
- Exodermis - The exodermis tissue is right underneath the epidermis and it replaces epidermis tissue as it wears away and dies off. This is very similar to how the inner bark replenishes the outer bark on the trunk which is explained in upcoming sections.
- Cortex - The cortex is a layer of cells that lies directly below the exodermis. The cortex transfers nutrients from the root hairs to the vascular tissue and is used for energy storage. The cortex separates the exodermis from the endodermis.
- Endodermis - The endodermis is the innermost layer of the cells with thicker cell walls. Some of these cells are coated in a water-repellent substance called suberin, which helps keep the endodermis watertight. The endodermis serves to regulate water and nutrient movement between the soil and the vascular tissue.
- Pericycle - The pericycle is composed of tissue that lies just inside the endodermis. The pericycle serves as internal support and protection for the root and it also forms new lateral roots by dividing rapidly in a specific location.
- Vascular Tissue - Vascular tissue is a bundle of cells that transport water and nutrients from the roots to the rest of the tree.

How do Trees Drink and Gather Nutrients?

Trees drink by increasing the concentration of salts in their roots such that their roots have a higher salt concentration than the surrounding soil. When this happens, water flows into the roots to cause the root's salt concentration to be in equilibrium (be the same) with the soil's salt concentration. This process is known as **osmosis**. As the tree drinks, any minerals and nutrients that are dissolved in the water will flow into the roots as well. The roots separate these nutrients and minerals through cells called sieve cells and the nutrients and minerals then make their way up to the trunk to start feeding the rest of the plant.

What are the Main Parts of a Tree Trunk?

Much like the variety of shapes and sizes seen with humans, tree trunks vary from one species to the next. However, there are parts that are common to all trees and these are the **bark**, the **vascular cambium layer**, the **sapwood**, the **heartwood**, and the **pith** (as shown in Figure 2).

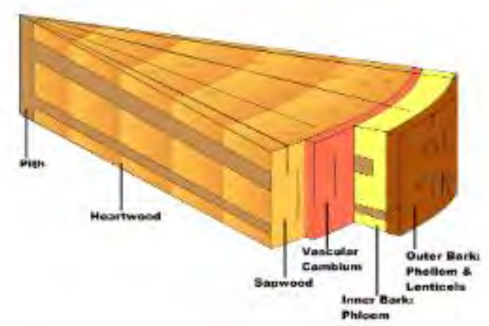

Figure 2 shows the anatomy of a tree trunk. Original image by Thomas Steiner.

The **bark** of a tree serves as a physical barrier for protection, insulation, and moisture control. Bark is separated into outer and inner bark.

- Outer bark is composed of dead cells, commonly referred to as cork. Outer bark is covered with fine oxygen-breathing pores called lenticels.
- Inner bark is composed of cells that transport sap and nutrients throughout the tree. As these cells age, they become outer bark.

The **vascular cambium layer** is a thin layer of cells with no specific task yet. This is where majority of the trees outward growth occurs. These cells continually divide with a varying rate throughout the year, creating **phloem** cells on the bark side and xylem cells on the inside.

- **Phloem cells** transport sap and other nutrients throughout the tree. These cells become phellem cells as they mature and die off.
- **Xylem cells** transport water and minerals throughout the tree. These cells become the sapwood as they mature and die off.

Sapwood is composed of the xylem cells created by the layer surrounding it, the vascular cambium layer. Sapwood is responsible for water transport and storage through the tree's daily water cycle. As these cells mature and die off, they harden and become more rot resistant, turning into heartwood.

Heartwood is a layer of wood composed of dead xylem cells and fiber bundles. Heartwood has a darker appearance than sapwood. Over time, the cells harden and become stronger, enabling the heartwood to be structural support for the tree.

The **pith** is the center most portion of the tree and is composed of soft spongy **parenchyma cells** (explained below). The pith is surrounded by a ring of xylem cells, which is then surrounded by a ring of phloem cells. This allows the pith to store and transport water and nutrients throughout the tree.

What Makes up a Tree Trunk on the Cellular Level?

As noted in the previous section, there are many different parts that make of a tree trunk. Within each of these parts, there are many different and uniquely specialized cells. The four main cells are **xylem**, **phloem**, **parenchyma**, and **fiber bundles**.

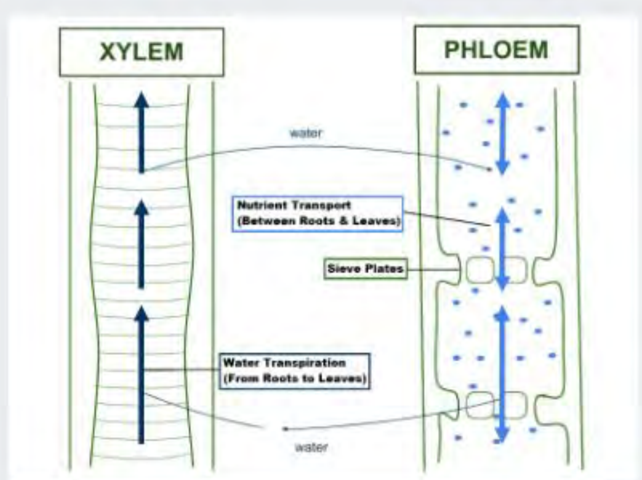

Figure 3 shows the inner workings of xylem and phloem. Image by KI3580.

- **Xylem Cells** - These cells are responsible for transporting water and minerals up from the roots throughout the tree. These cells combine together to form hollow tubes called vessel elements. It is important to note that xylem cells only transport water up (see Figure 3).
- **Phloem Cells** - These trunk cells are responsible for transporting sap, which contains sugars and other nutrients, up and down throughout the tree. Phloem cells combine together to form hollow tubes called sieve tubes. These tubes are separated into smaller sections by sieve plates which allow for the bidirectional flow of nutrients. It is important to note that the phloem can transport nutrients up and down (see Figure 3).
- **Parenchyma Cells** - Parenchyma cells provide support and nutrients to phloem and xylem cells and make up the bulk of plant cells.
- **Fiber Bundles** - Fibers are long, slender cells that typically occur in bundles. These cells are mostly composed of cellulose, a tough material that makes up the cells walls and provides cell with structural support.

How do Trees Grow?

Trees expand and increase their size through the vascular cambium layer in their trunk. This layer continually divides at different rates throughout the year into phloem and xylem cells. The xylem cells are created on the inside of the tree and they are responsible for sapwood and heartwood growth. The phloem cells are created on the bark side of the tree and will quickly convert itself into the cork-like wood that we commonly associate as bark.

How do Tree Rings Form?

Tree rings form every year as the tree is living and growing. These rings will be different sizes depending on the factors experienced during the growing season. These factors include: temperature, pests, diseases, access to water, nutrients, sunlight, and more. When the conditions are just right for the tree, the vascular cambium layer (refer back to Figure 2) will rapidly divide and create sapwood and bark at a set rate. This initial rapid growth creates lightly coloured, less dense wood called **early wood**. However, depending on the trees' environmental conditions, the growth rate of the rings could change.

As the season progresses towards winter, trees spend less energy on growth and more energy creating an energy store for the winter. This later slow growth creates the darkly coloured, more dense wood called **late wood**. As winter occurs, a tree experiences little to no growth but once spring comes around, the ring formation cycle repeats. This cycle is what gives trees the alternating light and dark circular patterns we see and are what we call **tree rings** (see Figure below).

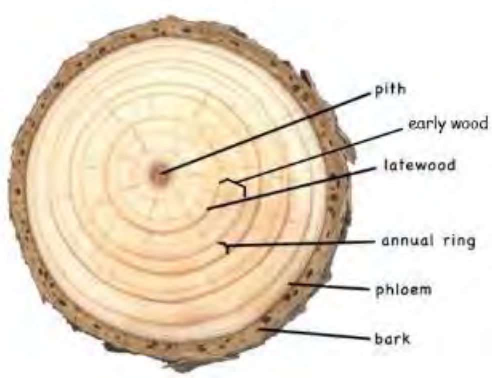

Figure 4 shows a cross section of a tree trunk, labelled with certain parts of the tree ring.

What Makes up a Tree Leaf on the Cellular Level?

The last main part of a tree are the leaves, which make up the canopy. As the roots are important for soaking in water and nutrients, leaves are important for soaking in sunlight, the other essential ingredient in giving plants life. In order to trap the sunlight and convert it so the tree can use it, tree leaves are composed of many specialized cells. The four main types of cells found in a leaf are the **epidermis cells**, **mesophyll cells**, **stomata**, and **vascular bundles**. These cells aid in photosynthesis, hormone production, and help move water to the outside of the leaf to be evaporated.

- **Epidermis** - The epidermis is the outer layer of cells that provides a physical barrier for protection and insulation for the leaf. The epidermis acts like a skin and is coated in a wax-like substance called cuticle, that helps prevent unwanted water loss. See Figure 5 for a visual representation.
- **Mesophyll** - These cells are composed of parenchyma cells in long tube-like arrangements. Mesophyll is split in two layers, the **palisade mesophyll** and the spongy mesophyll, and these cells make up the middle section of a leaf (see Figure 5).

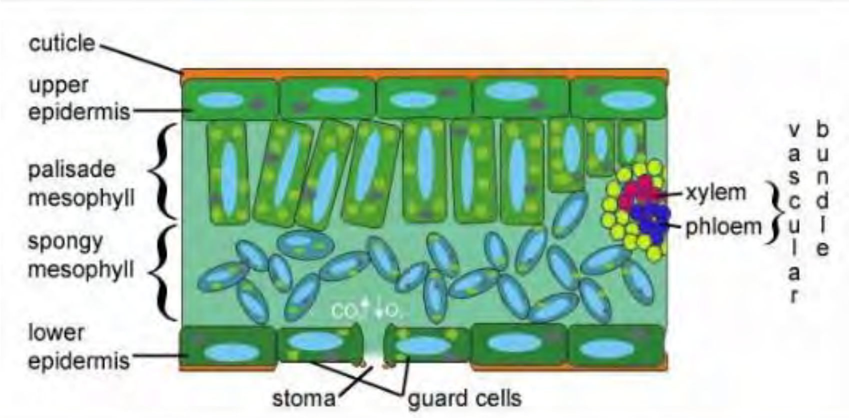

Figure 5 shows the cellular structure of leaves. Image by Maksim.

- **Palisade Mesophyll** - Palisade mesophyll is composed of tightly packed parenchyma tissue that contain large amounts of **chloroplasts**. Chloroplasts are small organelles filled with the photosynthetic pigment chlorophyll. Chlorophyll is responsible for **photosynthesis**, where energy from sunlight is converted to sugars. Since the chloroplasts need sunlight, the palisade mesophyll occupies the top inside portion of the leaves.

- **Spongy Mesophyll** - Spongy mesophyll is composed of loosely packed parenchyma tissue and occupies the bottom inside portion of the leaves. By packing the spongy mesophyll loosely, gases have plenty of room to move between the chloroplasts and the **stomata** allowing the chloroplasts access to fresh carbon dioxide.
- **Stoma** - As shown in Figure 5, stoma are little natural openings in the epidermis that allow for regulated gas exchange between the tree and the atmosphere. Specialized cells, called guard cells, open and close the stomata (a collection of stoma) when the leaf needs more carbon dioxide or when the tree needs to transpire.
- **Vascular Bundle** - A vascular bundle is a bundle of xylem and phloem cells that are essentially the veins and arteries of the leaves. Vascular bundles supply nutrients and water to the leaves for photosynthesis and transpiration. They also transport the sugars of photosynthesis to the rest of the tree.

Trees breathe by opening the guard cells around the stomata on the underside of their leaves. With the stoma open, gases from within the leaves can exchange with the air outside through diffusion until the gas concentrations have reached equilibrium or a balance.

What is Transpiration and Capillary Action?

Transpiration is the evaporation of water out of a tree. When the tree transpires, water is moved from the roots and up the stem using the properties of water cohesion and adhesion. With **cohesion**, water molecules are being attracted to themselves. With **adhesion**, water molecules are being attracted to other surfaces.

As one water molecule lifts itself up slightly to adhere to the inside of a small tube, or in a plant's case, the stem and leaves, water molecules below lift themselves up to cohere to the initial water molecule. This process is referred to as **capillary action** and for a model of this process, see Figure 6.

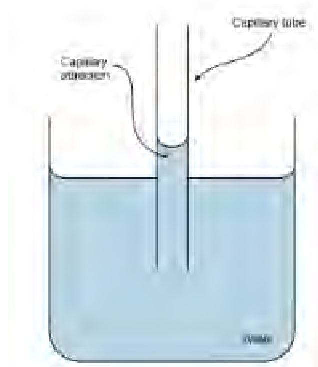

Figure 6 shows capillary action in action. The water inside the tube has lifted itself higher than the water outside the tube. Capillary action is why test tubes have a meniscus line. Image by CNX OpenStax.

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Plant growth and development

Ann Marie VanDerZanden
Published January 2008, Reviewed 2024

Photosynthesis, respiration and transpiration are the three major functions that drive plant growth and development (Figure 1). All three are essential to a plant's survival. How well a plant is able to regulate these functions greatly affects its ability to compete and reproduce.

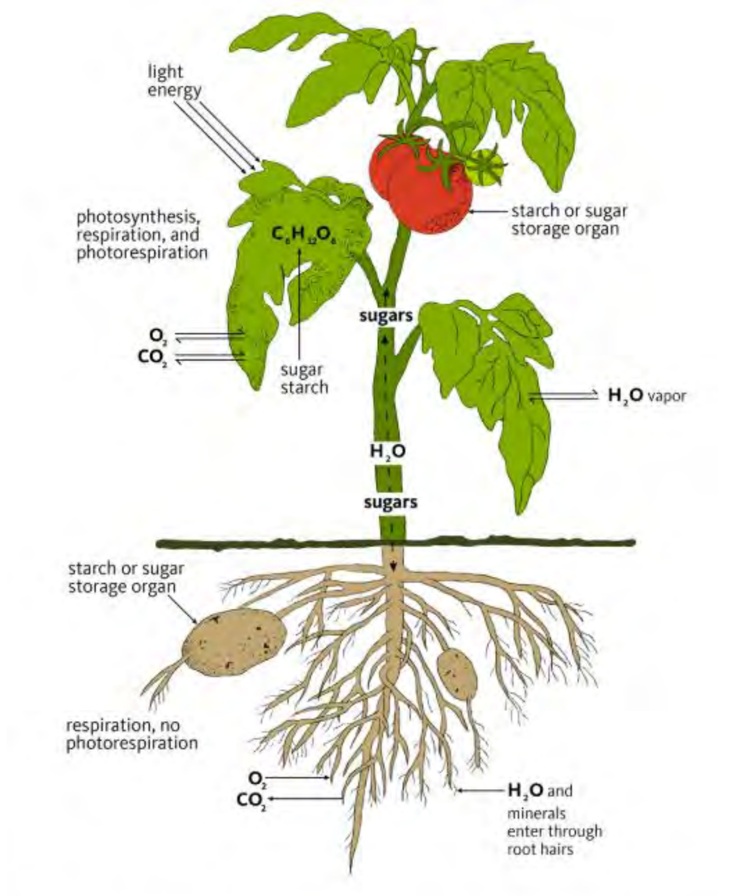


Figure 1. Photosynthesis, respiration, leaf water exchange, and translocation of sugar (photosynthate) in a plant.
Photo: Holly Thompson

Photosynthesis

One of the major differences between plants and animals is plants' ability to manufacture their own food. This process is called photosynthesis, which literally means "to put together with light." To produce food, a plant requires energy from the sun, carbon dioxide from the air and water from the soil. During photosynthesis, it splits carbon dioxide into carbon and oxygen, adds water and forms carbohydrates (starches and sugars). Oxygen is a byproduct.

> To produce food, a plant requires energy from the sun, carbon dioxide from the air and water from the soil.

The formula for photosynthesis can be written as follows:

Carbon dioxide + Water + Sunlight = Sugar + Oxygen **or**

6 CO2 + 6 H20 + Energy => C6H1206 + 6 02

After producing carbohydrates, a plant either uses them as energy, stores them or builds them into complex energy compounds such as oils and proteins. All of these food products are called **photosynthates**. The plant uses them when light is limited, or transports them to its roots or developing fruits.

Photosynthesis occurs only in the **mesophyll** layers of plant leaves and, in some instances, in mesophyll cells in the stem. Mesophyll cells are sandwiched between the leaf's upper and lower epidermis and contain numerous **chloroplasts**, where photosynthesis takes place. Chloroplasts are incredibly small. One square millimeter, about the size of a period on a page, would contain 400,000 chloroplasts.

Chlorophyll, the pigment that makes leaves green, is found in the chloroplasts. It is responsible for trapping light energy from the sun. Often chloroplasts are arranged perpendicular to incoming sun rays so they can absorb maximum sunlight. If any of the ingredients for photosynthesis — light, water and carbon dioxide — is lacking, photosynthesis stops. If any factor is absent for a long period of time, a plant will die. Each of these factors is described below.

Light

Photosynthesis depends on the availability of light. Generally, as sunlight intensity increases, so does photosynthesis. However, for each plant species, there is a maximum level of light intensity above which photosynthesis does not increase. Many garden crops, such as tomatoes, respond best to maximum sunlight. Tomato production decreases drastically as light intensity drops. Only a few tomato varieties produce any fruit under minimal sunlight conditions.

Water

Water is one of the raw materials for photosynthesis. It is taken up into the plant by the roots and moved upward through the xylem.

Carbon dioxide

Photosynthesis also requires carbon dioxide (CO2), which enters a plant through its stomata (Figure 2). In most plants, photosynthesis fluctuates throughout the day as stomata open and close. Typically, they open in the morning, close down at midday, reopen in late afternoon and shut down for good in the evening.

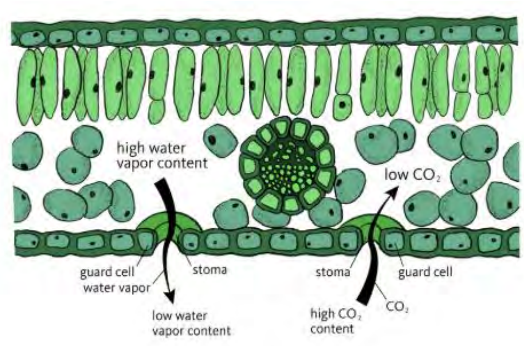


Figure 2. Stomata open to allow carbon dioxide (CO_2) to enter a leaf and water vapor to leave.
Photo: Holly Thompson

Carbon dioxide is plentiful in the air, so it is not a limiting factor in plant growth.

Carbon dioxide is plentiful in the air, so it is not a limiting factor in plant growth. However, it is consumed rapidly during photosynthesis and is replenished very slowly in the atmosphere. Tightly sealed greenhouses may not allow enough outside air to enter and thus may lack adequate carbon dioxide for plant growth. Carbon dioxide generators are used in commercial greenhouses for crops such as roses, carnations and tomatoes. In smaller home greenhouses, dry ice is an effective source of carbon dioxide.

Temperature

Although not a direct component in photosynthesis, temperature is important. Photosynthesis occurs at its highest rate between 65° and 85°F and decreases at higher or lower temperatures.

Respiration

Carbohydrates made during photosynthesis are of value to a plant when they are converted to energy. This energy is used for cell growth and building new tissues. The chemical process by which sugars and starches are converted to energy is called oxidation and is similar to the burning of wood or coal to produce heat. Controlled oxidation in a living cell is called respiration. It is shown by this equation:

$$C_6H_{12}O_6 + 6\,O_2 \Rightarrow 6\,CO_2 + 6\,H_2O + \text{Energy}$$

This equation is essentially the opposite of photosynthesis. Photosynthesis is a building process, while respiration is a breaking-down process.

Photosynthesis and Respiration.

	Photosynthesis	Respiration
Food	produces food	uses food
Energy	stores energy	releases energy
Water	uses water	produces water
Carbon Dioxide	uses carbon dioxide	produces carbon dioxide
Oxygen	releases oxygen	uses oxygen
Light	occurs in sunlight	occurs in the dark as well as light

Unlike photosynthesis, respiration does not depend on light, so it occurs at night as well as during the day. Respiration occurs in all life forms and in all cells.

Transpiration

When a leaf's guard cells shrink, its stomata open and water is lost. This process is called transpiration. In turn, more water is pulled through the plant from the roots. The rate of transpiration is directly related to whether stomata are open or closed. Stomata account for only 1% of a leaf's surface but 90% of the water transpired.

> The rate of transpiration is directly related to whether stomata are open or closed.

Transpiration is a necessary process and uses about 90% of the water that enters a plant's roots. The other 10% is used in chemical reactions and in plant tissues. Transpiration is responsible for several things:

- Transporting minerals from the soil throughout the plant.
- Cooling the plant through evaporation.
- Moving sugars and plant chemicals.
- Maintaining turgor pressure.

The amount and rate of water loss depends on factors such as temperature, humidity, and wind or air movement. Transpiration often is greatest in hot, dry (low relative humidity), windy weather.

A balancing act

In order for a plant to grow and develop properly, it must balance photosynthesis, respiration and transpiration. Left to their own devices, plants do a good job of managing this intricate balance. If a plant photosynthesizes at a high rate, but its respiration rate is not high enough to break down the photosynthates produced, photosynthesis will either slow down or stop.

On the other hand, if respiration is much more rapid than photosynthesis, the plant won't have adequate photosynthates to produce energy for growth. Hence, growth either will slow down or stop altogether.

When stomata are open, transpiration occurs, sometimes at a very high rate. A corn plant may transpire 50 gallons of water per season, but a large tree may move 100 gallons per day!

A corn plant may transpire 50 gallons of water per season, but a large tree may move 100 gallons per day!

Plants have problems if they lose too much water, so stomata close during hot, dry periods when transpiration is highest. However, CO_2, which is needed for photosynthesis, also enters the plant through open stomata. Thus, if stomata stay closed a long time to stop water loss, not enough CO_2 will enter for photosynthesis. As a result, photosynthesis and respiration will slow down, in turn reducing plant growth.

Many herb plants produce lots of high-energy oils, which help them survive in the dry landscapes where they evolved. These oils help them survive extended periods of stomatal closure.

Distinguishing Between Hardwood and Softwood Trees

By Steve Nix | Updated May 06, 2019

The terms hardwood and softwood are widely used in the construction industry and among woodworkers to distinguish between species with wood regarded as hard and durable and those that are considered soft and easily shaped. And while this is generally true, it is not an absolute rule.

Distinctions Between Hardwood and Softwood

In reality, the technical distinction has to do with the reproductive biology of the species. Informally, trees categorized as hardwoods are usually deciduous — meaning they lose their leaves in the autumn. Softwoods are conifers, which have needles rather than traditional leaves and retain them through the winter. And while generally speaking the average hardwood is a good deal harder and more durable than the average softwood, there are examples of deciduous hardwoods that are much softer than the hardest softwoods. An example is balsa, a hardwood that is quite soft when compared to the wood from yew trees, which is quite durable and hard.

Really, though, the technical distinction between hardwoods and softwoods has to do with their methods for reproducing. Let's look at hardwoods and softwoods one at a time.

Hardwood Trees and Their Wood

- **Definition and Taxonomy:** Hardwoods are woody-fleshed plant species that are angiosperms (the seeds are enclosed in ovary structures). This might be a fruit, such as an apple, or a hard shell, such as an acorn or hickory nut. These plants also are not monocots (the seeds have more than one rudimentary leaf as they sprout). The woody stems in hardwoods have vascular tubes that transport water through the wood; these appear as pores when wood is viewed under magnification in cross-section. These same pores create a wood grain pattern, which increases the wood's density and workability.

- **Uses:** Timber from hardwood species is most commonly used in furniture, flooring, wood moldings, and fine veneers.
- **Common species examples:** Oak, maple, birch, walnut, beech, hickory, mahogany, balsa, teak, and alder.
- **Density:** Hardwoods are generally denser and heavier than softwoods.
- **Cost:** Varies widely, but typically more expensive than softwoods.
- **Growth rate:** Varies, but all grow more slowly than softwoods, a major reason why they are more expensive.
- **Leaf structure:** Most hardwoods have broad, flat leaves that shed over a period of time in the fall.

Softwood Trees and Their Wood

- **Definition and Taxonomy:** Softwoods, on the other hand, are *gymnosperms* (conifers) with "naked" seeds not contained by a fruit or nut. Pines, firs, and spruces, which grow seeds in cones, fall into this category. In conifers, seeds are released into the wind once they mature. This spreads the plant's seed over a wide area, which gives an early advantage over many hardwood species.
- **Softwoods** do not have pores but instead have linear tubes called *tracheids* that provide nutrients for growth. These tracheids do the same thing as hardwood pores — they transport water and produce sap that protects from pest invasion and provides the essential elements for tree growth.
- **Uses:** Softwoods are most often used in dimension lumber for construction framing, pulpwood for paper, and sheet goods, including particleboard, plywood, and fiberboard.
- **Species examples:** Cedar, Douglas fir, juniper, pine, redwood, spruce, and yew.
- **Density:** Softwoods are typically lighter in weight and less dense than hardwoods.
- **Cost:** Most species are considerably less expensive than hardwoods, making them the clear favorite for any structural application where the wood will not be seen.
- **Growth rate:** Softwoods are fast-growing as compared to most hardwoods, one reason why they are less expensive.
- **Leaf structure:** With rare exceptions, softwoods are conifers with needle-like "leaves" that remain on the tree year-round, though they are gradually shed as they age. In most cases, a softwood conifer completes a changeover of all its needles every two years.

Angiosperms vs Gymnosperms

Ryan Pankau | January 23, 2021

Gymnosperms, like this Colorado blue spruce, are a group of nonflowering plants that emerged several hundred million years before flowering plants (angiosperms) entered the evolutionary history of the plant kingdom.

The plant kingdom has not always had the diversity we know today. It has taken hundreds of millions of years of evolution to bring about the diverse, complex group of flowering plants known as angiosperms. And for many millions of years prior to the emergence of angiosperms, the plant kingdom consisted of primarily of gymnosperms.

Today, these two branches of the plant family tree represent the primary dividing factor among land plants, with angiosperms much more abundant than their earlier kin, the gymnosperms. So, what are the major differences between angiosperms and gymnosperms and what factors lead to the incredible success of the angiosperms?

To step back even further in time, prior to emergence of the gymnosperms, plant life on earth began in the oceans. Recent research suggests that the first plant life to inhabit land dates back to almost 500 million years ago. These early terrestrial plants were nonvascular, meaning they did not have a vascular system of conductive tissue (think of the circulatory system in humans) to circulate water and nutrients among cells. Mosses, hornworts, liverworts and some kinds of algae are modern day nonvascular plants and representatives of early plant life on land

The development of a vascular system was a major step forward for the plant kingdom, occurring around 430 million years ago. Next came reproduction from seeds, which was yet another huge step forward at around 350 million years ago that ultimately lead to the emergence of the first gymnosperms in the fossil record around 319 million years ago.

Somewhere around 240-205 million years ago, the gymnosperms began to dominate the landscape on earth. Their conquest was fueled by the development of both seeds and pollen, which were major innovations in plant reproduction. Pollen grains could travel great distances to spread plant genes and seeds provided a protective coat around embryos. Seeds also built in a higher resistance to drought, allowing germination when conditions were optimal. These factors pushed gymnosperms to expand into much drier terrestrial environments.

Around 150 million years ago, the angiosperms emerged in the fossil record. They are most commonly known for the development of a more specialized seed that forms inside the ovary of a flower, surrounded by a protective fruit. With the development of flowers, the angiosperms began to incorporate and attract other life in their reproductive process.

Pollinating insects became major players in the evolutionary history of angiosperms assisting them in and explosion of diversity around 100 million years ago.

Today, angiosperms dominate the plant world with an estimated 300,000-500,000 species, compared to a mere 1,000 species of gymnosperms. The angiosperms include all the fruits and vegetables we eat, all of our native, deciduous trees and shrubs, as well as so many other plants that we encounter on a daily basis. Beyond the development of flowers and fruits, they also established more advance methods to transport water and sugars within their vascular tissue as well as other improvements in physiology that gave them an advantage over gymnosperms.

The biggest difference between gymnosperm and angiosperms lies in their seeds. Gymnosperm seeds are typically formed in unisexual cones and are known as "naked" seeds since they lack the protective cover angiosperms provide their seeds. In angiosperms, individual flowers can be unisexual, with separate male and female flower structures, or bisexual with both male and female parts on the same flower. While both groups use pollen in reproduction, angiosperms have developed an incredible diversity of strategies for pollen dispersal and, in combination with their insect friends from the animal kingdom, have went on to expand into the most diverse group of plants on earth.

Photo Caption: Gymnosperms, like this Colorado blue spruce, are a group of nonflowering plants that emerged several hundred million years before flowering plants (angiosperms) entered the evolutionary history of the plant kingdom.

Key Topic #2: Forest Ecology and Plant Communities

5. Identify different forest eco-zones in Alberta and their key characteristics and indicator plants.
6. Describe the importance of downed logs and coarse woody debris to the ecosystem.
7. Identify and explain both abiotic and biotic components that contribute to a healthy forested ecosystem.
8. Describe successional change in an Alberta forested stand over time, including changes in species composition, shade tolerance, and vertical positions within the canopy.
9. Explain the role of forests and other plant communities in watershed health.

Study Resources

Resource Title	Source	Located on Page
Canada's EcoZones: Taiga Plains, Taiga Shield, Boreal Plains, Prairies, Montane Cordillera,	*Bernhardt, T., Canadian Biodiversity Website*	32
Deadwood Habitat in Canadian Boreal Forests, excerpts	*Kopra, K. & Fyles, J., Sustainable Forest Management Netward, SFMN Research Notes Series 13, 2005*	43
Coarse Woody Debris - why is it essential in our forests?	*Sullivan, Adrianna, Cape Breton Privateland Partnership, 2017*	46
Focus on Forest Health	*Government of Alberta, 2013*	47
Healthy Forests for Clean Water	*North Carolina Forest Services, 2020-2025*	51

Canada's Ecozones

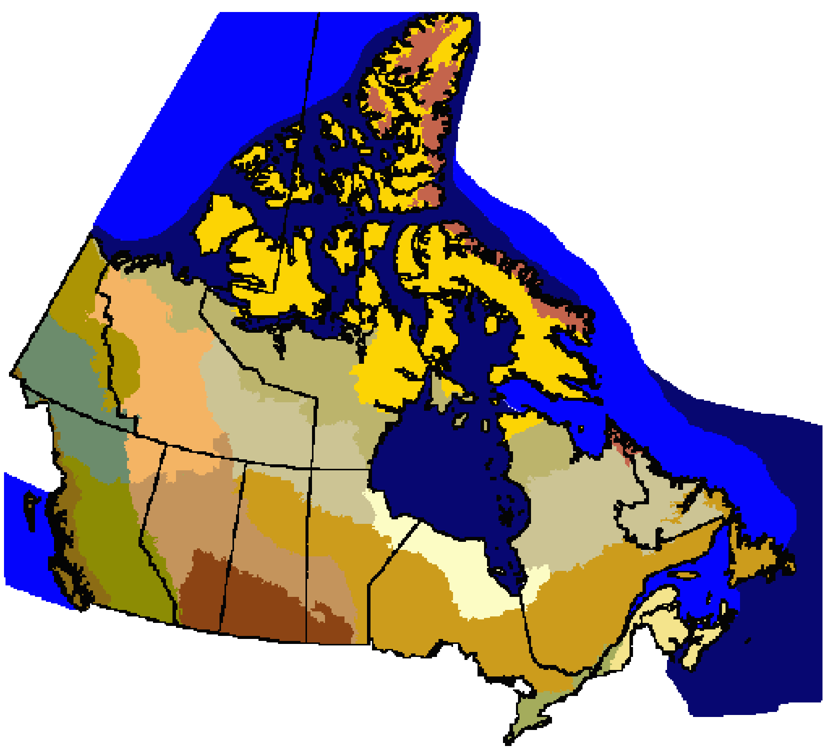
The Canadian Biodiversity Website

Introduction

Ecozones is a name given to one of the many ways to classify ecological systems. Other systems exist and the number of categories in some of them can be staggering. When trying to classify an area as large as Canada, the best approach is to have nested levels of classifications, so that a manageable number of categories exist when looking at the country as a whole while smaller areas still get their own category at another level.

The National Ecological Framework for Canada (Ecological Stratification Working Group 1996) uses ecozones for their classification. At the largest scale, there are fifteen terrestrial and five marine ecozones. These ecozones are so large that the maritime provinces can all fit into one of them (Atlantic Maritime). Smaller than the ecozones are the ecoregions, and the ecodistricts are smaller yet. Each smaller-scale classification fits nicely into the larger classification. There are over 200 ecoregions in Canada and even more ecodistricts.

Ecozones are large and very generalized, having roughly the same land features, climate and organisms throughout them. Still, there are inevitably still many differences across that large an area of land. Detailing those differences is done at the ecoregion and ecodistrict levels.



Canada's 15 terrestrial and aquatic ecozones

Taiga Plains

Location

The Taiga Plains are centered around the Mackenzie River in the western Northwest Territories, bordered by the mountains to the west, the arctic to the east, and the boreal forests of the boreal plains to the south.

Climate

Like the Taiga Shield to its east, the Taiga Plains has short, cool summers and long, cold winters. Mean summer temperatures range from 7ºC in the north to 14ºC in the south. Winter brings averages of -26ºC in the Mackenzie delta and a relatively mild -15ºC in the portion contained in Alberta and British Columbia. Snow and freshwater ice lasts for six to eight months, and permafrost is widespread. There is generally little rainfall here, only 200-500mm a year.

Geology and Geography

This ecozone is primarily horizontally layered sedimentary rock; limestone, shale, and sandstone. The largest river in the country, the Mackenzie, flows through this ecozone and dominates its west, while the east is in turn dominated by the Great Slave and Great Bear lakes. Most of the terrain is flat or slightly rolling, but where the river or its tributaries have cut through the ground, canyons hundreds of metres deep can be found. The permafrost leads to large areas being waterlogged and remnants of glacier activity make the landscape more varied.

Beaver pond, Keg River, Alberta
Photo: Dominic Collins

Flora and Fauna

Plants:

Fires are fairly common, and many species are especially adapted to it, resulting in a patchwork of forest types where each patch is at a different stage of recovery from fire. Trees in the Taiga Plains include paper birch, willows, trembling aspen, tamarack, green alder, white spruce, balsam poplar, lodgepole pine, jack pine, dwarf birch, black spruce, and balsam fir. Some of the smaller plants that grow here are fire snag, wild rose, Labrador tea, bearberry, sedges, ericaceous shrubs, cottongrass, moss, sphagnum moss, feathermoss, bog cranberry, and blueberry.

Mammals:

The black bear, lynx, and wolf are the only large carnivores to be found here; smaller carnivores include red fox, ermine, and marten. Large herbivores include woodland caribou, wood bison, moose, and barren-ground caribou, while snowshoe hare, red squirrel, arctic ground squirrel are some of the smaller herbivores.

Birds:

Some of the most common birds of prey here, the bald eagle, peregrine falcon, and osprey, are fish-eaters, though the hawk owl is not. Waterfowl, most of whom migrate to the Taiga Plains in spring and summer, include the red-throated loon, ring-necked duck, greater scaup, canvasback, and all manner of other ducks, geese and swans. Some ground-dwelling birds are the sharp-tailed grouse and willow ptarmigan, while some common birds of the forest include the raven, gray jay, boreal chickadee, common raven, and common redpoll.

Reptiles and Amphibians:

This region is too far north for reptiles, but the western toad, striped chorus frog, and wood frog can be found here.

Fish:

Fish that can be found in the lakes and rivers of the region include arctic lamprey, lake trout, lake and mountain whitefish, arctic cisco, longnose sucker, arctic grayling, dolly varden, burbot, walleye, and northern pike.

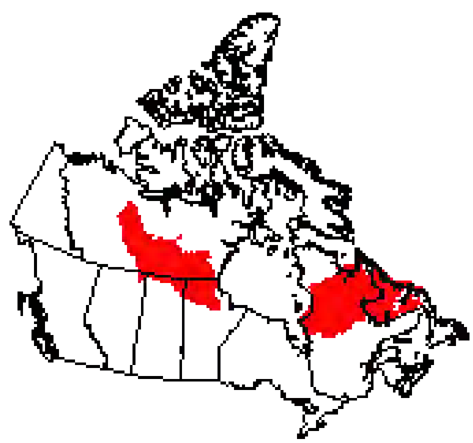
Invertebrates:

The large numbers of insects in this ecozone provide food for the insectivorous birds that come here to feed and breed. Molluscs like the muskeg stagnicola, arctic-alpine fingernail clam, and globular pea clam live in the waters of this ecozone.

Taiga Shield

Location

This ecozone stretches eastward from the Taiga Plains, just south of the Southern Arctic. It is interrupted by Hudson Bay and the Hudson Plains, but then continues to the Atlantic.



Climate

This ecozone has short summers with long days and cold, long winters with long nights. Average annual temperatures are just below freezing, and mean summer temperatures are at most 11ºC. Precipitation ranges from 200mm a year in the west to 1000mm on the Labrador coast.

Geology and Geography

As part of the Canadian Shield, the bedrock here is extremely old, and the region north of Great Slave Lake contains the oldest rock on the planet, over four billion years old. The terrain here is either flat or rolling hills. Advancing and retreating glaciers have scraped the ground bare at several points in the past, and the millions of depressions that have been left are now lakes. Much of the flat lands are temporarily or permanently waterlogged.

Flora and Fauna

Plants:

A patchwork of wetlands, forests, meadows, and shrublands covers this area. The northern edge of the ecozone is delineated by the tree line, and it is north of this that the more typical arctic tundra begins.

Trees in the Taiga Shield include black spruce, jack pine, green alder, paper birch, willow, tamarack, white spruce, balsam fir, trembling aspen, balsam poplar, white birch, and dwarf birch.

Other plants in the area include ericaceous shrubs, cottongrass, lichen, moss, sedge, sphagnum moss, Labrador tea, feathermoss, northern Labrador tea, yellow pond lily, cattail, water parsnip, water smartweed, water horsetail, water arum, marsh five-finger, ground juniper, kinnikinick, lichens, goldenrod, grass of Parnassus, shrubby cinqfoil, sweet gale, northern commandra, wild rose, wood horsetail, wild chives, twinflower, feathermoss, soapberry, cupidberry, crowberry, bearberry, high-bush cranberry, fireweed, fire snag, rock harlequin, fragrant shield fern, creeping juniper, prickly saxifrage, mountain cranberry, and gooseberry.

Mammals:

About fifty species of mammals are found in the Taiga Shield, including the large herbivores barren-ground caribou, woodland caribou, and moose. Wolves, black and grizzly bears and the lynx are the larger predators. Smaller predators include the coyote, red and arctic fox, muskrat, wolverine, weasel, mink, marten, otter, and least weasel. The smaller herbivores include the snowshoe hare, beaver, brown lemming, red-backed vole, northern red-backed vole, and red squirrel.

Wolf. Photo: S.D. MacDonald, Canadian

Birds:

Spring migration brings a multitude of bird species through this region, including various ducks, geese, loons and swans. Some stay, but others continue north to the arctic to breed. Representative birds of prey are the osprey and bald eagle. Shorebirds and seabirds found here include northern phalarope, Bonaparte’s gull, arctic tern, greater scaup, mew gull, Characteristic waterfowl are the arctic, pacific, and red-throated loons, red-breasted merganser, and the green-winged teal. Forest birds in the ecozone include northern shrike, tree sparrow, gray-cheeked thrush, raven, red-breasted merganser, red-winged blackbird, yellow warbler, common redpoll, white-crowned sparrow, flicker, and yellow-rumped warbler. Two representative ground-dwelling birds are the spruce grouse and willow ptarmigan.

Reptiles and Amphibians:

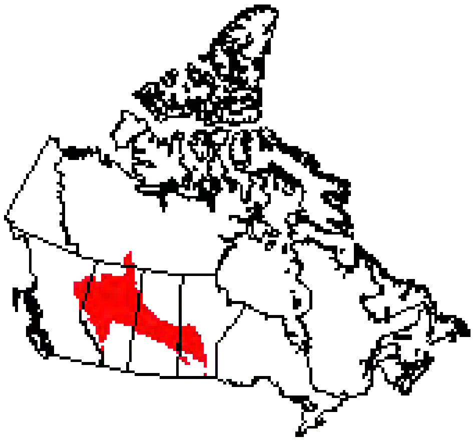
Three species of amphibians, the mink frog, wood frog, and blue-spotted salamander live here, but there are no reptiles.

Wood frog
Photo: David Green

Invertebrates:

The American copper butterfly is found here, as are the molluscs muskeg stagnicola, arctic-alpine fingernail clam, and globular pea clam.

Boreal Plains



Location

The Boreal Plains are found in the centre of Alberta, extending east through the centre of Saskatchewan and slightly south of centre Manitoba.

Climate

A more northerly extension of the Prairie ecozone to its south, the Boreal Plains ecozone endures mean annual temperatures of around freezing. Summers are short and warm, winters cold. The Rocky Mountains block much of the moisture, resulting in precipitation of 300mm in the west to 625mm in the east.

Glaciers from many ice ages have flattened the landscape, and the large ancient lakes that resulted from their meltwater have left many dunes and are still present in many cases as smaller lakes.

Geology and Geography

Flat or slightly rolling terrain is the rule here, and thick soil deposits overlay Cretaceous shale bedrock.

Flora and Fauna

Plants:

Much of the Boreal Plains are covered with forests despite heavy logging. Fires are common, and many species are very well adapted to them. Dominant tree species include white spruce, black spruce, balsam fir, jack pine, tamarack, white birch, water birch, Alaska paper birch, mountain alder, trembling aspen, Pacific willow, Bebb willow, pussy willow, Manitoba maple, and balsam poplar. The deciduous species are most commonly found in the south, the coniferous species to the north. The Saskatoon berry bush is one of the other plant species found here.

Wood Buffalo National Park
Photo: National Library of Canada

Animals:

Extensive logging has reduced the population and ranges of many species. Wetlands and rivers have also suffered from pollution, increased water use and other human activities.

Mammals:

Large carnivores in the ecozone include the black bear, wolf, and lynx. The most common large herbivores are elk, mule deer, white-tailed deer, moose, caribou, and bison. Smaller carnivores include the coyote, least weasel, river otter, badger, striped skunk, muskrat, marten, and fisher. There are many rodents, such as the northern pocket gopher, beaver, woodchuck, Richardson's ground squirrel, thirteen-lined ground squirrel, Franklin's ground squirrel, least chipmunk, porcupine, eastern cottontail, and snowshoe hare.

Dry Island Buffalo Jump Provincial Park, Alberta
Photo: National Library of Canada

Birds:

Characteristic birds of prey include the great horned owl, boreal owl, northern saw-whet owl, short-eared owl, Cooper's hawk, red-tailed hawk, broad-winged hawk, and turkey vulture. Some of the songbirds found here are the blue jay, evening grosbeak, rose-breasted grosbeak, ruby-throated hummingbird, cedar waxwing, whip-poor-will, purple finch, brown creeper, sedge wren, and the common crow. Some other birds of the forest are ruffed grouse, spruce grouse, northern flicker, downy woodpecker, and pileated woodpecker. Waterfowl include Franklin’s gull, American white pelican, common loon, sandhill crane, western grebe, wood duck, ring-necked duck, northern pintail, blue-winged teal, mallard, gadwall, redhead, canvasback, Canada goose, and whooping cranes, which nest in wetlands in the extreme north of the ecozone.

Amphibians and reptiles:

Two of the amphibian species here are the wood frog and american toad. The common garter snake can also be found.

Fish:

Predatory fish here include lake sturgeon, brown trout, lake trout, northern pike, and walleye. They prey on such species as cisco (lake herring), lake whitefish, goldeye, lake chub, emerald shiner, and yellow perch.

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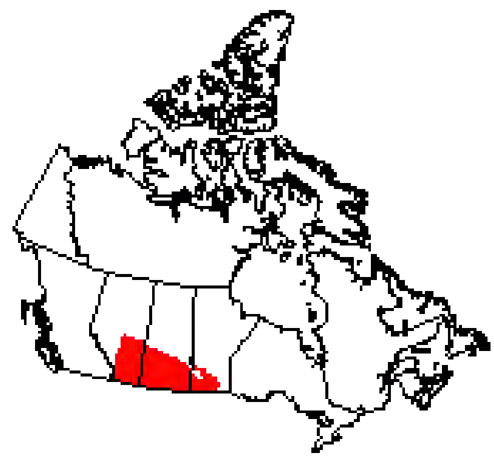
Prairies

Location



The Prairies cover the south of Alberta, Manitoba and Saskatchewan.

Climate

The Prairies are the northernmost branch of the Great Plains of North America and the most altered of the ecozones. The mountains to the west block much of the precipitation that would otherwise fall. That and the high winds make this ecozone very dry, although precipitation does generally increase towards the east. Temperatures are extreme due to the lack of access to the ocean's buffering. Winter temperatures average -10ºC and summers average 15ºC.

Geology and Geography

Glaciation has left its mark on the Prairies, flattening the landscape and leaving deposits from inland seas left behind by melting glaciers. These deposits are now the fertile plains that largely define the Breadbasket of Canada. Huge numbers of small temporary wetlands form in years with high precipitation. Gas and oil is plentiful in the region.

South Saskatchewan River

Flora and Fauna

Plants:

Almost 95% of the Prairies have been converted into farmland, with predictable effects on the original plant populations. Trees and shrubs are most commonly found in the eastern region.

Trees found in the Prairies include white spruce, black spruce, balsam fir, tamarack, water birch, Bebb willow, peachleaf willow, wolf willow, lodgepole pine, box elder, choke cherry, black cottonwood, eastern cottonwood, bur oak, trembling aspen, and balsam poplar. Just a few of the other plants that grow here are spear grass, wheat, blue grama grass, sagebrush, yellow cactus, prickly pear, buckbrush, chokecherry, Saskatoon berry bush, alkali grass, wild barley, red sampire, sea blite, Parry oat grass, June grass, yellow bean, sticky geranium, bedstraw, chickweed, needle grass, thread grass, snowberry, American silverberry, rose, silverberry, dryland sedge, black hawthorn, greasewood, plains larkspur , death camas, wild lupine, smooth aster, prairie sedge, and cattail.

Animals:

The widespread alteration of the natural habitat has resulted in diminished populations and ranges of many animals, and the Prairies contain a disproportionate number of threatened and endangered species.

Mammals:

The only large carnivore in the Prairies is the black bear. Large herbivores include whitetail deer (a recent invader), mule deer, pronghorn antelope, elk, and moose. Small carnivores include coyote, badger, red fox, longtail weasel, mink, river otter, black-footed ferret, and striped skunk. Rodents are numerous, such as the black-tailed prairie dog, white-tailed jack rabbit, snowshoe hare, Richardson's ground squirrel, Franklin's ground squirrel, thirteen-lined ground squirrel, least chipmunk, northern pocket gopher, olive-backed pocket mouse, Ord's kangaroo rat, white-footed mouse and beaver.

Birds:

Some of the birds of prey are the ferruginous hawk, red-tailed hawk, Swainson's hawk, burrowing owl, northern saw-whet owl, short-eared owl, long-eared owl, and turkey vulture. Songbirds include black-billed magpie, northern oriole, Audubon's warbler, grasshopper sparrow, lark sparrow, ruby-throated hummingbird, cedar waxwing, lark bunting, chestnut-collared longspur, and black-billed cuckoo. Birds of the forest that are found here include ruffed grouse, sharp-tailed grouse, sage grouse, northern flicker, downy woodpecker, red-headed woodpecker, and western meadowlark. Some of the waterfowl found here are the American avocet, great blue heron, snow goose, Canada goose, northern pintail, blue-winged teal, mallard, gadwall, redhead, western grebe, lesser scaup, ring-necked duck, canvasback, Eskimo curlew, piping plover, and whooping crane.

Northern saw-whet owl. Photo: John and Karen Hollingsworth, USFWS

Reptiles and Amphibians:

Among the amphibians that can be found here are the northern leopard frog, striped chorus frog, plains spadefoot, American toad, great plains toad, and tiger salamander. The area has several species of snakes and lizards, including the plains garter snake, gopher snake, western rattlesnake, western terrestrial garter snake, short-horned lizard, and prairie skink.

Fish:

Predatory fish in the Prairie waterways include northern pike, carp, and sauger. They prey on such fish as the lake whitefish, goldeye, lake chub, brassy minnow, emerald shiner and yellow perch.

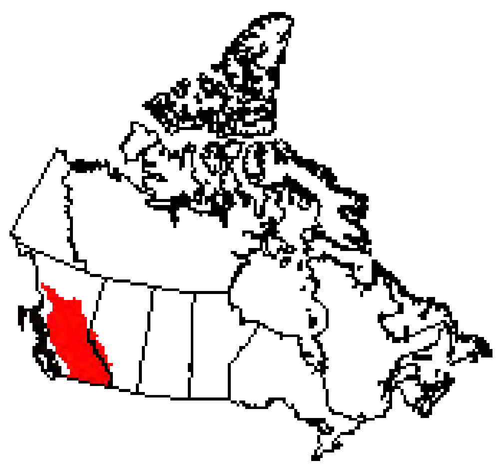
Insects:

Just a few of the insects are the German cockroach, boreal spittlebug, silver-spotted skipper, spring azure, American copper, monarch butterfly, mourning cloak, eastern black swallowtail, migratory grasshopper, and pallid-winged grasshopper.

Molluscs:

Three of the mollusc species in the Prairies are the valve snail, umbilicate promenetus, and globular pea clam.

Montane Cordillera



Location

This ecozone covers most of southern British Columbia and some of southwestern Alberta.

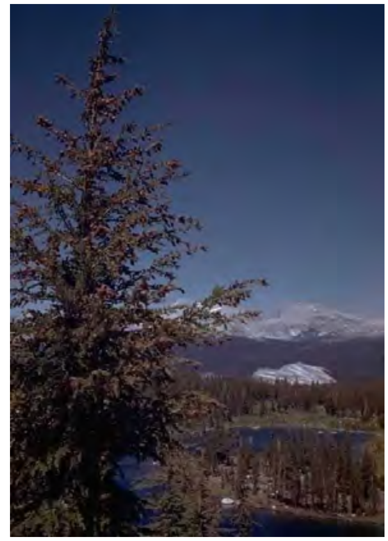
Climate

This is the most diverse of the country's ecozones in all respects. The effects of two mountain ranges means that climate varies in all three dimensions. The average annual temperature in the north of the ecozone is 0.5ºC, in the south 7.5ºC. The dry summers and wetter winters alike are mild, though increased elevation brings lower temperatures.

The Coast Mountains force air masses to rise, where they cool off and lose their moisture as rain or snow, a phenomenon known as orographic precipitation. The western side of the Coast Mountains receives 1200 to 1500 mm of precipitation in this way, while the eastern side receives only 300 mm in the south and 500 to 800 mm in the north and interior due to the dry air that makes it over the mountains. The Rocky Mountains at the eastern edge of the ecozone again catch precipitation, bringing 1200 mm of precipitation annually to the western side of the mountains.

Geology and Geography

The mountains that make up much of the ecozone are formed of faulted sedimentary rock. The plains and valleys here often consist of glacial moraine or deposits from ancient lakes.



Western hemlock. Photo: Charles Webber, Berkeley Digital Library Photo Collection

Flora and Fauna

Plants:

Plants in the ecozone are as varied as the landforms they grow on. Vegetation that may be common in one area is often completely absent from another. Trees in the area include Engelmann spruce, alpine fir, interior Douglas fir, lodgepole pine, western white pine, Rocky Mountain ponderosa pine, trembling aspen, western hemlock, Rocky Mountain red cedar, balsam poplar, paper birch, black spruce, white spruce, and western larch. Some of the other species found here are sagebrush, rabbitbrush, antelope-bush, mountain avens, bunchgrass, pine grass, and bluebunch wheatgrass.

Mammals:

The large herbivores include caribou, mule deer, white-tailed deer, moose, mountain goat, California bighorn sheep, and American elk. The large carnivores are the black bear, grizzly bear, wolf, lynx, bobcat, and cougar. Some of the small herbivores here are hoary marmot, yellowbelly marmot, Columbian ground squirrel, beaver, golden-mantled squirrel, yellow pine chipmunk, redtail chipmunk, beaver, northern bog lemming, and pika. Small carnivores that are found here include coyote, red fox, marten, wolverine, muskrat, badger, marten, mink, pallid bat, and striped skunk.

Birds:

Birds of prey such as northern saw-whet owl, short-eared owl, long-eared owl, burrowing owl, cooper's hawk, red-tailed hawk, sharp-shinned hawk, northern goshawk, and turkey vulture are found here. The shorebirds and seabirds of the area include long-billed curlew, spotted sandpiper, american bittern, common snipe, killdeer, and black tern. Songbirds of the Montane Cordillera include Stellar’s jay, black-billed magpie, sage thrasher, white-throated swift, red-winged blackbird, cedar waxwing, cassin's finch, house finch, purple finch, brown creeper, and American dipper. Waterfowl that are found here include sandhill crane, northern pintail, blue-winged teal, mallard, gadwall, redhead, ring-necked duck, canvasback, and Canada goose. The birds of the forest include blue grouse, sharp-tailed grouse, spruce grouse, chukar, California quail, Lewis' woodpecker, and downy woodpecker.

Mount Edith Cavell, Jasper National Park, Alberta
Photo: Peter Mirejovsky

Amphibians and Reptiles:

Some of the characteristic frogs and toads of the area are the wood frog, spotted frog, and western toad. One of the salamander species present here is the long-toed salamander. Snakes found in the region include rubber boa, common garter snake, racer, western rattlesnake, night snake, and western terrestrial garter snake. One of the lizards found here is the western skink.

Fish:

Fish species that live in the ecozone include lake whitefish, chiselmouth, lake chub, peamouth, leopard dace, and redside shiner. White sturgeon and sockeye salmon both come to freshwater to spawn.

Molluscs:

Molluscs found here include pig-toe, western-river pearl mussel, western floater, and arctic-alpine fingernail clam.

Insects:

A few of the insects that live here are red turpentine beetle, boreal spittlebug, spring azure, mourning cloak, and migratory grasshopper.

Deadwood Habitat in Canadian Boreal Forests
Excerpts

by Kristin Kopra & James Fyles
SFMN Research Note Series No. 13

Deadwood can be found in the form of both standing and downed dead trees. Standing dead trees (snags) provide necessary foraging and nesting cavity sites for many species of birds and small mammals. Without these snags, following disturbance many animal species would be without homes and/ or sources of food, which could eventually result in these species becoming locally extinct. Downed deadwood also provides necessary habitat for many insects, fungi and mosses, not to mention tree seedlings! Forest management has come a long way in terms of its treatment of deadwood. There is recognition that the removal of all deadwood following harvesting can be extremely harmful to the forest ecosystem. Still, questions persist regarding the functional and structural importance of deadwood.

Snags as habitat

***Bird*s**

Snags, or standing dead trees, provide important foraging and nesting habitat for many species of birds. Several species of birds, including woodpeckers, act as primary cavity excavators, meaning that they excavate holes, or cavities, in snags both when looking for food and to build homes. Without snags, these birds would not persist in forests. Some birds, as well as most cavity dependent mammals, are secondary cavity users, meaning that they depend on primary excavators and/ or natural decay of trees to form cavities that they can use for nesting.

Cavity-dependant bird species comprise anywhere from 20-40% of the birds in a given forest. Supporting this, researchers at the Greater Fundy Model Forest in New Brunswick have found that snags commonly comprise 5-10% of the total number of trees in mixedwood mature forests there, and that most of these snags show signs of usage by insectivorous birds. Snags, then, serve as important habitats for insects and the insectivorous birds that feed on them. Research conducted in black and white spruce and aspen mixedwood forests in Alaska showed that three different species of woodpeckers were reliant on snags following fire. These three species were able to co-exist because each had a unique foraging niche which was determined, in part, by the degree of charring incurred by snags as a result of the fire. The degree of charring determined what types of (and how many) insects were found in snags, which, in turn, determined which species of woodpecker foraged there. A large study in fire disturbed aspen mixedwood forests in Alberta illustrated that old aspen stands had the greatest species richness and that 63% of bird species sampled had their highest abundance in old stands. These findings were related to the structural heterogeneity of old stands, including the presence of standing dead trees that served as nesting and foraging sites for birds. Young stands contained the second highest species richness and abundance. Again, these numbers were attributed to forest structural attributes—one of the most important being the presence of standing and downed deadwood. Studies such as these illuminate the importance of snags to bird species (whether it be as nesting cavities or foraging grounds) in Canadian boreal forests.

Other Animals

There are many other living creatures that benefit from snags for a variety of reasons. Raptors use snags as perches, bats often roost under bark flakes, and small mammals may use excavated cavities for denning, foraging, and protection from thermal drought. Snags also provide some cover and, thus protection, from predators for small mammals such as martens. In addition, as discussed above, snags serve as home to many species of insects, including many species of beetles. In fact, the beetle species that live on dead and dying wood worldwide outnumbers all mammal, bird, reptile, and amphibian species found in the entire world! The importance of snags in the forest, then, is clear—as is the subsequent need to manage this important component of boreal forest ecosystems.

Downed deadwood as habitat

Small mammals

Small mammals depend on downed deadwood for denning and foraging sites as well as for protection from predators. Small mammals that have been studied in relation to deadwood habitat in Canadian boreal forests include marten, deer mice, and meadow and red back voles. In Alberta mixedwood boreal forests, it was concluded that the removal of trees and woody debris changed relative composition among three species (red back vole, meadow vole, and deer mice), with dominance moving from red-backed voles to deer mice as residual standing and downed deadwood decreased. Additionally, there was a much higher abundance of red backed voles on sites where residual trees were left in 40 m diameter circular patches and woody debris was evenly distributed throughout the cut site. While meadow vole populations actually increased with less dead wood, there was one grid in the study area where no meadow voles were counted at all. The significance of this finding lies in the fact that this grid was the most spatially isolated of all the grids, indicating that the degree of fragmentation can negatively affect mammal populations.

Martens, once one of the most abundant small mammals in eastern North America, have been extirpated in several areas in eastern Canada and the U.S. and are threatened in much of their remaining range. This is due, in part, to loss of habitat via harvesting and fire, as well as trapping. Marten have most often been found to prefer older coniferous and mixed forests (although this has not always been found to be the case), in part because of their structural diversity (including abundance of chronic wasting disease) and subsequent greater abundance of prey.

Deadwood lying on the forest floor provides martens with natal dens, protection from predators, and subnivean (below snow) habitat for denning and hunting during winter months. In Ontario, marten densities were found to be 67-90% lower up to 40 years following clearcutting compared to densities in uncut forest. Because of extreme losses in Newfoundland and New Brunswick, as well as the continuation of harvesting of remaining marten habitat in eastern North America, there is continued concern over the fate of this species. In areas where populations are viable, the possibility exists that future management can provide continued suitable habitat for these animals if care is taken to preserve viable amounts of older forests and/or younger forests with attributes that more closely resemble older forests (i.e. deadwood). On a landscape level, connectivity of patches has also been eluded to as a necessity for maintaining viable marten populations.

Amphibians

To date there have been extremely few studies conducted in the boreal forests of Canada linking deadwood habitat to amphibian populations. The few studies that we found (i.e. Greater Fundy Model Forest in New Brunswick) substantiate findings in many temperate forests of North America (and elsewhere) that amphibians such as toads, frogs, and salamanders rely on downed woody debris on land to protect them from thermal drought (i.e. drying out of their skin), predators, and to provide them foraging sites. Furthermore, these species depend on fallen logs in streams and lakes for breeding and feeding habitats as well. In southwestern Oregon State, amphibian populations were found to be positively correlated with levels of coarse woody debris. Results from studies conducted in New Brunswick support the claim that amphibians require deadwood for survival.

Bryophytes, lichens, fungi, and seedlings

Deadwood not only provides critical habitat for animal species, but it also is a preferred growing medium for various species of bryophytes, lichens, and fungi. In east-central Alberta, old aspen stands were found to have higher species richness of these life forms than younger stands, which, in turn, had higher species richness than mid-aged (economically mature) stands. These levels corresponded to the levels of downed woody material which is most abundant and diverse in old forests and lowest in economically mature forests, with young forests lying somewhere in between. In managed boreal spruce forests of northern Sweden, species richness was found to be higher for several species of mosses, fungi, and lichen in forests where downed woody debris was more abundant. This study also urges the consideration of the size of deadwood, as higher species richness was observed when fine woody debris was mixed with coarse woody debris than when just coarse woody debris existed.

Rotting wood found on the forest floor can also provide good seedbeds for several boreal species including both black and white spruce. The consistent supply of moisture and nutrients offered by downed wood encourages good seedling growth, which, in turn, promotes the natural succession of these species in the forest.

Coarse Woody Debris - why is it essential in our forests?

Coarse woody debris (CWD) is the decomposition of logs on the forest floor that provides nutrients to plants, habitat for wildlife, and food for insects and microorganisms.

Decaying wood is an essential part of a healthy ecosystem in the forest. They provide nursery-like conditions for trees to regenerate, and dead wood plays a critical role in providing shelter for wildlife species that are important in maintaining a bio-diverse forest.

IMPORTANCE IN WILDLIFE

CWD provides habitat to animals such as the snowshoe hare, the ruffled grouse, woodpeckers, variations of shrew and other small mammals, as well as bigger mammals like bobcats and black bears. Having CWD in your forest supports healthy populations of these animals, which not only helps with the biodiversity of your forest but makes it so you can enjoy the wildlife as well.

IMPORTANCE IN FOREST HEALTH

CWD can provide a significant amount of organic matter to the soil, which is crucial for tree growth. The decaying matter has the capability to provide nitrogen, potassium, and phosphate into the soil to be reused by other plants. The health of the soil is directly responsible for the health of the trees. It also helps hold moisture in the forest floor during dry spells.

IMPORTANCE IN CARBON STORAGE

CWD and organic matter store carbon in the forest, prolonging the release of carbon dioxide into the atmosphere. Some tree species that are resistant to rot could take hundreds to thousands of years to decompose, releasing carbon much slower than if that wood would be burned or used in a short term manner.

HOW CAN I CREATE COARSE WOODY DEBRIS IN MY FOREST?

Coarse woody debris happens naturally in forests already. Damages that occur to the forest such as wind storms, ice storms, fire, insects/disease, and competition between trees can be responsible for tree death and decay. When you're harvesting wood from your property, leaving the stumps, tops, and branches of trees can all help create CWD. Cutting down trees that are in decline can also help create CWD, but leaving these trees standing can also be beneficial to wildlife, and it will fall down eventually anyway!

Focus on Forest Health

spruce budworm

Did you know?

All coniferous trees produce two types of cones: a seed cone and a pollen cone.

Forests are complex ecosystems and a prominent part of Alberta's landscape. To understand forest health, one must first become familiar with forests and understand the complex systems that drive their **ecological processes**.

A forest is a large area of land primarily covered with trees. Although some tree **species** look similar, natural forests are rarely made of only one tree type. Some forests can be comprised of mainly broadleaf trees like poplar and birch whose wide, flat surfaced leaves turn colour and are shed in the fall. Other forests consist of conifers like spruce, pine and fir that have needles and produce cones. Quite often however, Alberta's forests contain a combination of both coniferous and broadleaf trees and are called mixed-wood forests.

But there are more to forests than just trees. Countless other living organisms such as smaller plants, animals, microorganisms and non-living components (e.g., soil, water, air) naturally and together form a forest ecosystem. As well, variations in geography, geology and climate combine to form distinct forest types. In Alberta, there are four natural forest regions: the boreal, subalpine, montane and aspen parkland. Specific trees, animals, soil and landscape characterize each region.

Ecological processes - the interactioins that occur between organisms (plants and animals) and the environment they live in.

Species - the smallest unit used to classify the lowest natural grouping of similar plants or animals, which form a successfully interbreeding population of organisms that are not able to successfully breed with any other organisms.

What is forest health?

Forest health is a term used to describe the condition of a forest and how well it is able to meet management objectives. From a forestry perspective, management objectives focus on the health of the trees. Forest health can also indicate the condition of the overall global environment. For example, acid rain and the greenhouse effect can be detected and monitored in a forest.

Alberta Government

Focus on Forest Health

How does a forest grow?

Succession is the term used to describe the process by which a forest originates, grows and changes over time. There are different stages in succession. In the first stages grasses, wildflowers, shrubs and small trees are the most common. In Alberta, early successional trees are often trembling aspen or lodgepole pine. As these trees grow they become the more dominant species of vegetation, resulting in more shade to the underlying forest floor. Then, other shade-tolerant plants and tree species, such as white spruce, will grow underneath, increasing the diversity of the forest. As time passes, certain trees will grow to become very old (over 100 years) while others may die of old age, disease or some disturbance. Sooner or later, a large-scale disturbance such as fire, insect or disease outbreak will remove most vegetation including the older trees, returning the nutrients back to the soil, and the process is able to start all over again.

Why are forests important?

In Alberta, we are fortunate to have abundant and healthy forest resources, which are important for many reasons. Economically, Alberta's forests provide a very significant contribution to the province's wealth. In fact, forestry is Alberta's third largest industry, supplying fibre materials to make paper and lumber products that are sold at home and abroad. Environmentally, forests cycle carbon, produce oxygen, protect watersheds and provide habitat for wildlife. Socially, they provide humans with scenic recreational areas for camping, fishing, hunting, hiking, bird watching and tourism.

dwarf mistletoe berries

How do we know if a forest is healthy?

A healthy forest is able to sustain itself ecologically while providing for society's economic, social, recreational and spiritual needs and values. To determine if a forest is healthy, measures must be taken with a particular set of perspectives in mind. A hiker might measure the health of a forest by the green scenery; a birdwatcher might measure the number of bird species present. Overall, the health of the forest may be measured against many variables: the health of trees, the amount and type of wildlife within the forest, and the amount of **biodiversity**.

Biodiversity - or biological diversity is the variety of life in a given area.

Who manages the forest health program in Alberta?

Overseeing the forest health program within Alberta's forests is one of the mandates of Alberta Environment and Sustainable Resource Development. Forest Health Officers, foresters and technicians work in partnership with the public, forest companies, universities and other provincial and federal government departments to manage certain pests that adversely affect forest health. All of this ensures that Alberta's forests and ultimately Canada's forests are able to meet the specific management objectives set for today and the future. Sustainable Resource Development works closely with other provincial and federal agencies and their counterparts in the United States to collectively provide forest health information on a national and international level.

Factors Affecting Forest Health

Many factors have negative effects on the health of a forest. Some are biotic or living, such as insects, disease-causing organisms or mammals. Others are abiotic or non-living, such as drought and severe weather events like hail and ice storms. Most factors are a natural part of the forest ecosystem. However, when some organisms threaten the overall health of the trees, or compete with us in the use of the forest, we identify them as **pests**. Typically, pests are organisms that occur in unwanted numbers and places.

Common factors affecting forest health:

1. Insects and Mites
2. Disease-causing Organisms
3. Disorders
4. Mammals and Birds
5. Exotic Pests and Invasive Plants

There are over 10 000 species of insects and mites found in Alberta and many of them use forests in one way or another. Forest insects and mites commonly use trees as a source of food and shelter during certain stages of their life cycles. Usually they are a natural part of the ecosystem, but when the population and activity of a certain species becomes extreme, they can damage the health of a forest by weakening and even killing many trees. Mountain pine beetle, spruce budworm, forest tent caterpillar and large aspen tortrix are examples of forest insect pests in Alberta.

In a healthy forest, forest insects and mites play important roles. They are sources of food to other insects, spiders, birds and small mammals. They also remove weakened trees to make room for healthy, young plants.

Disease-Causing Organisms can affect living trees by limiting growth, causing abnormal tree growth, weakening trees or even killing them. There are many different kinds of disease-causing organisms in Alberta's forests, such as parasitic plants and microorganisms, including fungi. Examples of forest tree diseases in Alberta include Armillaria root disease, spruce needle rust, western gall rust, and lodgepole pine dwarf mistletoe.


spruce beetle

Did you know?

Forest insects and disease accounted for 36% of timber volume loss in Alberta between 1988 and 1992.

Pests - Insects, other animals, disorder, invasive plants and pathogens that can threaten a forest by damaging the trees and environment that people think are valuable.

It is important to note, as with all native organisms in a forest, most diseases are natural and must not be viewed as purely negative. They can be beneficial by removing weakened trees, creating openings in the forests and helping the process of decomposition and nutrient cycling.

Disorders are non-contagious, non-living elements of the environment that can damage trees. They include adverse weather events such as hail and ice storms, drought, pollution, nutrient deficiencies and mechanical injuries.

Mammals and birds use trees for food, shelter and/or hunting grounds, and are a natural part of the forest ecosystem. Sometimes their actions hinder the growth of trees and increase the possibility of infection from insects and diseases. Elk, bear, porcupine, snowshoe hares, red squirrels, mice, and yellowbellied sapsuckers are typical examples of mammals and birds that damage trees.

Exotic pests and invasive plants are organisms that are introduced into an area that is beyond their natural range of occurrence and become pests in the new environment. They are also referred to as either alien, non-native, non-indigenous or introduced pests. In the past, introductions have been intentional or unintentional. Having evolved in a different ecosystem, these non-native species may have few natural enemies in their new environment, which can often lead to outbreak populations and can damage native tree species. Asian gypsy moth, Asian longhorned beetle, and European spruce bark beetle are some examples of exotic pests that could threaten Alberta's forests.

purple loosestrife

Non-native invasive plant species, often referred to as weeds, can affect the health of the native plant community of the forests they invade. Invasive plants are characteristically adaptable, aggressive and have a high reproductive capacity. Invasive plants are introduced to forested areas on vehicles, on equipment and in seed mix. Also, soil disturbances resulting from many types of activities provide weed seeds with a suitable location to germinate and flourish. These plants have the ability to alter wildlife habitats, displace native threatened or endangered plant species and reduce the grazing capacity of native range land. Purple loosestrife, scentless chamomile and tall buttercup are examples of exotic plants that have invaded Alberta.

HEALTHY FORESTS FOR CLEAN WATER

North Carolina Forest Service

Did You Know?

We all need clean water to stay healthy, yet less than one percent of the water on earth can be used by humans as drinking water. Whether you drink water from a well or a municipal supply, forests keep that water clean and abundant. They do this by capturing rainwater and recharging underground aquifers. They also act as a natural filter as water moves over land, cleaning it of pollutants so it arrives at our lakes, rivers and streams in a better condition. We call this an ecosystem service — something our environment provides that people need, but don't have to pay for.

Natural Water Filter

Forests act as a natural water filter. When it rains, any water that does not soak into the ground becomes runoff and travels downslope to the closest stream, river or lake. As runoff travels it picks up nutrients from excess fertilizer and animal waste carrying that nutrient pollution into our waters, which is mainly nitrogen and phosphorus. All plants, including trees, use nitrogen and phosphorous for growth. But excess nutrients that get washed into streams, rivers and lakes support the growth of plants like algae. When there are a lot of pollutants in the water and an overgrowth of algae, it causes health concerns not only for the people who fish, swim or drink that water, but also other plants, fish, and insects that live in the water. Tree roots are an important mechanism for absorbing nutrient pollution before it reaches our waters

Green Swamp. Photo Credit: Misty Buchanan

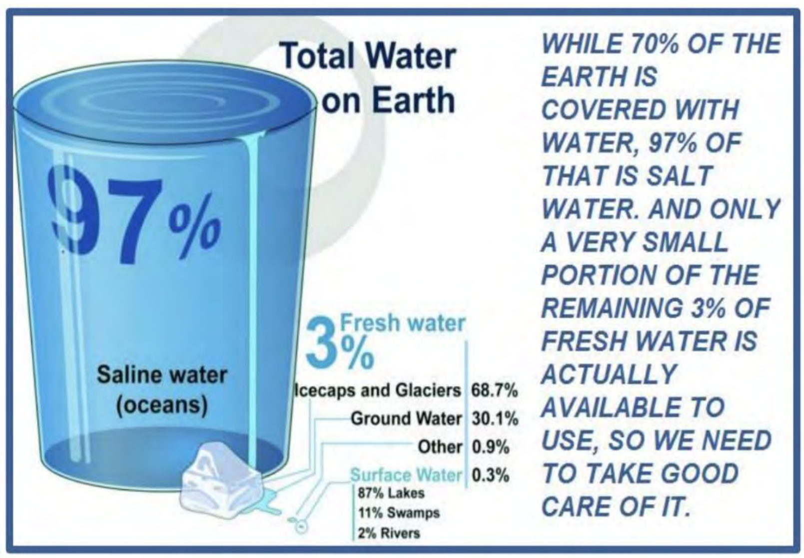
Rainfall runoff that flows over parking lots and roads also picks up oil, grease, trash or other pollutants. This rainfall runoff then flows into storm drains that flush the water directly to the stream, river or lake it drains to, without any treatment. But healthy forests, especially when properly managed and maintained, catch this runoff, slow its speed and allow pollutants to settle out. The trees in the forests also absorb some of the heavy metals, chemicals, and oil that come off pavement and other surfaces.

Keep Your Land in Place

Tree roots hold the soil in place, which reduces erosion and keeps the soil from washing into our waterways. Soil erosion, or sediment, is a main source of water pollution. Human activities like construction, plowing agricultural fields, or cutting trees can increase the amount of soil that enters our waters, when carelessly or unprofessionally done. Sediment in the water clogs the gills of fish and other wildlife. It also covers rocks in the bottom of streams and rivers which these animals depend upon, to hide amongst or to lay their eggs on. Sedimentation can reduce the life that the waters support. However, this type of pollution is easy to reduce simply by following best management practices for construction, farming and forestry. The easiest way to keep soil in place is by encouraging healthy trees to grow, especially along streams.

Abundant Water

Forests increase the amount of water that is available for human use, and reduce the amount of water that travels across the surface of the land. Not only do living tree roots hold soil in place, but as trees age new roots grow and old roots die, creating small spaces (pores) in the soil, which allows water to soak and infiltrate into the soil. While all plant roots, even grasses, have this effect, tree roots extend further through the soil. Trees' support roots are larger and they decay more slowly, so even dead or declining tree roots contribute to long term soil stability and soil porosity. As forests are cut to build subdivisions and shopping malls, and soil surfaces are replaced with asphalt and concrete, less water is able to soak into the ground to fill underground aquifers.



Less Flooding

The more parking lots, roads, buildings and grassed lawns within a community, the more water runs off the surface of the land to storm drains, retention ponds and streams, rivers and lakes. In fact, a one acre parking lot releases 36 times more water than one acre of forest (Changing Landscapes, USDA NA– TP–01–14 A3). The volume of water is not the only factor contributing to flooding, the speed that the water reaches its destination increases the potential for flooding even more.

Trees and their surrounding green spaces slow water flow so that the precipitation can infiltrate into the soil. But even water that does not soak into the ground is slowed on its way, so that peak flow is reduced and pressure on the banks of streams, rivers and lakes to hold all that water is eased. Large floods make the news and cause major economic damage. Small floods cause loss of property from erosion and can be an issue for those living near streams, rivers and lakes. As surface runoff is reduced and slowed, by plants and trees, flooding is also reduced.

Water Management

A watershed is the area of land that water travels across on its way to a stream, river or lake. What happens uphill, or upstream, in a watershed has an effect on everyone downstream. As population continues to increase, it becomes more important that communities create a watershed plan that identifies how clean the water is, how the land is used and where water pollution is coming from. This type of plan identifies places in the watershed where forests, parks and other open places are needed and where they can be restored, and protected. Most watershed plans include a combination of protection and restoration measures. Protecting natural resources is more cost-effective than restoration but, unfortunately, such efforts often occur after significant impacts have already occurred. Working lands and undeveloped greenspaces allow people to work the land, explore the forests, play in the parks and exercise outside while the water is cleaned and replenished.

Forest Management

Well managed forests provide many benefits for water, people and wildlife. An unmanaged stand of trees may have a high density, with too many trees crowded together. This means the trees grow more slowly as they must compete for a limited amount of soil nutrients, water and light. And that stress makes the trees more susceptible to diseases and pests, such as pine beetles. Crowded and stressed trees can also make it easier for wildfire to spread rapidly from tree to tree. Removing or thinning the stressed, damaged and diseased trees from a forest gives healthy trees more room to grow, and standing healthy trees protect the water. Prescribed fire, or managed burns, reduce the growth of invasive plants and other competing vegetation. These management practices allow increased light and precipitation to reach the forest floor. As more light reaches the ground native plant life, such as wildflowers, shrubs and grasses can grow to provide food and shelter for large and small wildlife. Not only are forests an important habitat for wildlife but, when forests, green spaces and riparian areas are connected, they create paths that animals can use to move from one area to another. Healthy forests can look quite different from one another, depending on their age, the tree species composition, and how the different tree species grow. To benefit all types of wildlife, different types of forests at different stages of growth, from young to mature, are necessary. Managed forests not only contribute to clean water but can provide a source of income for landowners. Management can include commercial thinning, partial cuts or clear cuts. Registered foresters, management plans, and forestry best management practices are important to ensure that the trees, as well as the soil and water, are not damaged or degraded during such activities.

Think About It

While technology can do many things, we should take advantage of the natural processes around us. Retaining trees and forested land does more than give wildlife a home, it provides the resources humans need to exist and to thrive. Forests do this more inexpensively than man-made infrastructure. Managing our forests responsibly, recognizing their value and including them in planning considerations is necessary for clean water, now and in the future.

NCF-Envirothon 2025 Alberta

Forestry Study Resources

Key Topic #3: Forest Management

10. Describe the harvesting systems and the best management practices associated with each utilized within forests in Alberta.
11. Identify silvicultural techniques used to prepare harvested land for tree planting in Alberta.
12. Explain why sustainable harvest and use of forest, grasslands, and other plant communities is essential to maintain a healthy ecosystem.
13. Define an urban forest and describe how common urban forestry practices influence the environmental, economic, and social well-being of urban communities.

Study Resources

Resource Title	**Source**	**Located on Page**
Timber Harvest Methods	*Grundberg & Vanderwel, 1994*	56
A Guide to Site Preparation	*Government of Canada, 2017*	58
Caring for Alberta's Forests	*Alberta Forest Products Association (n.d.)*	62
Urban Forests and Climate Change	*Climate Atlas of Canada. (n.d.) Forests and Climate Change. Prairie Climate Centre. https://climateatlas.ca/urban-forests-and-climate-change*	64

Timber Harvest Methods

Several methods can be used to harvest timber. Each method has advantages and disadvantages. Your objectives for the present and future use of your forested land will influence the harvest method that you choose. The harvest method will, in turn, affect other decisions such as cutblock size, layout and road location.

Clearcut Harvest

Clearcutting removes all merchantable trees from the cutblock at the same time. This method is the most economical way to harvest. It is appropriate for most species but is especially suited to even-aged stands of sun loving (shade intolerant) species such as lodgepole pine or aspen. For land use options that require removal of the forest, clearcutting is probably the only realistic option. One common misconception about clearcutting is that you must remove all the forest at once. Although you harvest all the merchantable trees in a certain area, the size of that area can be large or small depending on your objectives. A series of small clearcuts, promptly regenerated, can provide periodic, sustainable income while maintaining a healthy forest with diverse age classes.

Partial Cut Harvest

In partial cut harvest systems, the initial harvest does not remove all the merchantable trees from any unit of land. Partial cut methods are intended to encourage natural regeneration. The three partial cut systems are:

- Selection method - harvesting selected trees in an uneven-aged stand either individually or in small groups at periodic intervals throughout a harvesting rotation. Harvested trees may be the most valuable trees, the poorest quality trees, the oldest trees or trees of a certain species.
- Shelterwood method - harvesting mature trees in two or more cuttings to allow establishment and early growth of seedlings under partial shade and shelter of older trees.
- Seed tree method - leaving individual trees or groups of trees uncut to provide seed to regenerate the cutover area. The amount of tree cover initially removed increases from selection to shelterwood to seed tree method.

The selection method is best adapted to uneven-aged stands of shade tolerant species such as spruce or fir. It can also be used to convert even-aged stands to uneven-aged stands if the species being managed is capable of regenerating in a partially shaded stand. Selection cuts are often considered to be less visually offensive than clearcuts. As such, they are frequently favoured in areas where recreation or scenic values are important. Selection cuts may also be used to harvest timber from sensitive areas such as steep slopes or buffer strips where it is desirable to maintain permanent tree cover.

Unlike the selection method, the shelterwood and seed tree methods will not provide a continuous cover of mature trees. Once young trees are well established on the cutover, the remaining larger trees are removed, leaving only the even-aged regeneration. Windthrow is a serious concern in all partial cut systems. If residual trees blow down, uprooted stems can displace significant amounts of soil and can be unsightly. The impact on soils, watersheds and aesthetics may be worse than if the trees had been harvested. As well, salvage harvests usually cost more than clearcutting. Planning a partial harvest to minimize windthrow requires considerable expertise. The risk of windthrow is related to soil texture, soil moisture, wind speed and the species, age, rooting habit, size and crown development of the residual trees. In general, selection cutting that removes very little of the mature stand in the initial harvest is the least likely to result in windthrow problems. Consult a professional forester for advice on the shelterwood and seed tree methods.

No Harvest

You may decide not to harvest if the benefits of the forest are worth more to you than the cash value of the timber. However, not harvesting can have long-term impacts. If the forest is overmature or if it consists of an even-aged stand with just one or two tree species, it may be more susceptible to damage from insects, disease or fire. Management activities, including timber harvesting, may be desirable to maintain a healthy, diverse forest.

Natural Resources Canada | Ressources naturelles Canada

A Guide to Site Preparation

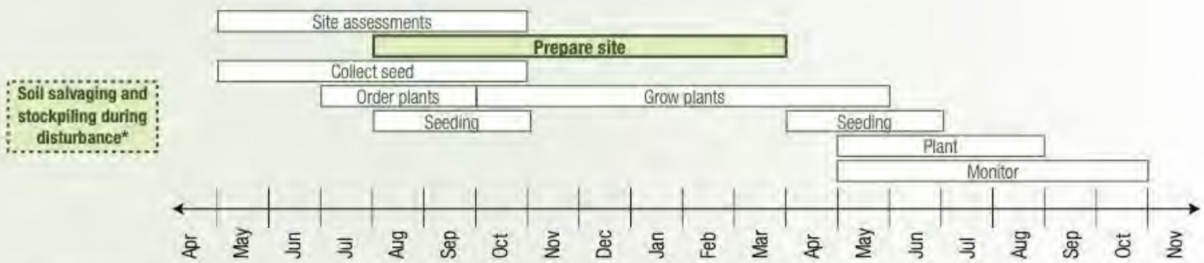
Deciding which technique is appropriate for your site

Reclaiming industrial sites in Alberta's boreal forest is not always a straightforward process. The footprints left by infrastructure and equipment are often characterized by compacted mineral soils, loss of micro-topography, too much or too little water and competition. In addition, some natural site characteristics such as thick layers of moss can present constraints to tree establishment. These conditions often slow and may even prevent tree growth.

Canada

Site preparation can improve growing conditions by addressing factors that limit plant growth. Site preparation is conducted after site reconstruction and before revegetation, and begins with an assessment of site limiting factors (Fig. 1).

Figure 1. Generalized timeline of activities related to site preparation.



*Note: Not all sites require salvaging (e.g., exploration sites). Where soil has been salvaged, it is assumed to have been replaced prior to site preparation activities.

When is site preparation appropriate?

Site preparation is appropriate when the site conditions are likely to limit or prevent the establishment of target vegetation. While there are several kinds of site limiting factors, many of them relate to compacted soils, competition and soil nutrients, and temperature (Fig. 2).

The need for site preparation also depends on the forest type, target vegetation and end land use. Some forest types such as aspen or pine stands on dry sites may regenerate naturally if managed carefully. On more challenging sites where the objective is a commercial forest, site preparation can increase the reliability and speed of tree regeneration. If the objective is wildlife habitat, site preparation can speed the return to forest cover and increase species diversity by providing a range of microsites and reducing competing vegetation.

Figure 2. Typical factors that can limit plant growth on reclaimed sites.

What is the best site preparation method?

The best technique is selected based on the forest type, site limiting factors and the soil moisture regime (Fig. 3). Each site preparation method has the potential to improve local growing conditions, but success depends on how well each method matches site conditions.

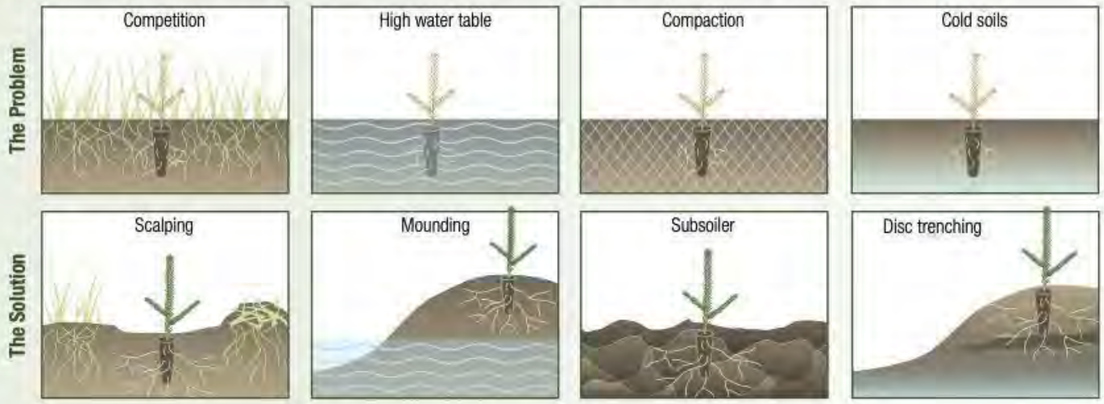
Figure 3. Site preparation techniques and the limiting factors they address.

Limiting Factor	Soil Moisture	Competition	Compacted Soils	Nutrient-Poor	Cold Soils
Wet sites	Mounding	Mounding Plowing*	Mounding Plowing	Mounding	Mounding Plowing
Dry sites	Scalping Scarification Disc trenching (wide trench)	Scalping Scarification Mixing* Disc trenching*	Mixing Winged subsoiler Straight ripper	Mixing Disc trenching (small trench)	Scalping Scarification Mixing Disc trenching

*Note: the indicated techniques may alleviate competition by exposing microsites, but these microsites may lead to increased competition if a vegetation management plan is not in place.

For example, most conifer trees planted directly on a very wet site will die from root saturation (Fig. 4). Mounding can create elevated planting sites and warmer microsites for trees to grow. On a dry site, scalping may be needed to physically separate seedlings from competing vegetation. Site preparation techniques can also be used to improve the success of seeding and/or natural regeneration efforts.

Figure 4. Examples of limiting factors and site preparation solutions.



What happens after a site has been prepared?

Operator training is critical for successful site preparation treatments, and immediate post-treatment quality control assessments are critical, especially at project start-up, to ensure that treatments are delivered as planned. For example, if mounds were not created high enough on a very wet site, planted seedlings may not establish in the long term. Timing is also critical. Site preparation creates desirable microsites, and competing vegetation may quickly occupy a site unless target species are planted or able to naturally seed into these microsites. To ensure success, managers should plant or seed sites shortly after treatment and have a vegetation management plan in place (see Factsheet *A Guide to Regeneration Planning*).

We would like to acknowledge COSIA (Canada's Oil Sands Innovation Alliance) for their contribution to this project.

Also available under the title : Guide sur la préparation de site – Choisir la technique appropriée pour son site

For more information, please contact: nrcan.silviculturetoolkit-outilssylviculture.rncan@canada.ca

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Caring for Alberta's Forests

Alberta Forest Products Association

Responsibly managing the province's forests ensures they continue to thrive for generations to come.

Forested lands make up more than 60 percent of Alberta, and these forests help people, plants and animals in innumerable ways. Forests capture carbon, maintain important watersheds and are home to thousands of wildlife species. They connect us to nature and history, and hold a significant importance for Indigenous peoples in Alberta.

Alberta's forest industry employs more than 30,000 Albertans, and provides lumber and plywood to build the homes and buildings we live and work in, as well as pulp and paper products for the books we love, medical supplies we need, and even the screens we watch.

"Alberta's forests affect the province's quality of life in so many ways that people may not even think about," says Aspen Dudzic, director of communications for the Alberta Forest Products Association. "Air quality, clean drinking water, biodiversity, flood and fire control all depend on the health of our forest ecosystems. In addition, forests provide economic, social and cultural benefits for many communities across the province. We have such a healthy abundance of forest today because of Alberta forest companies' decades-long commitments to sustainable forest management practices."

Effective forest management

Ensuring the sustainable harvesting and regeneration of Alberta forests is critical to the environmental, economic, social and cultural health of the province.

That's why, before harvesting a single tree, Alberta forestry companies create 200-year forest management plans that must be approved by the provincial government. These comprehensive plans dictate how ecological functions will be protected and how operations will result in a healthy forest in the future. Factors like vegetation, wildlife, water sources, soil quality and climate change are all factored in along with input from Indigenous communities.

Strategic plans that cover such a long duration ensure that Alberta's forests remain healthy for generations to come. "Under the very best conditions, most of our native tree species can live up to 120 years. That's the kind of timescale forest management planners have to consider to maintain the long-term health of our forests. Forests beyond that age are at risk of wildfire and pest infestation," affirms Dudzic.

Strategic regeneration

Following a harvest, companies are required by law to regenerate harvest areas — this can be done by planting with a similar mix of trees, or by creating optimal conditions for forests to regenerate themselves naturally. Alberta forest companies grow three trees for every one harvested — this translated into more than 100 million coniferous trees in 2021 alone. Over the past 20 years, Alberta forestry companies have regrown nearly two billion trees. And, they are required to monitor their replanted forest ecosystems for at least 14 years to ensure they remain healthy and viable.

Growing back bio-diverse, healthy forests that provide multiple benefits for Albertans requires tools like strategic harvesting, which mimics the benefits of fire without the risks. Unlike fires, harvesting is carefully planned and controlled — the size, shape and location of harvest areas are chosen for maximum benefit and minimum risk. Taking care to ensure companies cut less forest than what is grown each year results in less than one percent of Alberta's forest being harvested each year.

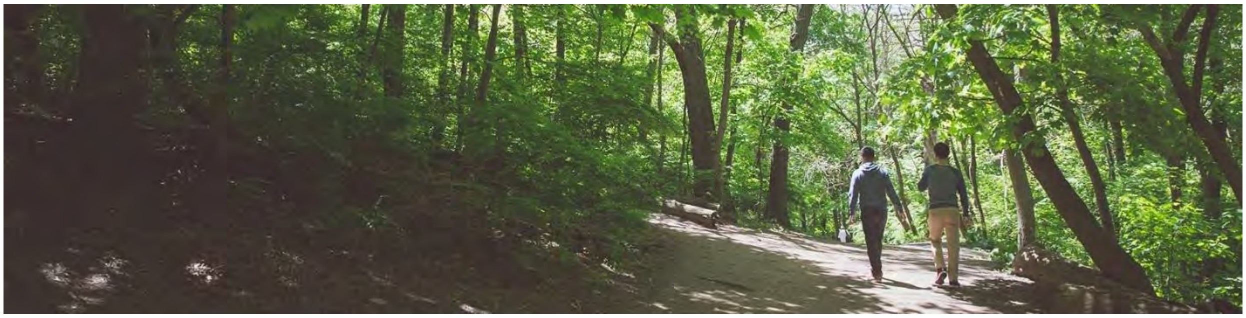
Strategic harvesting also means leaving buffer zones around important features like wetlands, rivers, sensitive wildlife habitat and sites of cultural importance. The harvested areas help the forest, too — creating spaces between stands of mature forest can slow the spread of fire and disease, making mature forests less vulnerable. The outcome is that Alberta has a natural distribution of young and mature forests, rather than a disproportionate area of mature and over-mature forests.

Plus, since trees take in carbon from the atmosphere, the carbon in the harvested trees stays locked in the products and materials produced by the forest sector. When trees burn due to wildfires or decay following insect infestation, carbon is released back into the atmosphere.

Through effective forest management, Alberta maximizes a number of benefits: fire and insect risks are mitigated, carbon stays sequestered in wood products, newly replanted areas absorb more carbon and a natural distribution of young and old forests.

Such thoughtful planning continues to evolve as the forest industry develops innovative ways to carry out sustainable forest management (SFM). That means Alberta forests will continue to thrive, now and in the future.

Urban Forests and Climate Change



In her work as Winnipeg's City Forester, Martha Barwinsky talks to a lot of people about trees. "People love trees," she laughs, saying that many people tell her "cool stories about trees: they remember this tree, and they climbed that tree, or their grandfather planted a tree and now they go and pick apples from it."

In recent years, cities have increasingly recognized the importance of a healthy urban tree canopy as an essential and valuable part of urban life. There are many compelling reasons why people – and cities – love trees.

Barwinsky notes that there are practical and tangible benefits to a healthy urban tree canopy, including "reduced cooling costs: reduced energy costs all around." She points out that trees help offset the urban heat island effect, keeping our cities cooler. They also help manage stormwater runoff, reducing demands on drainage infrastructure, and help prevent river bank erosion. [**1**][**2**]

Urban forests are an essential asset in dealing with our changing climate.

She also says that there are "a lot of intangible benefits as well, such as helping our psychological well-being, our social well-being, and the social structure of our communities." Recent research suggests that trees are beneficial to our physical and mental health as well as better community cohesion, and improved quality of life. [**2**][**3**]

All of this makes urban forests an essential asset when dealing with our changing climate. In the face of rising heat and the threat of more extreme weather hazards, urban forests and green spaces can improve health and well-being, provide a buffer against heat extremes and dangerous weather events, and promote community resilience, all while helping us save money on costs such as air conditioning and municipal infrastructure. [**3**]

Unfortunately climate change also poses real challenges to the health of our urban forests. Barwinsky strikes a cautionary note about the seriousness of the threat: "When it's lost, then people realize what value it had. Let's not get to that point, where we realize what we've lost."

Urban forests are already difficult to manage: a typical Canadian city is not a friendly place for many tree species, and the most effective urban forestry practices are costly and labour-intensive. Climate change makes these existing challenges worse, but also adds entirely new and troubling problems.

We need only look at the summer of 2018 in Winnipeg to see why. The city experienced 26 days that were 30 °C or warmer, which is the most since 1988 (when there were 34 such hot days). [**4**][**5**] Climate projections show that this unusual heat is likely to be the "new normal" in the near future. [**6**] This will have lasting consequences for trees. Barwinsky says that "there are a number of tree species that are going to suffer. They are going to have a hard time getting through those hot conditions, those dry conditions."

And yes, it was also a very dry summer. The total precipitation in Winnipeg over June, July, and August was only half the normal amount. [**4**] Barwinsky clearly sees the effects of drought stress in some local tree species . But she points out that not all impacts will be immediately apparent, since "trees don't necessarily show the effects of those changes immediately: it can take five years, it can take ten years."

Other threats can appear suddenly and unexpectedly – damaging insect infestations, for example. The recently introduced emerald ash borer killed off 99% of Toronto's 850,000+ Ash trees in less than a decade. [**7**][**8**] It has now been found in Winnipeg as well. [**9**] Barwinsky notes that "Where normally some of these invasive pests may not be able to survive our winters, and particularly our growing season, with climate change they might start surviving, and we're going to have a problem managing them." Warmer climates allow insects to reproduce and spread more quickly, but warm and dry conditions are also stressful for trees, leaving them with less capacity to defend against pests and infection in the first place. [**10**]

Urban foresters are rising to the challenge of climate change in part by adjusting their management plans to account for the changing climate. For example, Barwinsky notes that currently "when we plant trees, we water them for the first two years to get them established. After that, they're on their own. Possibly in the future we may have to water these trees over a longer period of time." She also reports that the city has embarked on a program of rapid removal of infected trees to address the growing threat of invasive pests.

But protecting the health of urban forests requires long-term planning for resilience as well as short-term crisis management. One of the most challenging aspects of planning for the hazards of climate change is knowing that unpredictable threats (such as the arrival of the ash borer) are likely to arise. Barwinsky says that the best strategy for dealing with the unexpected is to expand the diversity of the urban forest. She notes that in urban forestry "there has always been a tendency to create monocultures of particular tree species that perform really well in an urban environment. But we need to continue to move away from that monoculture mindset."

Changes in mindset are essential when it comes to dealing with climate change. As Barwinsky says, "The most important thing is that we have to recognize that it's happening. Recognizing that and getting started on it and knowing we've got to change what we're doing: that's a big part of it." Appreciating the impact of climate change on our trees and the value of trees in dealing with climate change is key to taking action in the short term and cultivating resilience in the long term.

This shift in attitude has to include all the stakeholders, politicians, and citizens who benefit from the advantages of urban forests. After all, a majority of Winnipeg's trees are on private land and thus not in the City Forester's care. "The City of Winnipeg can't do it all", Barwinsky says. "We need partnerships to get the message out and to help people understand what we're faced with," she says.

Community groups and residents' associations have long taken a keen interest in tree health and maintenance, and are an important way for citizens and city staff to collaborate on education and action. Barwinsky's team also does outreach in schools, and she sees that "there's a greater awareness with this next generation" about the importance and value of trees. Collective effort and education as well as well-funded and -directed government programs are key to preserving and expanding our much-loved and much-needed urban forests in the face of climate change.

Our cities are much better off when they have healthy, thriving forest canopies. [**11**] The benefits of trees will only become more valuable in all senses – promoting community resilience, improving health and well-being, and providing economic benefits to private citizens and public budgets – as our climate continues to change.

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Key Topic #4: Field Skills and Identification

14. Identify the common trees of Alberta forests (common and scientific names) by leaves, bark, branching patterns, buds, fruit, and other characteristics without the use of a key.
15. Utilize common forestry tools including a D-tape, clinometer, a scaled map to make forestry measurements and determine stand volume in field scenarios.
16. Use satellite imagery to interpret current and historical land use, stand succession, and forest growth.

Study Resources

Types of Trees Harvested in Alberta and Their Uses

March 25, 2024

Alberta, a province known for its stunning landscapes and rich natural resources, has huge forests that are super important for its economy and the environment. The variety of tree types in Alberta's forests shows how special the region is and supports industries like lumber, paper, essential oils, and biomass fuels. This blog post explores the cool world of Alberta's forestry, discussing the trees cut down, their unique traits, and the many ways they're used. We'll discuss species like the tall Lodgepole Pine, tough White Spruce, and versatile Aspen and see how crucial they are for Alberta's economy and local communities. With climate change and habitat loss in mind, sustainable forestry practices are in the spotlight more than ever. This post will dive into the types of trees harvested in Alberta, their uses, and balancing resource use in one of Canada's most forest-filled provinces.

Overview of Alberta's Forest Industry

Alberta's forest industry is a major pillar of its economy, contributing billions of dollars and providing employment opportunities to thousands of residents. Forestry in Alberta is not just about cutting down trees for wood; it is a nuanced sector that requires balancing economic gains with environmental preservation. This balance is achieved through sustainable management practices that ensure the long-term health and productivity of forest ecosystems. Sustainable management includes strategies like replanting trees, protecting wildlife habitats, and using forestry methods that minimize environmental impact.

In terms of operations, Alberta's forestry sector employs various methods to harvest timber. Clear-cutting, where large forest areas are cut down, is common but increasingly complemented by selective logging. Selective logging involves carefully choosing and cutting down only mature or diseased trees, thereby preserving the forest structure and reducing environmental disturbance. These methods, like shelterwood cutting and seed tree harvesting, reflect Alberta's commitment to sustainable forestry practices. The emphasis on sustainability protects the environment and ensures that the forestry industry can continue to be a vital part of Alberta's economy for generations.

Main Types of Trees Harvested in Alberta

Coniferous Trees

Coniferous trees, often called evergreens because they retain their foliage year-round, are a significant backbone of Alberta's forestry sector. These trees, distinguished by their needle-like leaves and cone-bearing seeds, thrive in Alberta's varied climate, from cold winters to warm summers. Among the most harvested in this category are the Lodgepole Pine, known for its tall, straight trunk and utility in construction and pulp industries, and the White Spruce, favoured for its strength and versatility in building materials and paper production. Coniferous forests contribute to the province's economy through timber and related industries and play a crucial role in maintaining ecological balance, offering habitat to wildlife and acting as natural carbon sinks.

Lodgepole Pine (*Pinus contorta*)

Description: The Lodgepole Pine is a tall, slender tree that can reach up to 80 feet in height. It's easily recognizable by its narrow conical shape and the bark that turns from smooth and yellow-brown in young trees to dark and furrowed in older ones.

Habitat and Growth Conditions: Lodgepole pines prefer higher elevations and are predominantly found in the western parts of Alberta. They thrive in sandy or gravelly soils requiring full sunlight and are adaptable to dry and moist conditions.

Commercial Value: Lodgepole Pine is highly valued for its strong and flexible wood, which makes it ideal for construction materials, particularly framing and panelling. Additionally, it's used for making poles, plywood, and pulpwood.

White Spruce (*Picea glauca*)

Description: White Spruce is a robust tree that can grow up to 60 feet tall. It features a conical shape, with short, stiff needles and a smooth, grey bark that becomes scaly with age.

Habitat and Growth Conditions: This versatile tree is found across a vast range within Alberta, from lowland bogs to dry, upland areas. White Spruce prefers moist, well-drained soils but can adapt to various soil types and conditions.

Commercial Value: Due to its resilience and medium to fine texture, White Spruce wood is extensively used in the construction industry for products such as lumber, pulp for paper, and crates. It’s also sought after for Christmas trees due to its symmetrical shape and pleasant aroma.

Black Spruce (*Picea mariana*)

Description: Black Spruce is a small to medium-sized tree that grows to 30-50 feet. It is characterized by its straight trunk and narrow, conical shape. Its bark is thin, scaly, and grayish-brown, while the tree’s needles are short, stiff, and dark bluish-green, giving off a distinctive aromatic scent when crushed.

Habitat and Growth Conditions: Thriving in cooler climates, Black Spruce is commonly found in the boreal forests of Alberta, favouring wet, swampy areas. It is well-adapted to survive in harsh conditions, including poor soil and fire-prone environments, as it can regenerate quickly by releasing seeds stored in its cones after a fire.

Commercial Value: Black Spruce is highly prized for its wood used in the construction and paper industries. Its dense wood makes it suitable for producing lumber, poles, and pulpwood. Additionally, the tree is a source of spruce gum and essential oils, which have various medicinal and fragrant uses. Sustainable harvesting practices are essential to prevent overexploitation and preserve the natural habitats where Black Spruce plays a critical ecological role.

Balsam Fir (*Abies balsamea*)

Description: The Balsam Fir is a medium-sized conifer that often reaches heights of 45 to 75 feet, distinguished by its pyramidal shape and flat, long-lasting needles that give off a pleasant, balsamic fragrance when crushed. The bark is smooth and gray on younger trees, becoming rougher and more deeply furrowed with age.

Habitat and Growth Conditions: This tree is commonly found in the cool climates of northern Alberta, thriving in moist, acidic soils. It prefers well-drained sites and can be found in pure stands and mixed forests, often alongside spruces and birches.

Commercial Value: Balsam Fir is highly valued not only for its iconic status as a Christmas tree due to its dense, symmetrical branches and long-lasting aroma but also for its wood, used in manufacturing paper and lumber. Additionally, the resin, or “Canada balsam,” extracted from its bark, is used in the optical industry for making microscope slides and in traditional medicine for its healing properties. Sustainable harvesting practices, such as selective cutting and maintaining biodiversity, are crucial for preserving Balsam Fir populations and their habitats.

Deciduous Trees

Deciduous trees, contrasting with their coniferous counterparts, mark the changing seasons with their vivid transformations. Shedding their leaves annually, these trees play a crucial role in the ecological balance and the human economy. With leaves that burst into vibrant colours in autumn before falling, deciduous species contribute to biodiversity, act as crucial carbon sinks, and serve various commercial uses. In the following sections, we will explore the dominant deciduous trees found in Alberta, their unique characteristics, habitats, and their significant value in nature and industry.

Aspen (*Populus spp*.)

Description: Aspen trees, including species like Trembling (Quaking) Aspen and Balsam Poplar, are known for their fast growth and ability to regenerate quickly after disturbances. They have smooth, white bark and leaves that turn yellow in the fall.

Habitat and Growth Conditions: Aspen trees are incredibly adaptable, thriving in various soil types and moisture levels. They're commonly found throughout Alberta, from wetlands to semi-arid regions, and they often are the first species to repopulate cleared areas.

Commercial Value: Aspen wood is soft but strong, making it a popular choice for manufacturing furniture, pulp, and paper. Due to its quick turnover rate, Aspen is also used in sustainable forestry practices, providing a continuous supply without excessive impact on ecosystems.

White Birch (*Betula papyrifera*)

Description: The White Birch, also known as Paper Birch, is celebrated for its distinctive white, peeling bark and elegant stature. Growing up to 70 feet in height, it displays a slender profile with oval to triangular leaves that turn a bright yellow in the fall, offering a stunning contrast against its bark.

Habitat and Growth Conditions: White Birch thrives in cool, northern climates and is commonly found throughout Alberta. It prefers sunny, well-drained sites. It is adaptable to various soil conditions but flourishes in moist, sandy, or loamy soils. This species is often one of the first to colonize burned or clear-cut areas, playing a crucial role in forest regeneration.

Commercial Value: The wood of the White Birch is hard and dense, making it valuable for furniture, flooring, and plywood. Its bark, renowned for its waterproof qualities, has traditionally been used by Indigenous peoples to craft canoes and other containers. Additionally, the sap of the White Birch can be tapped to make syrup or fermented to produce birch beer, adding to its diverse commercial applications.

Balsam Poplar (*Populus balsamifera*)

Description: The Balsam Poplar, standing tall at an average height of 50 to 80 feet, commands attention with its robust stature and thick, fissured bark that darkens with age. Its broad leaves, which turn yellow in the fall, emit a distinctive resinous fragrance in the spring that fills the air with a sweet scent. These trees are easily identifiable by their large, sticky buds coated with a resin used in traditional salves and balms.

Habitat and Growth Conditions: Predominantly found along rivers, in floodplains, and in moist, well-drained soils, the Balsam Poplar prefers abundant sunlight. It is a resilient species capable of thriving in cold climates across Alberta. Its ability to quickly colonize disturbed areas makes it an essential player in natural forest regeneration processes.

Commercial Value: The wood of the Balsam Poplar, while softer and lighter than that of many hardwoods, is highly valued for its versatility. It is used in the production of pulp and paper and the manufacture of crates and pallets. The sticky resin from its buds, known for its medicinal properties, is useful in various therapeutic products. This tree, with its rapid growth and ability to reproduce both sexually and asexually, is also significant in sustainable forestry practices, contributing to ecosystem recovery and maintenance.

Harvested Trees in Industries

Trees harvested in Alberta's forestry industries serve critical roles beyond their ecological contributions. Highlighted below are some of the primary uses of trees in various industries:

- Construction Industry: Trees like the White Birch and Balsam Fir are valued for their dense, strong wood, suitable for structural materials, flooring, and roofing. Aspen and Balsam Poplar are also commonly used in construction for their quick growth and affordability.
- Paper and Pulp Industry: Aspen and balsam poplar's soft but strong woods make them preferred choices for producing high-quality paper products, including magazines, books, and packaging materials.
- Furniture Manufacturing: Due to its durability and aesthetic appeal, White Birch wood is commonly used to make furniture, offering both functional and decorative value.
- Pharmaceutical and Cosmetic Industries: The resin extracted from Balsam Fir and Balsam Poplar buds is used in traditional and modern therapeutic products, including salves, balms, and certain perfumes, for its healing properties.
- Cultural and Recreational Products: Indigenous peoples have traditionally used the waterproof bark of the White Birch to craft canoes, while its sap is tapped for making syrup or fermented to produce birch beer, demonstrating its diverse cultural applications.

Sustainability Practices in Forestry

Sustainability stands at the forefront of modern forestry practices in Alberta, ensuring that the vast wealth of forests remains available for future generations while maintaining the ecological balance. A key focus within these practices includes promoting methods that reduce environmental impact, such as selective logging—which targets specific trees for harvest while preserving the surrounding forest structure and biodiversity. Additionally, reforestation initiatives are diligently pursued, with millions of trees being planted annually to replenish harvested areas. These efforts are supplemented by strict regulations that limit the size and frequency of cuts, aiming to mimic natural disturbance patterns and promote a diverse age range among forest stands. Integrating traditional knowledge with scientific research further enriches these sustainability efforts, emphasizing the importance of forests as commercial resources and as vital ecosystems supporting many species, including humans. Through these comprehensive strategies, Alberta's forestry sector is making significant strides toward achieving a delicate balance between resource utilization and conservation.

Conclusion

The forests of Alberta play a profound role in shaping both the economy and the environment, serving as pivotal hubs of biodiversity, carbon sinks, and sources of raw materials for various industries. The sustainable management and harvesting of these forests contribute significantly to Alberta's economic vitality, particularly through the construction, paper and pulp, and pharmaceutical industries, and ensure the preservation of these natural resources for future generations. The future of forestry in Alberta appears promising, with an increasing emphasis on sustainable growth and practices that aim to balance economic gains with environmental stewardship. Efforts towards reforestation, responsible harvesting, and innovative forestry practices are imperative to maintain this delicate equilibrium.

Businesses, policymakers, and individuals must support and advocate for sustainable forestry practices to contribute to a sustainable future. Whether by choosing products from responsibly managed forests, supporting policies that protect natural resources, or simply spreading awareness, every action counts towards preserving the rich forestry heritage of Alberta. By collectively committing to sustainability, we can ensure our environment's and economy's prosperity for future generations.

Lodgepole Pine

Pinus contorta var. latifolia Loudon.

TREE: Tall, slender conifer, with little taper and straight trunk. Bark orange-brown, somewhat scaly, less than 2 cm thick. Branches curve upwards; self pruning in pure stands. **SIZE:** 20-30 m high; trunk 30-45 cm in diameter. **LEAVES:** Needle-shaped, in bundles of two, $2\frac{1}{2}$-8 cm long, spirally twisted, stiff, very sharp pointed, yellowish-green; form dense clusters toward the ends of twigs. **CONES:** Short-cylindrical to egg-shaped, curved away from branch tip, 2-5 cm long, remain on trees for many years; scales armed with small prickles. **DISTRIBUTION:** Grows on a wide variety of sites but prefers well drained sandy soils in the western part of the province. It is abundant in the Rocky Mountain and foothills regions. **NOTES:** Lodgepole Pine and Jack Pine *(P. banksiana Lamb.)* hybridize freely where the ranges of these two species overlap in central Alberta. As of May 1984, Lodgepole Pine is the official provincial tree of Alberta.

Tamarack

Larix laricina (Du Roi) K. Koch Larch

Photo by D. Johnson

TREE: Slender with a straight trunk having little taper. Bark thin, smooth, and grey when young becoming dark reddish-brown and scaly when older. Branches curved slightly downwards. **SIZE:** 20 m high; trunk 30-60 cm in diameter. **LEAVES:** Needle-shaped, in feather-like clusters of 10-20; 2-4 cm long, soft, flexible; pale green turning bright yellow in autumn; shed in autumn. **CONES:** $2^1/_2$ cm long, reddish when young becoming brown when mature; open in the autumn and persist on tree through the winter and following summer. **DISTRIBUTION:** Found in wetlands in central and northern Alberta. In northern Alberta it can also be found on better drained sites such as valley slopes. **NOTES:** Lyall's or Subalpine Larch *(L. lyallii* Parl.*)* is found in the subalpine zone in the mountains, from Lake Louise to the Montana border.

Photo by D. Griffin

White Spruce

Picea glauca (Moench) Voss

TREE: Dense conifer with a straight, tapered trunk. Bark scaly, thin, grey to ashy-brown. Branches horizontal. **SIZE:** Averages 25 m high; trunk 65 cm in diameter. Under favorable conditions 40 m high; trunk 130 cm in diameter. **LEAVES:** Needle-shaped, four-sided, 2-3 cm long, straight, stiff, sharp pointed, bluish-green; aromatic when crushed. **CONES:** Cylindrical, 4-5 cm in length, located at the ends of twigs; yellow when young turning brown when mature, smooth margins. Cones open in the autumn and drop during the winter or spring. **DISTRIBUTION:** Common throughout western, central, and northern Alberta. It is found in a variety of soil types and climatic regions.

Black Spruce

Picea mariana (Mill.) BSP.

Bog Spruce, Swamp Spruce

TREE: Dense conifer with a straight trunk. Bark thin, greyish-brown and scaly. Branches upturned at ends forming a distinctive club-like shape at the crown. **SIZE:** Averages 10 m high; trunk 25 cm in diameter. Under favorable conditions 30 m high; trunk 92 cm in diameter. **LEAVES:** Needle-shaped, four-sided, 1-2 cm, long; straight, thick, stiff, blunt, bluish green. **CONES:** Spherical, 2-3 cm long, purplish to dark brown; usually several in a cluster; retained for one or more years. **DISTRIBUTION:** Most common in wetlands throughout central and northern Alberta.

Balsam Fir

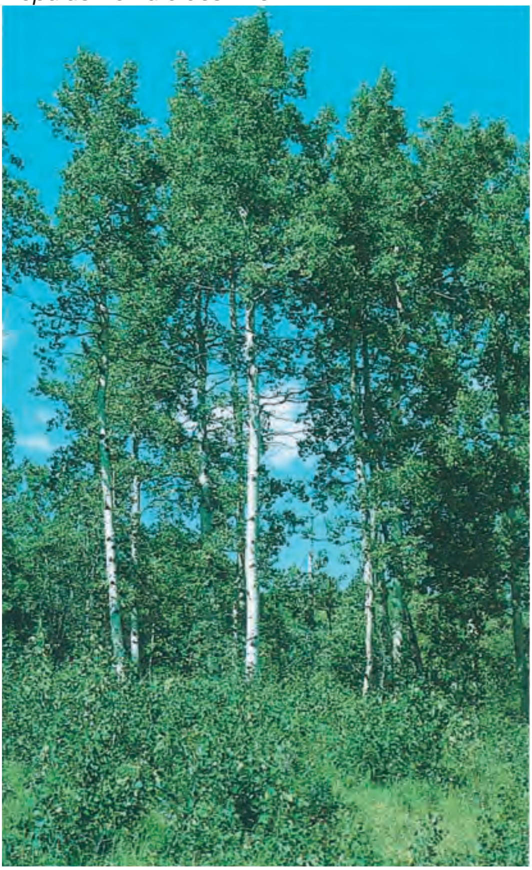
Abies balsamea (L.) Mill.

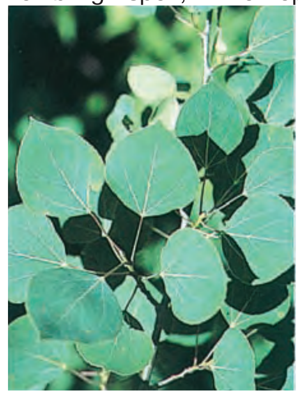
TREE: Symmetrical conifer with narrow, conical crown. Bark smooth, pale grey and blistered on young trees, rough, scaly and brown on older trees. Branches horizontal. **SIZE:** 18 m high; trunk 45 cm in diameter. **LEAVES:** Needle-shaped, flattened, 2-3 cm long, bent upward, rounded or blunt tipped; dark shiny green surface and whitish underside. **CONES:** Oval or oblong, 5-10 cm long, dark purple; disintegrate on tree and do not fall. **DISTRIBUTION:** Common tree in north-eastern Alberta which has adapted to a variety of soils and climates. **NOTES:** Subalpine Fir *(A. lasiocarpa* (Hook.) Nutt.), a mountain species, is similar in appearance to Balsam Fir. It is larger, 25 m high, and its leaves are greyish-green to pale blue-green. Subalpine Fir is mainly distinguishable from Balsam Fir by slight differences in their cones.

Aspen Poplar

Populus tremuloides Michx.

Trembling Aspen, White Poplar





TREE: Slender with a long straight trunk and rounded crown. Bark smooth, greenish-white on young trees becoming somewhat blackened and furrowed near base on older trees. Branches restricted to tops on mature trees. **SIZE:** Averages 20 m high. Trunk 25 cm in diameter. Under favorable conditions 30 m high; trunk 61 cm in diameter. **LEAVES:** Alternate, simple, oval to ovate, 4-6 cm wide; fine, irregular, rounded teeth on margin; slender, flattened petiole, usually longer than the leaf-blade; deep green upper surface, paler underside. **FLOWERS:** Small, hairy, drooping catkins appear before the leaves. **FRUIT:** Small, green capsules splitting when ripe to form a cotton mass. **DISTRIBUTION:** Very common and widespread throughout forested regions, but grows best in well drained soils. **NOTES:** Leaves tremble with slight breezes because of flattened leaf petioles. This tree suckers freely when cut or damaged. Root suckering is the primary method of propagation.

Balsam Poplar

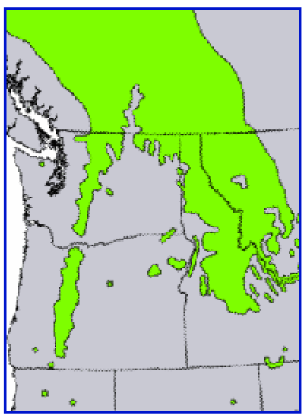
Populus balsamifera L.

Black Poplar, Balsam

TREE: Slender, with a long, straight trunk and narrow crown. Bark light grey and smooth on young trees, dark grey and furrowed on mature trees. Branches stout, pointing upward. **SIZE:** Averages 20 m high; trunk 40 cm in diameter. Under favorable conditions 30 m high; trunk 120 cm in diameter. **LEAVES:** Alternate, simple, ovate to ovatelanceolate, 8-15 cm, long; fine, irregular, rounded teeth on margin; shiny dark green surface, with whitish-green underside sometimes with rusty brown resin stains; winter buds large and pointed and covered with sticky resin. **FLOWERS:** Small, drooping catkins, appear before the leaves. **FRUIT:** Small, green capsules splitting when ripe to form large amounts of loose cotton mass that is blown about by spring breezes. **DISTRIBUTION:** Common and widespread throughout most of Alberta but grows best on rich, moist soils and low lying terrain. **NOTES:** A similar species, called Black Cottonwood *(P. trichocarpa* Hook.), is found in the western parts of the province. It is very difficult to differentiate from Balsam Poplar because both species hybridize freely. Balsam Poplar readily suckers when the main trunk is cut or damaged.

Engelmann Spruce

Engelmann Spruce – *Picea engelmannii*



USGS Distribution Map

This mountain native is a medium size tree that grows to 130 feet (40 meters), about half the size of a tall Sitka spruce.

Needles: The needles of Engelmann spruce are thin and sharp like other spruce trees and stick out all around the twig like a bottle brush. You can easily identify spruce trees by touching their sharp needles. Also, spruce needles are unique in growing from short, woody pegs that remain after the needles fall off.

Cones: The 3-inch cones are similar to those of mountain hemlock, but the scales are paper-thin, narrower and come to a point.

Bark: The the thin, gray bark breaks into small scales on large trees.

Where it grows: Engelmann spruce grows in the mountains east of the Cascades crest above 3000 feet (900 meters). Although it is not common in the Cascades, it is more abundant in the mountains to the east in Idaho and Montana. It is shade tolerant, and some shade is required for the healthy development of seedlings. You can find Engelmann spruce growing under a canopy of large trees where it competes well with other shade-tolerant conifers.

Engelmann spruce at Hoyt Arboretum.

Similar Tree: Sitka spruce grows only at low elevations along the Pacific Coast and Columbia River. The easiest way to distinguish Engelmann spruce from Sitka spruce is by location. You can also distinguish them by rolling a needle between your fingers. The flat Sitka needle will not roll, but the square-shaped Engelmann needle will.

Uses: Like other spruces, Engelmann spruce is used for making paper, lumber, and fine musical instruments such as guitars and violins.

Names: Engelmann spruce is named after nineteenth-century physician and botanist George Engelmann. Other common names: Silver spruce, white spruce, and mountain spruce.

Spruce needles with unique pegs

Guide to Forestry Measurement Tools

Woodland owners routinely measure elements of a forest, such as property acreage, boundaries, ground slope, standing timber characteristics, and log volumes. Measurements have become even more important as people increasingly understand the ecological importance of forestry.

Over the years, many sophisticated instruments have been developed to make forestry measurements. However, the majority of measurements require only a few simple and inexpensive pieces of equipment. Investing in the right equipment can go a long way toward best forestry practices.

Tools

The tools listed below are some of the most integral equipment to a forester's toolkit. While not exhaustive, this offers a great start to being equipped to handle many of the basic forestry tasks.

Diameter Tape

In order to manage, buy, and sell standing timber, it is necessary to measure trees' diameters. Diameter tape is used to measure a tree's diameter, usually at breast height. This is called the Diameter Breast Height (or DBH).

Diameter tape is unique because it has regular length measurements on one side and diameter conversions on the other. The Lufkin Artisan Diameter Tree Tape features a rugged, vinyl-covered steel case and a special claw hook designed for anchoring in tree bark at $129.60 per tape roll.

The Spencer Logging Diameter AutoRewind Tape is 75 ft long and costs just $60.00. It features automatic rewind, an aluminum case, and an active bumper to cushion the blade tip.

Logger Tape

Logger tape is a self-retracting reel tape that foresters use to measure felled timber. A horseshoe nail holds the end of the tape in place while the forester makes a measurement. Once completed, a gentle tug will make the nail release and the tape will rewind. The reels are built to withstand rough treatment in the elements.

Tree Calipers

Tree calipers offer more precise data when measuring tree and log diameters. However, compared to diameter tape, they are cumbersome. This means foresters only use them when the measurement needs to be precise.

Clinometer

A clinometer is used to measure vertical angles, such as ground slope, road grade, or tree height. This handheld instrument comes in many models. The best models have degree and percent scales.

Suunto Clinometers are used to measure tree heights, vertical angles, and slopes all over the world by foresters, surveyors, engineers, cartographers, and more and can be purchased for $231.

The Brunton Omni-Slope Sighting Clinometeris just $169.95. This product offers fast and accurate readings, whether you are measuring the height of a tree, avalanche danger, or judging the pitch of a cave.

Compass

A handheld compass measures direction in degrees. Compasses are used to establish plots and determine property lines. A handheld compass is sufficient for most forestry purposes and its compact frame makes it easy to carry. In order to get the most accurate readings, hold the compass level while using.

Compasses come at various prices and abilities, depending on what you are looking for. Compasses such as the Brunton TruArc 3 are reliable and trusted for just $19.95 per compass. Other compasses offer more to extend their abilities. The SILVA Ranger 2.0 Quad Compass, at $49.49 per compass, features a mirror, slope card, and distance lanyard.

The Brunton Omni-Sight Sighting Compass features special aluminum housing to ensure ruggedness and a rare earth magnet that ensures exceptional accuracy, all for $169.95. Finally, the GEO Pocket Transit is most notable for its hinge inclinometer that reduces the number of measurements required in the field by allowing for simultaneous trend and plunge measurements. This high-quality tool costs $719.95.

Biltmore Sticks

The Biltmore stick is used to measure tree diameters at DBH. The tool, shaped like a yardstick, can help you calculate the diameter based on the principle of similar triangles.

To use, you stand 25 inches from the tree and hold the Biltmore stick so that it is flush with the tree. Using only one eye, you then line up the left side of the stick with the left edge of the tree. Then, line the right edge of the tree with the corresponding number on the Biltmore stick. This is the first diameter measurement. Confirm by repeating the process on the others side of the tree, and take the average of your two measurements.

Angle Gauge and Wedge Prisms

The basal area is the measurement of the cross-sectional area of a given tree trunk, measured in square feet at DBH. The basal area of a section of a forest is the sum of the basal areas of individual trees (measured in square feet per acre).

An angle gauge is used to measure the average basal area within a given area. This tool, which is held from a fixed distance from the eye to function properly, quickly measures whether a tree in inside or outside of a given plot.

The wedge prism is a wedge-shaped piece of glass that deflects the tree trunk image when viewed. They are available in a range of dimensions to fit the size of the trees being measured.

Increment Borer

Tree borers allow foresters to extract core samples from trees. The increment borer extracts a small straw-shaped sample (generally 0.2 inches in diameter) that runs from the bark to the center of the tree. By examining the tree rings, the forester can determine the age, growth rate, and soundness of the tree.

Borer lengths vary in two-inch increments. They range from an 8-inch minimum to a much larger sampling depth.

The hole can introduce decay into the trunk. In order to prevent decay, trees are limited to one bore every six years. Furthermore, the forester reinserts the extracted core back into the hole after it has been used.

Laser Rangefinder

Laser rangefinders allow foresters to measure distances, angles, and heights. With this high-tech instrument, foresters can look through the viewfinder and have the machine calculate the measurements of the different points where they direct the rangefinder.

IMAGE: https://www.istockphoto.com/photo/modern-optical-range-finder-isolated-on-white-background-isolated-black-plastic-gm1184688338-333596405

For a price of $450, the Laser Technology TruPulse 200L was designed to make professional measurements at a low cost. It uses TruTargeting technology and premium built-in features for reliable results. Or, you can opt for the Laser Technology TruPulse 200X for $1,995. This instrument can instantly measure slope distance, and inclination and calculate the horizontal and vertical distance with a single push of a button.

Global Positioning System (GPS)

Foresters use GPS systems for many tasks, but most often to mark the location of features in a forest plot. GPS systems allow you to make a point at a location of interest so that you can revisit that spot later on.

You can consider buying a GPS system or downloading a phone app such as Avenza. Visit the Southern Regional Extension Forestry website for more examples of apps. For the most accuracy, cheap apps may not always be reliable. In cases where precision is vital, licensed surveyors using high-quality GPS systems are your best bet.

Tree Marking Paint

Not every visit into the forest merits tree marking paint. However, there are times of the year when paint is a useful device. For instance, tree marking can be used to show which trees should be cut before a harvest.

Aervoe Tree Marking Paint is fast drying, has excellent adhesion, and can be bought for a price of $5.63 per case. Aervoe Wet Coat Tree Marking Paint is built for wet conditions. It is built to mix with the water in wet wood allowing the paint to penetrate deep into the pores of the lumber.

Field Books

Foresters may need to write down a note to remember what they have measured while out in the forests. For this reason, it is important to carry a notebook while working.

That said, a standard notebook is a risky proposition. In case of rain, it is best to carry a notebook that is built to weather the elements. This could prevent you from losing all of your data. A wide range of forestry field books is available to help you meet this need.

Conclusion

Forest owners have many responsibilities to measure the trees on their property. Providing workers with the appropriate instruments to measure tree height, diameter, distances, and more will make for more accurate data and more efficient use of time.

Investigate forest change with recent satellite imagery

The recent satellite imagery tool provides information regarding vegetation health around the world and can help validate near real-time alerts. New images are populated daily, showing the latest satellite imagery from the Sentinel-2 and Landsat 8 systems.

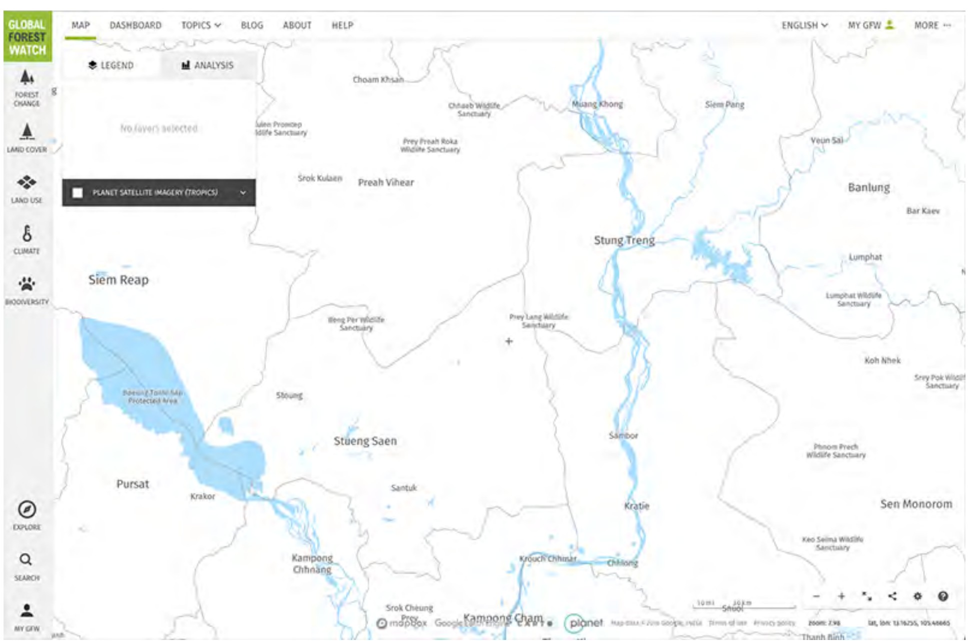
The imagery offers global geographic coverage at a 10 x 10-meter resolution with Sentinel-2, and a 30 x 30-meter resolution with Landsat 8. The Sentinel-2 satellite revisits locations every 10 days, while Landsat 8 revisits locations every 16 days.

Another resource to help validate near real-time alerts is the 5-meter resolution Planet imagery. The Planet imagery basemap is updated monthly starting September 2020 and is available for the tropics. Six-month mosaics are also available for past years. Learn more about the Planet basemap and other available basemaps here.

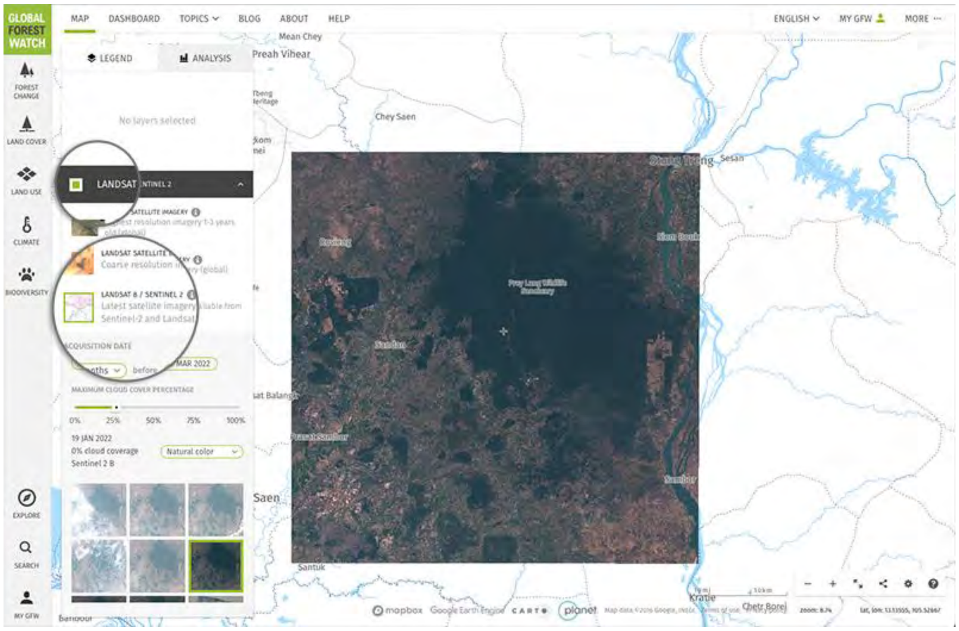
Recent satellite imagery features

Recent satellite imagery can help show what an area looks like in near real-time and facilitate validation of forest change data, such as deforestation or fire alerts.

1. To use the recent satellite imagery tool, situate the crosshair in the center of the map over your area of interest. Check the selection box in the dark gray bar at the bottom of the Legend panel, then select the option labeled “Landsat 8 / Sentinel 2”. The tool will only work if the crosshair is situated above land. For the best results, zoom in to a specific location before activating the tool.

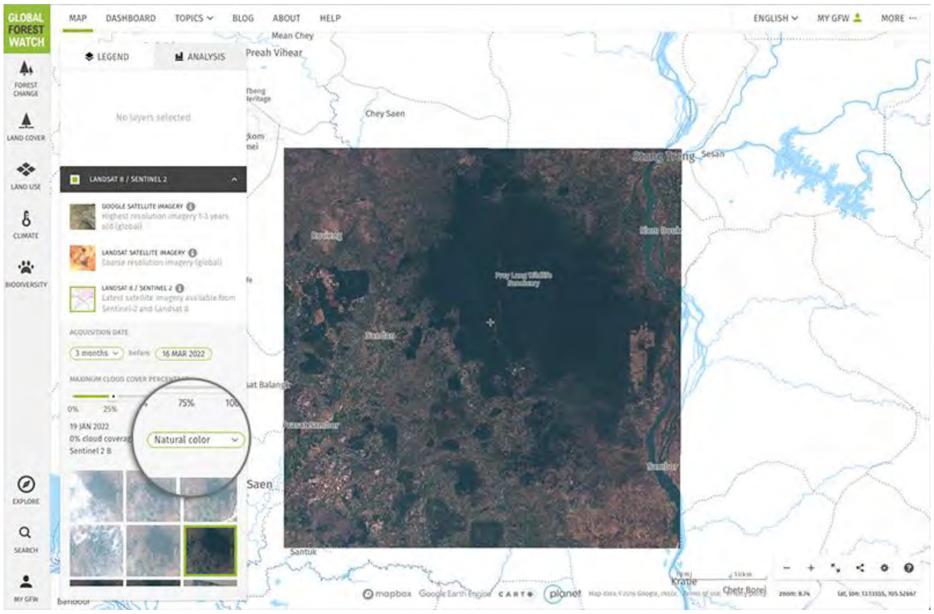


Zoom in to the location you’d like to investigate with recent satellite imagery.

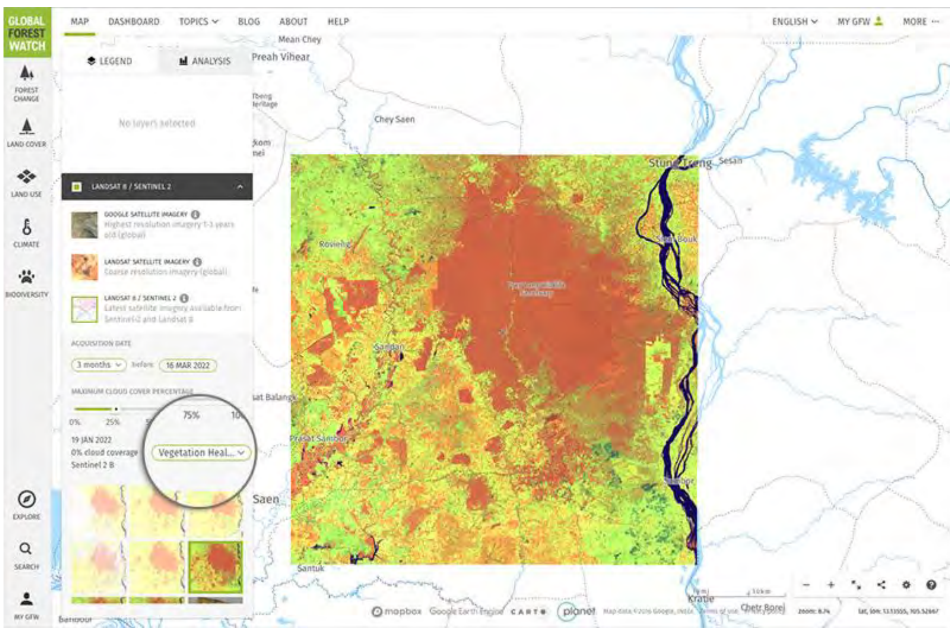


Check the selection box in the dark gray bar at the bottom of the Legend panel, then select the option labeled "Landsat 8 / Sentinel 2" to activate the tool.

2. The "Acquisition Date" drop-down menu at the top of the pop-up window allows you to access images 1 week, 2 weeks, 4 weeks, 2 months, 3 months, 6 months or 12 months before a specified date. The default acquisition date will be 3 months before the present date, but can be changed by clicking on the date.
3. Adjust the cloud cover percentage by clicking and dragging the bar to the desired percentage. The default is set at 25%, which means only satellite imagery with less than 25% cloud cover will load. The higher the maximum cloud cover percentage, the more images will appear in your search; however, some of these images may be obscured by clouds.
4. There are two imagery options available: natural color or vegetation health. The natural color imagery uses information from visible light (red, green and blue) to show Earth's surface as it would appear to the human eye. The vegetation health imagery is detected using the Normalized Difference Vegetation Index (NDVI), which uses information from both red and near-infrared reflectance. The NDVI method relies on the fact that healthy vegetation absorbs most visible light and reflects most near-infrared light that strikes its surface. When interpreting imagery that shows vegetation health, red indicates healthy growing vegetation, green indicates bare ground and black/purple indicates water bodies. While the natural color imagery is more intuitive, some details can be lost as images can be hazy and subtle features can be difficult to recognize. By contrast, the vegetation health imagery highlights differences in land cover and can make the images easier to interpret.



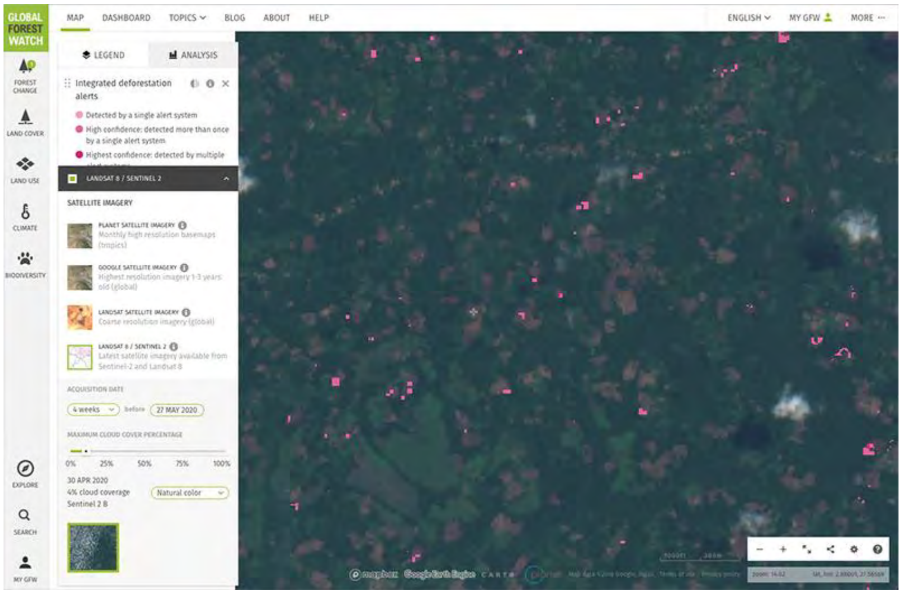
Select "Natural color" to view imagery from visible light, displaying the Earth's surface as it would appear to the human eye.



Select "Vegetation Health" to view imagery from NDVI. The red/orange colors reflect healthy vegetation, whereas the green color reflects bare ground. The black/purple colors reflect water bodies.

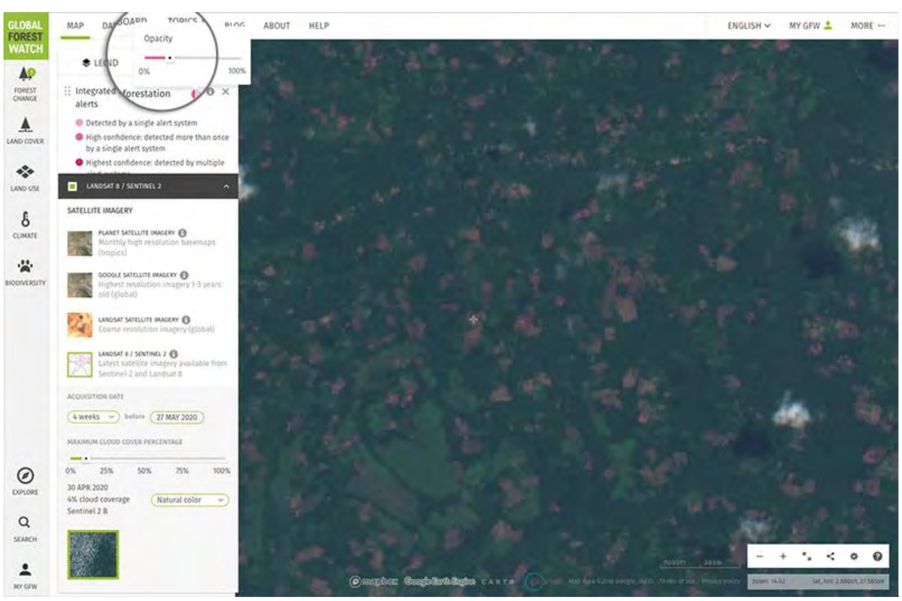
Use the recent satellite imagery tool

1. Let's say you are managing this area in the Democratic Republic of Congo. In this example, you can see how the deforestation alerts align with the brown – or cleared – areas in the natural color satellite imagery.



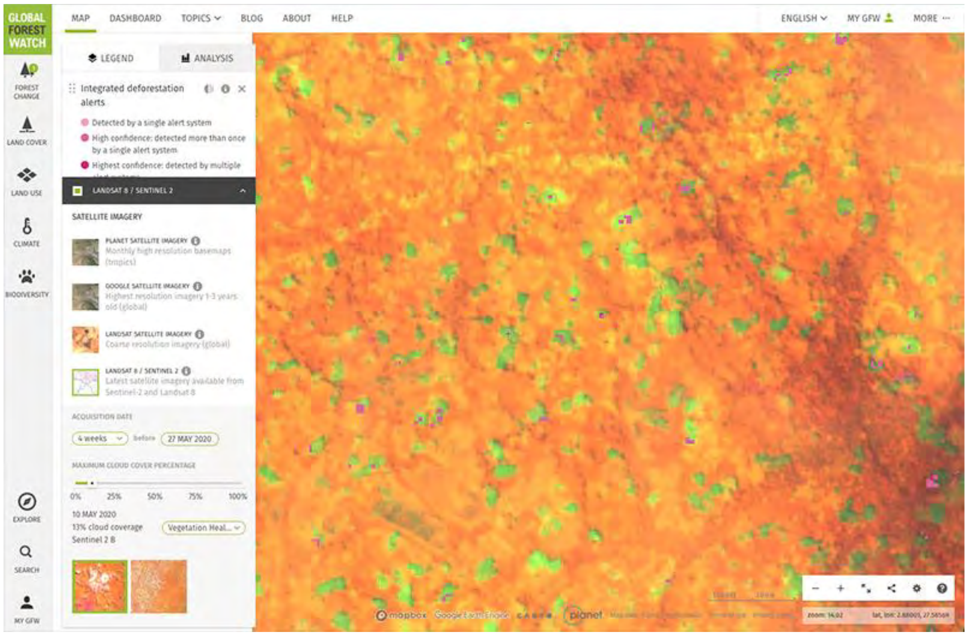
Activate recent satellite imagery over the area you'd like to investigate. The deforestation alerts and satellite imagery indicate tree cover loss based on the brown clearing zones beneath the alerts.

2. The deforestation alerts are activated for April 1st, 2020 through May 16th, 2020. This shows locations of potential deforestation for that time period.
3. To investigate further, recent satellite imagery within the past four weeks was selected. The maximum cloud cover percentage was lowered and "natural color" was selected for the images. This will help you get started in verifying whether the alerts indicate any clearings.
4. The deforestation alert opacity was reduced in order to see a clearer satellite image beneath the alerts. Learn more about how to reduce data layer opacity here. In the example below, there is evidence of clearings throughout this area based on the brown areas where the alerts are.



Reduce the deforestation alert opacity to help reveal more of the underlying recent satellite images.

5. Zooming in closer to the area can also provide a clearer view of the characteristics of the clearing, helping to determine whether the clearing is from human or natural causes, as well as what the likely driver of the clearing was (e.g., small-holder agriculture, commercial agriculture, mining, logging, fire, etc.).
6. To investigate and verify further, you can activate the vegetation health imagery. Here, the alerts are overlaid on green patches, indicating bare ground – you can now verify that clearing has occurred in this area.



Activate the vegetation health imagery to help identify areas of likely tree cover loss. The green patches indicate bare ground and likely clearing.

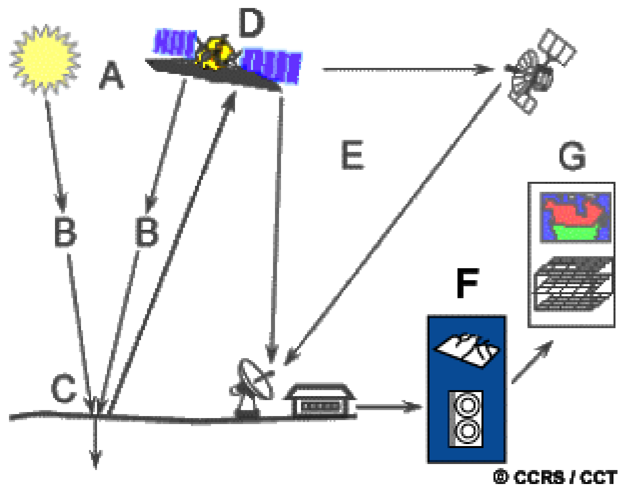
7. From here, you can begin taking the necessary steps to investigate on the ground and take appropriate action. Learn more about how the Forest Watcher mobile app can help you investigate forest change while offline and in the field here.

In short, recent satellite imagery is a powerful tool to help monitor, verify and investigate an area of interest before heading into the field. Identifying whether tree cover loss has occurred before investigating on the ground can save you time, money and other resources and allow you to focus your efforts on where forest threats are actually occurring. Additionally, it can be used in reports, policy briefs, presentations and throughout the media to show where deforestation has likely occurred and its likely cause.

Fundamentals of Remote Sensing

Section 4 - Image interpretation & analysis

Introduction



In order to take advantage of and make good use of remote sensing data, we must be able to extract meaningful information from the imagery. This brings us to the topic of discussion in this chapter - interpretation and analysis - the sixth element of the remote sensing process which we defined in Chapter 1. Interpretation and analysis of remote sensing imagery involves the identification and/or measurement of various targets in an image in order to extract useful information about them. Targets in remote sensing images may be any feature or object which can be observed in an image, and have the following characteristics:

- Targets may be a point, line, or area feature. This means that they can have any form, from a bus in a parking lot or plane on a runway, to a bridge or roadway, to a large expanse of water or a field.
- The target must be distinguishable; it must contrast with other features around it in the image.

Much interpretation and identification of targets in remote sensing imagery is performed manually or visually, i.e. by a human interpreter. In many cases this is done using imagery displayed in a pictorial or photograph-type format, independent of what type of sensor was used to collect the data and how the data were collected. In this case we refer to the data as being in **analog** format. As we discussed in Chapter 1, remote sensing images can also be represented in a computer as arrays of pixels, with each pixel corresponding to a digital number, representing the brightness level of that pixel in the image. In this case, the data are in a **digital** format. Visual interpretation may also be performed by examining digital imagery displayed on a computer screen. Both analogue and digital imagery can be displayed as black and white (also called monochrome) images, or as colour images (refer back to Chapter 1, Section 1.7) by combining different channels or bands representing different wavelengths.

When remote sensing data are available in digital format, **digital processing and analysis** may be performed using a computer. Digital processing may be used to enhance data as a prelude to visual interpretation. Digital processing and analysis may also be carried out to automatically identify targets and extract information completely without manual intervention by a human interpreter. However, rarely is digital processing and analysis carried out as a complete replacement for manual interpretation. Often, it is done to supplement and assist the human analyst.

Manual interpretation and analysis dates back to the early beginnings of remote sensing for air photo interpretation. Digital processing and analysis is more recent with the advent of digital recording of remote sensing data and the development of computers. Both manual and digital techniques for interpretation of remote sensing data have their respective advantages and disadvantages. Generally, manual interpretation requires little, if any, specialized equipment, while digital analysis requires specialized, and often expensive, equipment. Manual interpretation is often limited to analyzing only a single channel of data or a single image at a time due to the difficulty in performing visual interpretation with multiple images. The computer environment is more amenable to handling complex images of several or many channels or from several dates. In this sense, digital analysis is useful for simultaneous analysis of many spectral bands and can process large data sets much faster than a human interpreter. Manual interpretation is a subjective process, meaning that the results will vary with different interpreters. Digital analysis is based on the manipulation of digital numbers in a computer and is thus more objective, generally resulting in more consistent results. However, determining the validity and accuracy of the results from digital processing can be difficult.

It is important to reiterate that visual and digital analyses of remote sensing imagery are not mutually exclusive. Both methods have their merits. In most cases, a mix of both methods is usually employed when analyzing imagery. In fact, the ultimate decision of the utility and relevance of the information extracted at the end of the analysis process, still must be made by humans.

Section 5.2 Forestry

Forests are a valuable resource providing food, shelter, wildlife habitat, fuel, and daily supplies such as medicinal ingredients and paper. Forests play an important role in balancing the Earth's CO2 supply and exchange, acting as a key link between the atmosphere, geosphere, and hydrosphere. Tropical rainforests, in particular, house an immense **diversity of species**, more capable of adapting to, and therefore surviving, changing environmental conditions than monoculture forests. This diversity also provides habitat for numerous animal species and is an important source of medicinal ingredients. The main issues concerning forest management are depletion due to natural causes (fires and infestations) or human activity (clear-cutting, burning, land conversion), and monitoring of health and growth for effective commercial exploitation and conservation.

Humans generally consider the products of forests useful, rather than the forests themselves, and so extracting **wood** is a wide-spread and historical practice, virtually global in scale. Depletion of forest resources has long term effects on climate, soil conservation, biodiversity, and hydrological regimes, and thus is a vital concern of environmental monitoring activities. Commercial forestry is an important industry throughout the world. Forests are cropped and re-harvested, and the new areas continually sought for providing a new source of lumber. With increasing pressure to conserve native and virgin forest areas, and unsustainable forestry practices limiting the remaining areas of potential cutting, the companies involved in extracting wood supplies need to be more efficient, economical, and aware of sustainable forestry practices. Ensuring that there is a healthy regeneration of trees where forests are extracted will ensure a future for the commercial forestry firms, as well as adequate wood supplies to meet the demands of a growing population.

Non-commercial sources of forest depletion include removal for agriculture (pasture and crops), urban development, droughts, desert encroachment, loss of ground water, insect damage, fire and other natural phenomena (disease, typhoons). In some areas of the world, particularly in the tropics, (rain) forests, are covering what might be considered the most valuable commodity - viable agricultural land. Forests are burned or clear-cut to facilitate access to, and use of, the land. This practice often occurs when the perceived need for long term sustainability is overwhelmed by short-term sustenance goals. Not only are the depletion of species-rich forests a problem, affecting the local and regional hydrological regime, the smoke caused by the burning trees pollutes the atmosphere, adding more CO2, and furthering the greenhouse effect.

Of course, monitoring the health of forests is crucial for sustainability and conservation issues. Depletion of key species such as mangrove in environmentally sensitive coastline areas, removal of key support or shade trees from a potential crop tree, or disappearance of a large biota acting as a CO2 reservoir all affect humans and society in a negative way, and more effort is being made to monitor and enforce regulations and plans to protect these areas.

International and domestic forestry applications where remote sensing can be utilized include sustainable development, biodiversity, land title and tenure (cadastre), monitoring deforestation, reforestation monitoring and managing, commercial logging operations, shoreline and watershed protection, biophysical monitoring (wildlife habitat assessment), and other environmental concerns.

General forest cover information is valuable to developing countries with limited previous knowledge of their forestry resources. General cover type mapping, shoreline and watershed mapping and monitoring for protection, monitoring of cutting practices and regeneration, and forest fire/burn mapping are global needs which are currently being addressed by Canadian and foreign agencies and companies employing remote sensing technology as part of their information solutions in foreign markets.

Forestry applications of remote sensing include the following:

1) **reconnaissance mapping**:

Objectives to be met by national forest/environment agencies include forest cover updating, depletion monitoring, and measuring biophysical properties of forest stands.

- forest cover type discrimination
- agroforestry mapping

2) **Commercial forestry**:

Of importance to commercial forestry companies and to resource management agencies are inventory and mapping applications: collecting harvest information, updating of inventory information for timber supply, broad forest type, vegetation density, and biomass measurements.

- clear cut mapping / regeneration assessment
- burn delineation
- infrastructure mapping / operations support
- forest inventory
- biomass estimation
- species inventory

3) **Environmental monitoring**

Conservation authorities are concerned with monitoring the quantity, health, and diversity of the Earth's forests.

- deforestation (rainforest, mangrove colonies)
- species inventory
- watershed protection (riparian strips)
- coastal protection (mangrove forests)
- forest health and vigour

Canadian requirements for forestry application information differ considerably from international needs, due in part to contrasts in tree size, species diversity (monoculture vs. species rich forest), and agroforestry practices. The level of accuracy and resolution of data required to address respective forestry issues differs accordingly. Canadian agencies have extensive a priori knowledge of their forestry resources and present inventory and mapping needs are often capably addressed by available data sources.

For Canadian applications requirements, high accuracy (for accurate information content), multispectral information, fine resolution, and data continuity are the most important. There are requirements for large volumes of data, and reliable observations for seasonal coverage. There is a need to balance spatial resolution with the required accuracy and costs of the data. Resolution capabilities of 10 m to 30 m are deemed adequate for forest cover mapping, identifying and monitoring clearcuts, burn and fire mapping, collecting forest harvest information, and identifying general forest damage. Spatial coverage of 100 - 10000 km2 is appropriate for district to provincial scale forest cover and clear cut mapping, whereas 1-100 km2 coverage is the most appropriate for site specific vegetation density and volume studies.

Tropical forest managers will be most concerned with having a reliable data source, capable of imaging during critical time periods, and therefore unhindered by atmospheric conditions.

Section 5.21 - Species Identification & Typing

Background

Forest cover typing and species identification are critical to both forest conservation managers and forestry companies interested in their supply inventory. Forest cover typing can consist of reconnaissance mapping over a large area, while species inventories are highly detailed measurements of stand contents and characteristics (tree type, height, density).

Why remote sensing?

Remote sensing provides a means of quickly identifying and delineating various forest types, a task that would be difficult and time consuming using traditional ground surveys. Data is available at various scales and resolutions to satisfy local or regional demands Large scale species identification can be performed with multispectral, hyperspectral, or airphoto data, while small scale cover type delineation can be performed by radar or multispectral data interpretation. Both imagery and the extracted information can be incorporated into a GIS to further analyze or present with ancillary data, such as slopes, ownership boundaries, or roads.

Hyperspectral imagery can provide a very high spatial resolution while capturing extremely fine radiometric resolution data. This type of detailed spectral information can be used to generate signatures of vegetation species and certain stresses (e.g. infestations) on trees. Hyperspectral data offers a unique view of the forest cover, available only through remote sensing technology.

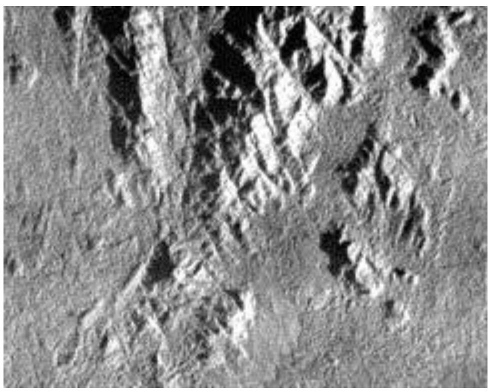
Data requirements

Requirements depend on the scale of study to be conducted. For regional reconnaissance mapping, moderate area coverage, with a sensor sensitive to differences in forest cover (canopy texture, leaf density, spectral reflection) is needed. Multitemporal datasets also contribute phenology information that may aid in interpretation by incorporating the seasonal changes of different species.

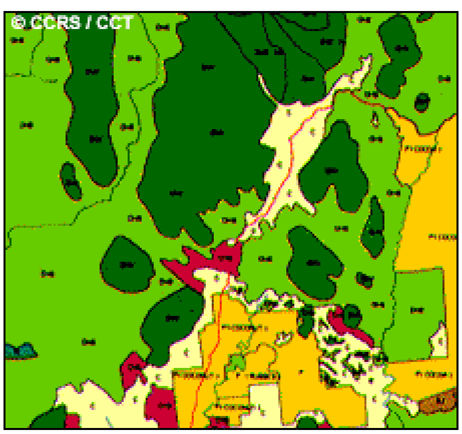
For detailed species identification associated with forest stand analysis, very high resolution, multispectral data is required. Being able to view the images in stereo helps in the delineation and assessment of density, tree height, and species. In general, monitoring biophysical properties of forests requires multispectral information and finely calibrated data.

Canada vs. International

Current sources of data used operationally for forest cover typing and species identification applications within Canada are aerial photography, orthophotography, Landsat TM, and SPOT data. Landsat data are the most appropriate for executing reconnaissance level forest surveys, while aerial photography and digital orthophoto are the preferred data source for extracting stand and local inventory information. Airphotos are the most appropriate operational data source for stand level measurements including species typing. SAR sensors such as RADARSAT are useful where persistent cloud cover limits the usefulness of optical sensors.



In humid tropical areas, forest resource assessments and measurements are difficult to obtain because of cloudy conditions hindering conventional remote sensing efforts, and difficult terrain impeding ground surveys. In this situation, reliability of data acquisition is more crucial than resolution or frequency of imaging. An active sensor may be the only feasible source of data, and its reliability will facilitate regular monitoring. Radar will serve this purpose, and an airborne sensor is sufficient for high resolution requirements such as cover typing. This type of data can be used for a baseline map , while coarser resolution data can provide updates to any changes in the baseline.



Case study (example)

Inventory Branch, Ministry of Forests, Province of British Columbia, Canada

This is an example of the operational requirements and procedure for a provincial department involved in a number of forestry applications using remote sensing technology.

The Inventory Branch is responsible for maintaining a database of Crown Land information concerning historical, stand, and sustainable forest management information which is used for determining timber volumes and annual allowable cuts. The inventory itself is performed every ten years with 1:15,000 scale aerial photography, and updated with satellite imagery every two years.

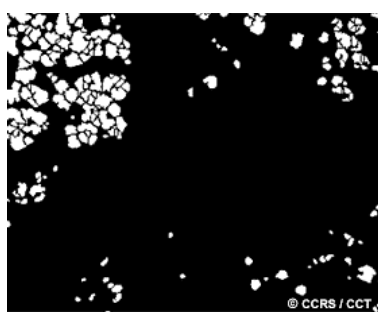
The Inventory branch requires geocoded, terrain corrected data. For most studies, the branch currently buys precision geocoded data, and for large scale mapping projects, they will cut costs by obtaining systematic versus precision geocoded data. Further processing is done in-house on workstations. Some location data are now being provided by the private sector, conducting field traverses with GPS (global positioning system) data.

Present planimetric accuracy requirements are 20 m, but will be more demanding in the near future. Airphotos and orthophotos meet requirements and are good for interpretation but are limited by expense. Data continuity is important, as monitoring will be an ongoing operation. TM data for updating maps is reasonable in cost and information content for interim monitoring.

Much of the updating in the Ministry of Forests is done with TM data, either brought digitally into a MicroStation workstation to perform heads-up digitizing, or in transparency form with the image overlain onto existing maps using a projection device. The Ministry of Forests is presently investigating the potential of a number of data sources with various levels of processing applied, and integration possibilities to assess accuracy versus cost relationships.

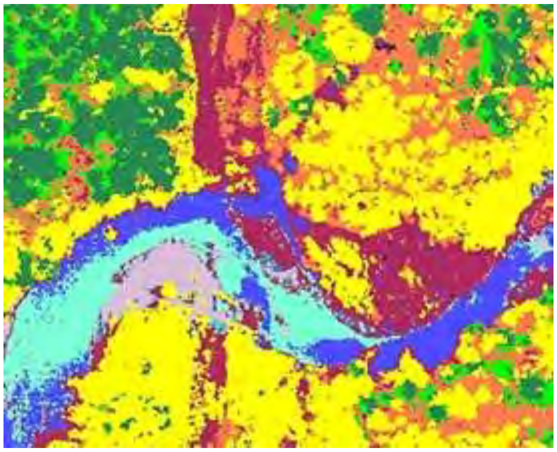
The Ministry of Forests in B.C. employs an expert system SHERI (System of Hierarchical Expert Systems for Resource Inventories) to provide a link between remotely sensed data, GIS and growth and yield modelling. The end to end information flow is complete with the generation of final products including forest cover maps incorporating planimetric and administrative boundary information.

Case study (example)



Hyperspectral image and recent stem count from hyperspectral imagery

Forest companies use hyperspectral imagery to obtain stem counts, stand attributes, and for mapping of land cover in the forest region of interest. These images depict a false colour hyperspectral image of a Douglas fir forest on Vancouver Island at a resolution of 60 cm. The imagery was acquired in the fall of 1995 by the CASI (Compact Airborne Imaging Spectrometer). Attributes obtained from the imagery (a subset is shown) include:



- Stand Area (hectares) 9.0
- Total number of trees 520
- Tree density (stems/ha) 58
- Crown closure (%) 12.46
- Average tree crown area (sq m) 21.47

The corresponding land cover map contains the following classes:

- Dark green: conifers
- Green: lower branches
- Light purple: gravel
- Yellow: deciduous
- Orange: dry ground cover
- Red: wet ground cover
- Blue (light): water
- Blue (dark): deep or clear water

All imagery courtesy of MacMillan Bloedel and ITRES Research Limited.

Section 5.22 – Burn Mapping

Background

Fire is part of the natural reproductive cycle of many forests revitalizing growth by opening seeds and releasing nutrients from the soil. However, fires can also spread quickly and threaten settlements and wildlife, eliminate timber supplies, and temporarily damage conservation areas. Information is needed to help control the extent of fire, and to assess how well the forest is recovering following a burn.

Why remote sensing?

Remote sensing can be used to detect and monitor forest fires and the regrowth following a fire. As a surveillance tool, routine sensing facilitates observing remote and inaccessible areas, alerting monitoring agencies to the presence and extent of a fire. NOAA AVHRR thermal data and GOES meteorological data can be used to delineate active fires and remaining "hot-spots" when optical sensors are hindered by smoke, haze, and /or darkness. Comparing burned areas to active fire areas provides information as to the rate and direction of movement of the fire. Remote sensing data can also facilitate route planning for both access to, and escape from, a fire, and supports logistics planning for fire fighting and identifying areas not successfully recovering following a burn.

Years following a fire, updates on the health and regenerative status of an area can be obtained by a single image, and multitemporal scenes can illustrate the progression of vegetation from pioneer species back to a full forest cover.

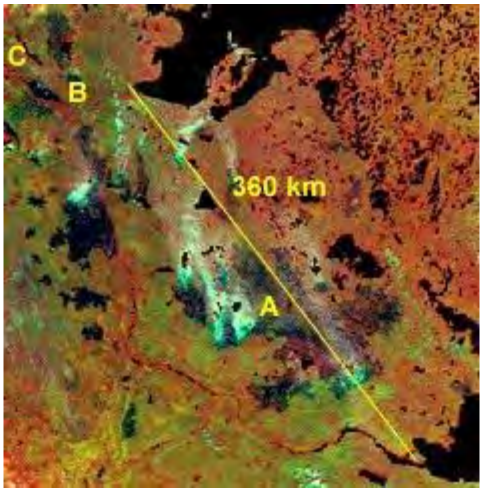
Data requirements

While thermal data is best for detecting and mapping ongoing fires, multispectral (optical and near-infrared) data are preferred for observing stages of growth and phenology in a previous burn area. The relative ages and area extent of burned areas can be defined and delineated, and health of the successive vegetation assessed and monitored. Moderate spatial coverage, high to moderate resolution, and a low turnaround time are required for burn mapping. On the other hand, fire detection and monitoring requires a large spatial coverage, moderate resolution and a very quick turnaround to facilitate response.

Canadian vs. International

Requirements for burn mapping are the same, except where cloud cover precludes the used of optical images. In this case, radar can be used to monitor previous burn areas, and is effective from the second year following a burn, onwards.

Case study (example) Northwest Territory Burn



Burned and burning forest near Norman Wells, NWT

In the western Northwest Territories along the Mackenzie River, boreal forest covers much of the landscape. Natives rely on the forests for hunting and trapping grounds, and the sensitive northern soil and permafrost are protected from erosion by the forest cover. In the early 1990's a huge fire devastated the region immediately east of the Mackenzie and threatened the town of Fort Norman, a native town south of Norman Wells.

The extent of the burned area, and the areas still burning, can be identified on this NOAA scene, as dark regions (A). The lake in the upper right is Great Bear Lake, and the lake to the lower right is Great Slave Lake. The distance represented by the yellow line is approximately 580 km. The course of the Mackenzie River can be seen to the left of these lakes. Fort Norman (B) is located at the junction of the Mackenzie River and Great Bear River, leading out of Great Bear Lake. At that location, the fire is on both sides of the river. Norman Wells (C) is known as an oil producing area, and storage silos, oil rigs, homes, and the only commercial airport in that part of the country were threatened. Fires in this region are difficult to access because of the lack of roads into the region. Winter roads provide only seasonal access to vehicles in this part of Canada. The small population base also makes it difficult to control, let alone fight, a fire of this magnitude.

Haze and smoke reflect a large amount of energy at shorter wavelengths and appear as blue on this image.

Section 5.6 - Land Cover / Biomass Mapping

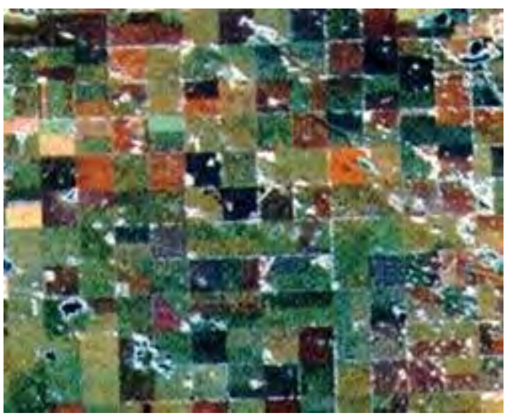
Background

Land cover mapping serves as a basic inventory of land resources for all levels of government, environmental agencies, and private industry throughout the world. Whether regional or local in scope, remote sensing offers a means of acquiring and presenting land cover data in a timely manner. Land cover includes everything from crop type, ice and snow, to major biomes including tundra, boreal or rainforest, and barren land.

Regional land cover mapping is performed by almost anyone who is interested in obtaining an inventory of land resources, to be used as a baseline map for future monitoring and land management. Programs are conducted around the world to observe regional crop conditions as well as investigating climatic change on a regional level through biome monitoring. Biomass mapping provides quantifiable estimates of vegetation cover, and biophysical information such as leaf area index (LAI), net primary productivity (NPP) and total biomass accumulations (TBA) measurements - important parameters for measuring the health of our forests, for example.

Why remote sensing?

There is nothing as practical and cost efficient for obtaining a timely regional overview of land cover than remote sensing techniques. Remote sensing data are capable of capturing changes in plant phenology (growth) throughout the growing season, whether relating to changes in chlorophyll content (detectable with VIR) or structural changes (via radar). For regional mapping, continuous spatial coverage over large areas is required. It would be difficult to detect regional trends with point source data. Remote sensing fulfills this requirement, as well as providing **multispectral**, **multisource**, and multitemporal information for an accurate classification of land cover. The multisource example image shows the benefit of increased information content when two data sources are integrated. On the left is TM data, and on the right it has been merged with airborne SAR.



Data requirements

For continental and global scale vegetation studies, moderate resolution data (1km) is appropriate, since it requires less storage space and processing effort, a significant consideration when dealing with very large area projects. Of course the requirements depend entirely on the scope of the application. Wetland mapping for instance, demands a critical acquisition period and a high resolution requirement.

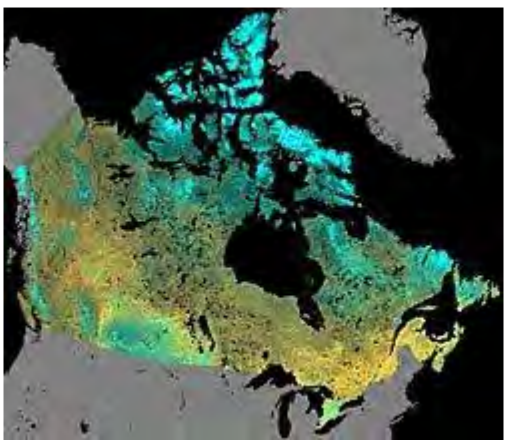
Coverage demand will be very large for regional types of surveying. One way to adequately cover a large area and retain high resolution, is to create mosaics of the area from a number of scenes.

Land cover information may be time sensitive. The identification of crops, for instance canola, may require imaging on specific days of flowering, and therefore, reliable imaging is appropriate. Multi-temporal data are preferred for capturing changes in phenology throughout the growing season. This information may be used in the classification process to more accurately discriminate vegetation types based on their growing characteristics.

While optical data are best for land cover mapping, radar imagery is a good replacement in very cloudy areas.

Case study (example)

NBIOME: Classification of Canada's Land Cover



A major initiative of the Canada Centre for Remote Sensing is the development of an objective, reproducible classification of Canada's landcover. This classification methodology is used to produce a baseline map of the major biomes and land cover in Canada, which can then be compared against subsequent classifications to observe changes in cover. These changes may relate to regional climatic or anthropogenic changes affecting the landscape.

The classification is based on NOAA-AVHRR LAC (Local Area Coverage) (1km) data. The coarse resolution is required to ensure efficient processing and storage of the data, when dealing with such a large coverage area. Before the classification procedure, cloud -cover reduced composites of the Canadian landmass, each spanning 10 day periods are created. In the composite, the value for each pixel used is the one most cloud free of the ten days. This is determined by the highest normalized difference vegetation index (NDVI) value, since low NDVI is indicative of cloud cover (low infrared reflectance, high visible reflectance). The data also underwent a procedure to minimize atmospheric, bidirectional, and contamination effects.

The composites consist of four channels, mean reflectance of AVHRR channels 1 and 2, NDVI and area under the (temporal NDVI) curve. 16 composites (in 1993) were included in a customized land cover classification procedure (named: classification by progressive generalization), which is neither a supervised nor unsupervised methodology, but incorporates aspects of both. The classification approach is based on finding dominant spectral clusters and conducting progressive merging methodology. Eventually the clusters are labelled with the appropriate land cover classes. The benefit is that the classification is more objective than a supervised approach, while not controlling the parameters of clustering, which could alter the results.

The result of this work is an objective, reproducible classification of Canada's land cover.