2024 Forestry

STUDY RESOURCES

2024 NCF-ENVIROTHON
NEW YORK

Forestry

Table of Contents

NCF-Envirothon 2024 New York

Forestry Study Resources

Key Topic #1: Plant Biology and Growth

1. Explain the fundamentals of plant biology as they apply to trees and other common plants.
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).

Study Resources

Resource Title	Source	Located on
Tree Anatomy and Functions	*Canadian Light Source, Trans-Canadian Research and Environmental Education (TREE), 2023*	Pages 4-13
Forest Environment: Tree Physiology	*Michigan State University Extension, 2001 (Revised 2019)*	Pages 14-31
Plant Physiology: Photosynthesis, Transpiration, and Respiration	*Master Gardner/ Colorado State University Extension, CMG GardenNotes #141, 2023*	Pages 32-34

Study Resources begin on the next page! ➡

Tree Anatomy and Functions

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.

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.

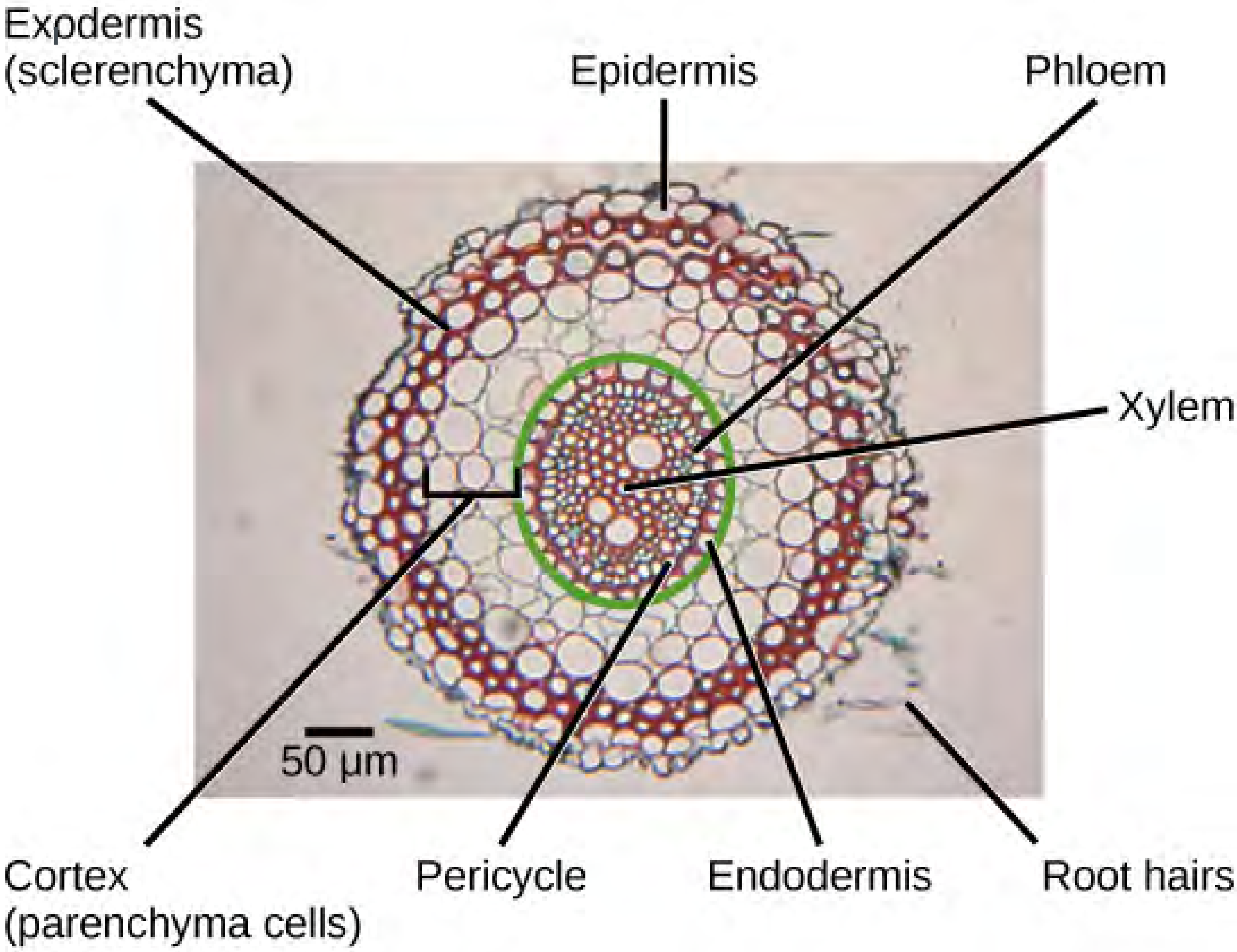


Figure 1 shows a cross-section of the cellular structure of roots. Image by CNX OpenStax.

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).

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.

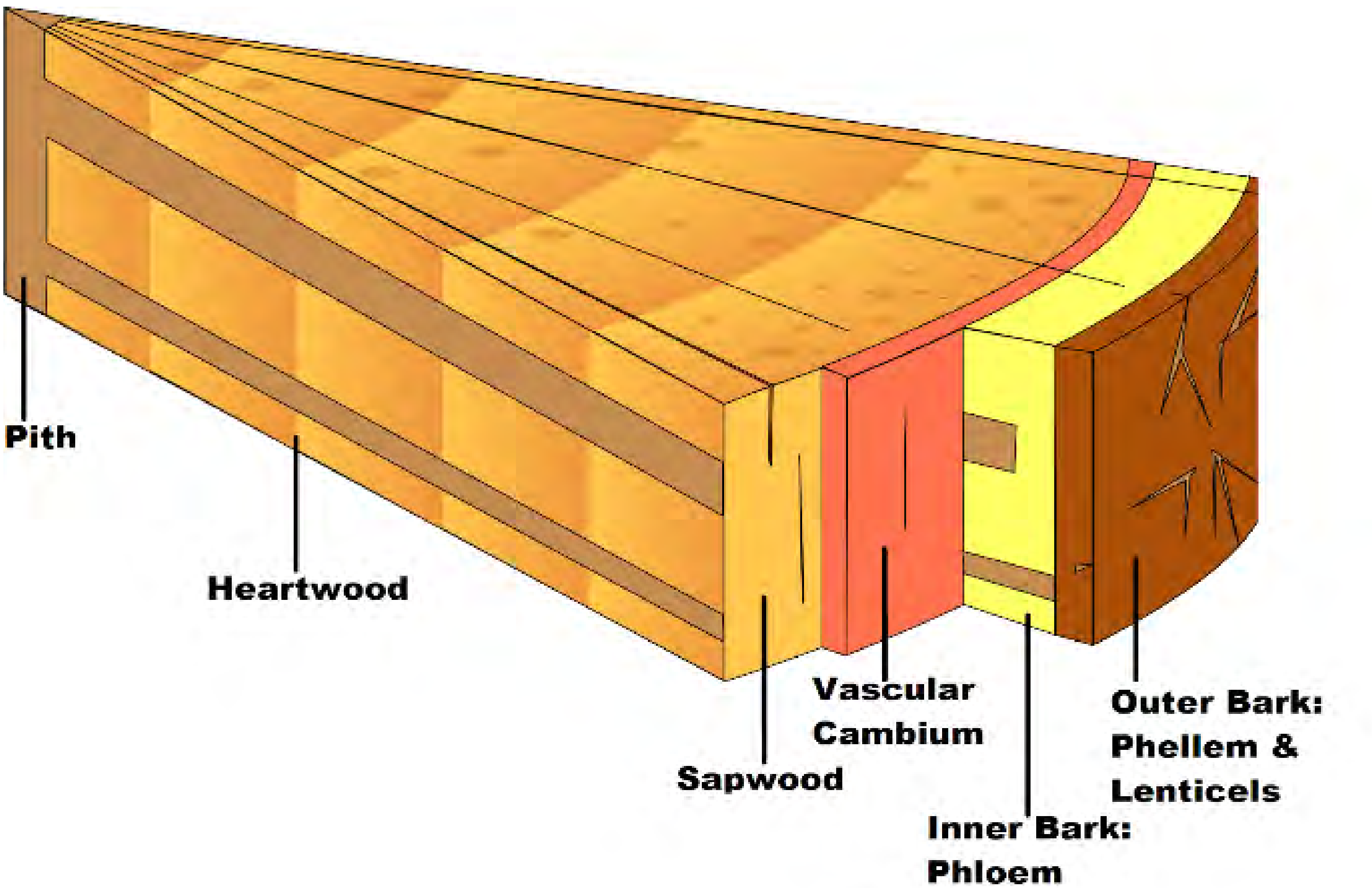


Figure 2 shows the anatomy of a tree trunk. Original image by Thomas Steiner.

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**.

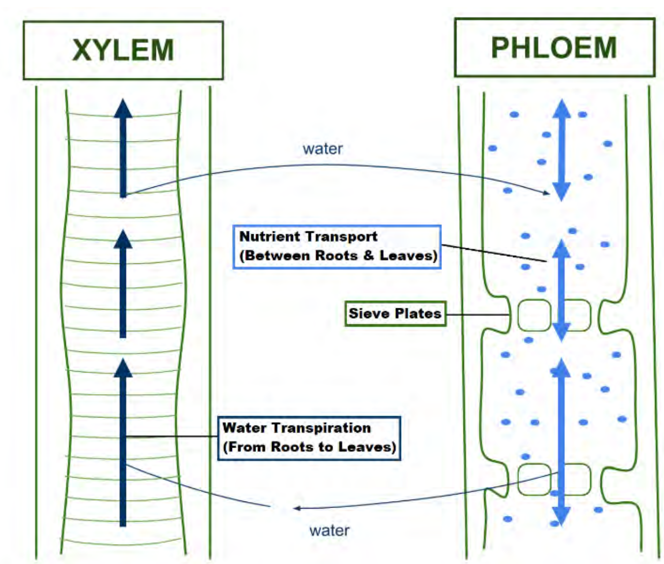


Figure 3 shows the inner workings of xylem and phloem. Image by KI3580.

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).

I

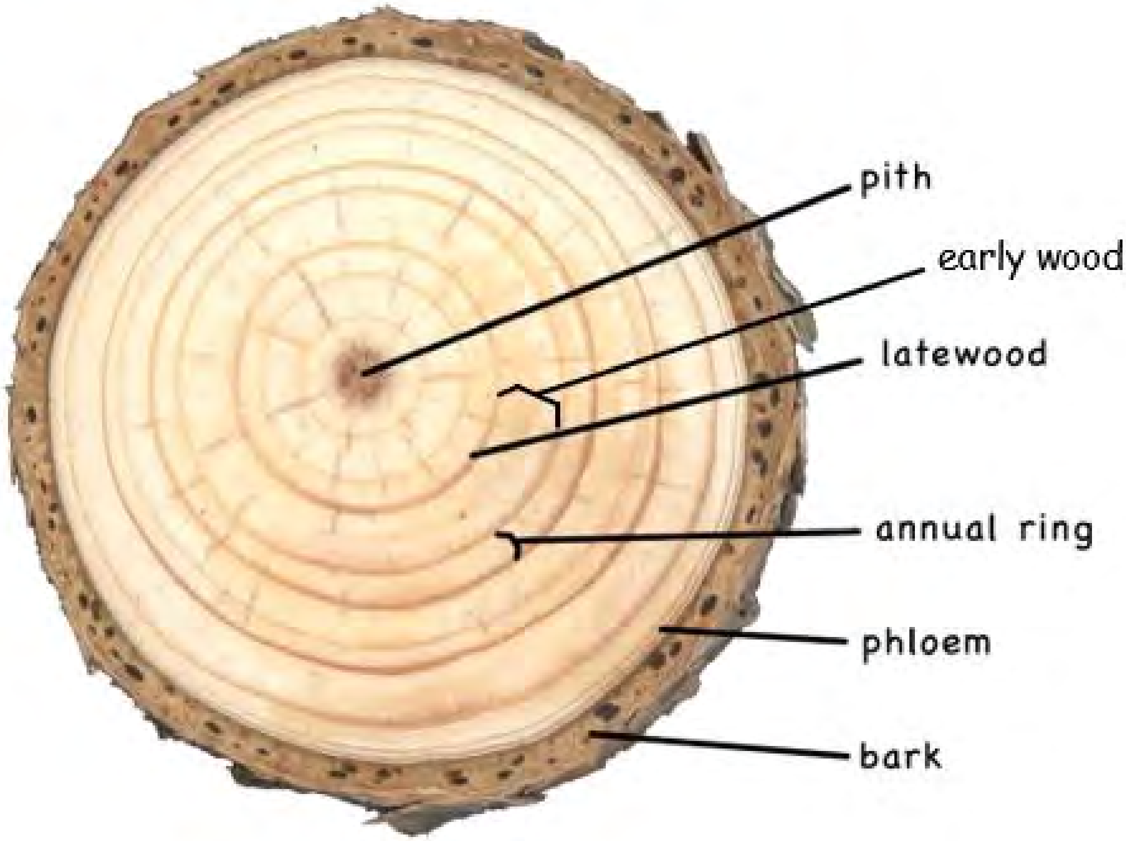


Figure 4 shows a cross section of a tree trunk, labelled with certain parts of the tree ring.

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).

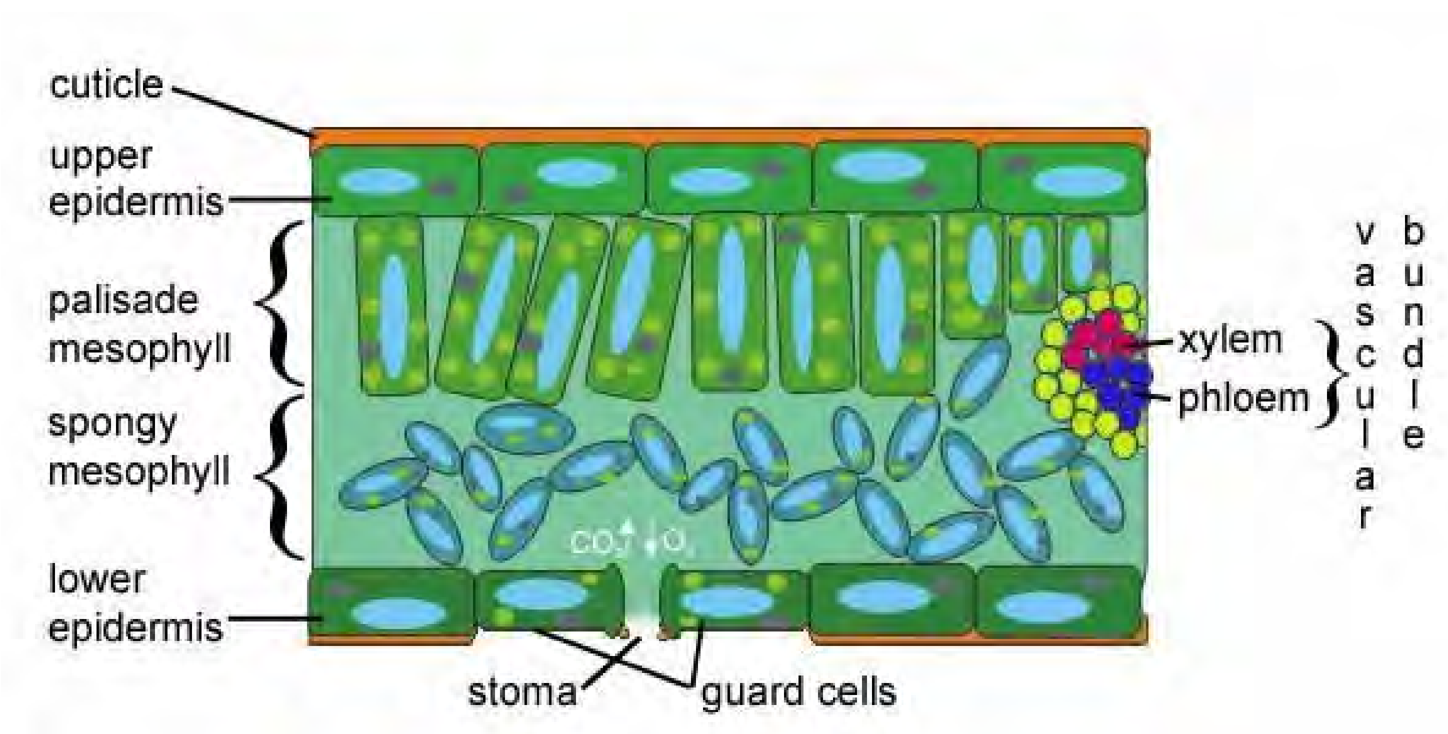


Figure 5 shows the cellular structure of leaves. Image by Maksim.

- **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.

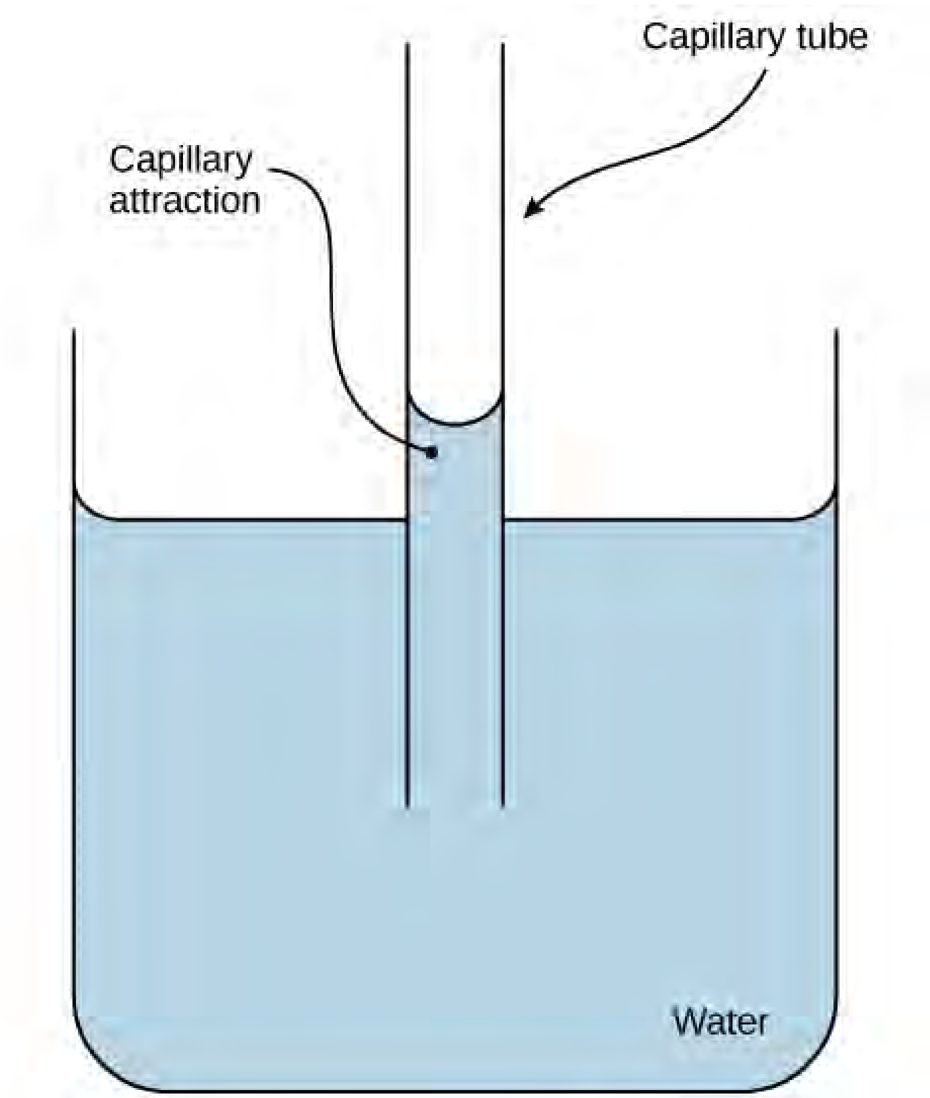


Figure 6 shows capillary action in action. The water inside the tube has lifted itself higher than the water outside the tube. Capillary action is why test tubes have a meniscus line. Image by CNX OpenStax.

TREE PHYSIOLOGY

Quite a bit of time is spent on tree physiology, which is key to understanding many of our forest management practices, especially the concepts of shade tolerance and vegetation succession. Additionally, the topics of forest health, hydrologic cycle, and nutrient cycles are discussed.

This is a fairly long section for several reasons. One, it provides the basis for much of what is addressed later in terms of forest management. Two, it has many connections to the Michigan Curriculum standards, particularly in science. Three, there are a lot of neat activities and observations associated with the topic.

Concept List:

The Necessities of Life
Tree Parts
Photosynthesis and Respiration
Chlorophyll
Tree Growth
Fall Color Change
Sunlight
Environmental Factors
Tree Regeneration Strategies
Longevity
Winter Adaptations

Little Known or Interesting Factoids About Tree Physiology

- *Trees both produce AND consume oxygen.*
- *Young forests capture more carbon from the atmosphere than old forests.*
- *Old forests have more stored carbon in the biomass than young forests.*
- *The food that trees produce for themselves are sugars.*
- *The purpose of photosynthesis is to capture and store energy.*
- *Green light is the only part of the visible light spectrum that plants can't use.*
- *The timing of Autumn color change is largely controlled by lengthening nights.*
- *Conifers lose needles each fall, just the same as broad-leaf trees.*
- *Trees grow TWO rings each year, one in the spring and another during the summer.*
- *Swamp trees don't necessarily prefer swamps.*
- *Tree species have highly variable requirements for light, nutrients, and moisture.*
- *Oceans produce more oxygen and store more carbon than forests.*

Some Important Terms

- Photosynthesis
- Respiration
- Oxygen
- Carbon Dioxide
- Trophic Level
- Food Chain
- Chlorophyll
- Anthocyanin
- Carotenoid
- Abscission Layer
- Cambium
- Meristem
- Annual Rings
- Spring/Summerwood
- Cellulose
- Mycorrhizae
- Producer
- Consumer
- Glucose
- Shade Tolerance
- Crown
- Canopy
- Compartmentalization

The Necessities of Life

The following is brief discussion of each of six key requirements for trees. More detail of some topics is found later in this guide.

1. **Sugars** supplied by photosynthesis. Air and water are chemically recombined to form glucose, which stores energy captured from the sun. Oxygen is a byproduct.

2. **Water** is required for most metabolic activities and serves as a vehicle to carry materials through a tree. A large tree may move as much as 50-100 gallons of water on a hot summer day.

3. **Nutrients**. It's not how much of a particular nutrient exists in the environment, it's a matter of how *available* the nutrient is to the tree. For example, the atmosphere is largely composed on nitrogen, but trees can only use nitrogen in forms that have been altered by soil bacteria and other organisms. The major chemical elements used by plants are: carbon, hydrogen, oxygen, phosphorus, potassium, nitrogen, sulfur, calcium, iron, and magnesium. You might be able to remember this by a jingle formed using the abbreviations for these elements: C H O P K N S Ca Fe Mg . . . "see hopkins café, might good."

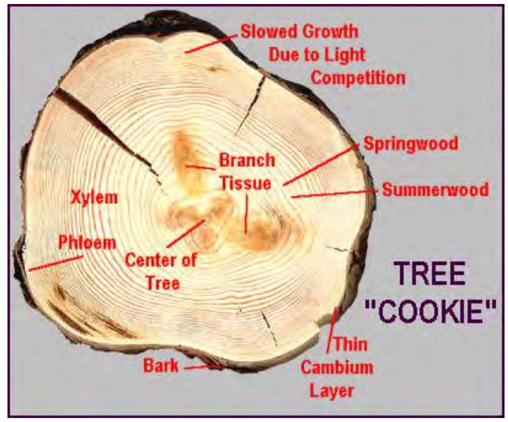
4. **Hormones and enzymes**. These chemicals are critical in the controlling the timing and activity of physiological processes. They are usually produced in the roots or leaves. We don't often think of plants having "hormone" deficiencies, but they are critical to the survival of any organism, including trees.

5. **Mycorrhizae**. Pronounced *"my-core-HI-zee",* this a group of beneficial fungi associated with most tree roots. It represents an ecologically symbiotic relationship where the fungi receive food from the tree and the trees receive greatly enhanced nutrient and water absorption. Mycorrhizae will also protect tree roots from other invading fungi. There tends to be very specific species relationships between fungus and tree.

6. **Environmental factors**. A tree needs an appropriate mix of precipitation, temperature, sunlight, and soils in order to thrive. These factors need to occur at the right time. Each tree species has a different set of environmental requirements. Changing climate will lead to changing environmental factors, which can lead to changes in forest ecosystems.

Tree Parts

The parts and structure of a tree has obvious components and some not so obvious components.



What makes a tree a tree?

First, a tree has all the characteristics of green plants. Beyond that, a tree is a tall plant with woody tissue. It has the capability to "push" its crown (the primary location for photosynthesis) above other vegetation competing for light. Also, most people don't readily connect trees with having **flowers** but they do, although our conifers (pines, spruces, firs, etc.) don't have true flowers with petals. The reproductive structures of each species are particularly unique and are used more than any other structure to categorize trees. This categorization is called **taxonomy**. The tree identification chapter talks more about taxonomy.

> ***Definition of a tree:*** *A woody perennial plant, typically large and with a well-defined stem or stems carrying a more or less definite crown -* **note**, *sometimes defined as attaining a minimum diameter of 5 inches and minimum height of 15 feet at maturity with no branches within 3 feet of the ground.*
>
> *-Society of American Foresters, 1998*

A tree has a dilemma in terms of gathering its resources. It has a distinct light-gathering advantage of having its leaves high above other plants, but there is the problem of getting water and soil nutrients to the upper tissues. The microenvironment in the upper canopy is also rather hostile to sensitive tissues. At the other end of the tree, the roots are dependent upon materials produced way up in the crown. This problem, of course, is solved by the structure of the tree **trunk, or bole**, a most distinctive feature of trees.

Most of a tree trunk is dead woody tissue and serves only to support the weight of the crown. The very outside layers of the tree consists of bark. Underneath the bark is a **cork cambium** layer that generates new bark. Under the cork cambium lies a thin band of **phloem**, which is living tissue that transports materials from the crown to the roots. Under the phloem is another **vascular cambium zone** that produces both new phloem cells and new xylem cells. The wider band of **xylem,** or **sapwood,** transports water to the crown, but is not necessarily living. The innermost portion of the trunk is non-living **heartwood**, which is a repository for many waste products of the tree's living tissue. Only a thin band around the trunk, roughly a centimeter wide, is living tissue.

Each year, a tree grows a pair of **annual rings** (TWO rings each year!). In the spring, the usually wider and thinner-walled layer grows. It is called "**springwood**". In the summer, through about mid-July, a usually darker and thicker-walled layer is produced. It is called "**summerwood**". Annual rings are typical in temperate forest trees and tropical forest trees that have regular, annual dry seasons. In tropical humid rainforests, trees grow continually and do not have rings. The oldest portion of a tree is at the bottom and on the inside.

Parts List

Without going into a lot detail, important parts of a tree are:

Leaves	Broad-leaf or needles, the primary site of photosynthesis and the production of hormones and other chemicals
Twigs & Branches	Support structure for leaves, flowers, and fruits. Arrangement varies from species to species by growth strategy. Can sometimes have photosynthetic tissues. Two kinds of growth tissue, at the twig tips and cambium under the bark.
Crown	The upper region of the tree made up of leaves, twigs, branches, flowers, and fruits. Crowns of many trees are collectively called the "canopy".
Flowers	May have both female & male parts, or only or the other. Some trees are either all female or all male (i.e. aspen). Flowers may have a full complement of flower parts, or may be missing certain elements. Conifers do not have petals and associated structures.
Fruits & Seeds	All trees have seeds. Most trees have seeds inside fruits. Most fruits are NOT edible, but many are, such as apples, cherries, nuts, etc.
Trunk or Bole	Most definitions of trees include a "single bole" concept, but many of our tree species sometimes occur with multiple stems. The main functions of a trunk are transport and support. The trunk has growth tissue called cambium.
Bark	A highly variable tree part. The main function is to protect the sensitive living tissues from weather and predation (by animals, insects, fungi, etc.)
Roots	Roots serve two main functions; collection of nutrients and water, and anchoring the tree. Roots also have growth tissue, bark, and wood. Like twigs and branches, roots have two kinds of growth tissue, at the twig tips and cambium under the bark. Fine root hairs are where absorption occurs.

Tree Growth

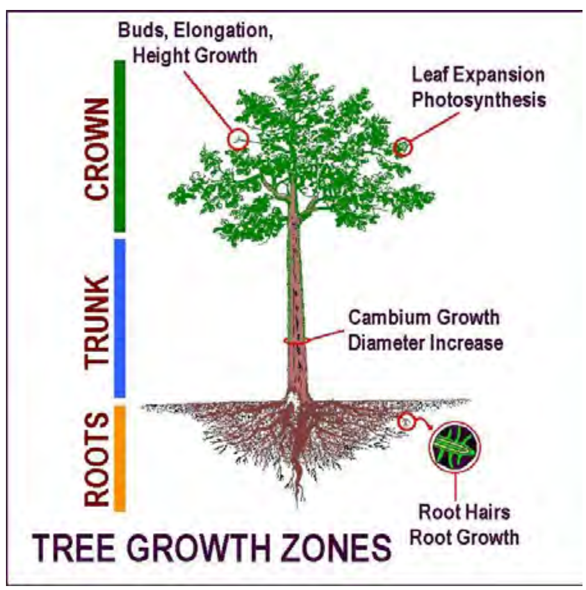
So, photosynthesis produces all this glucose. . . what then? Essentially, the energy in glucose is used by trees (and most other living things) to drive metabolic processes that produce tissues and maintain life functions. Keep in mind that this whole thing called life is a big solar powered system!

A tree will draw nutrients and minerals from the soil, break them down and put them back together to form compounds and chemicals that we recognize as a tree. The most common material made by a tree is "cellulose." Cellulose is a complex sugar that is the main component of wood and many other plant tissues. It's also an extremely useful material for lots of human uses, such as food products, paper, strengthener in plastics and concrete, clothing, and other things.

Wood is the answer to the tree challenge of pushing a crown as high as possible to obtain the best light-capturing position as possible, while maintaining a connection with water and nutrient supplies in the soil.

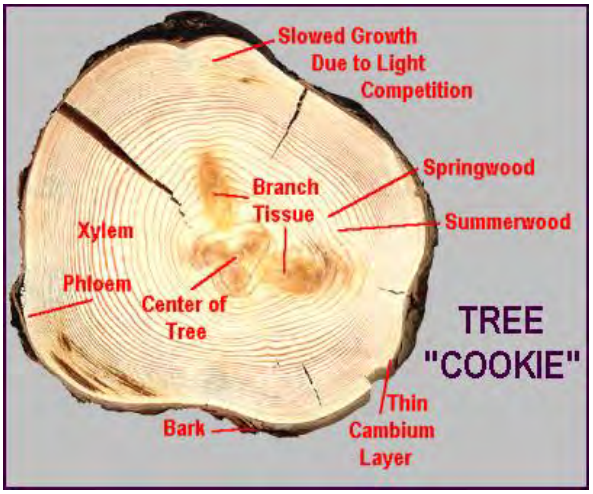
Where does a tree grow? In three places.

- At the twig tips (meristem).
- At the root tips (meristem).
- Around the outside of the trunk, branches, and roots (cambium).



A tree with growth zones illustrated, branch meristem, root meristem, cambium.

One region of tissue expansion or tree growth is at the tips of both twigs and roots, called the "meristem." This is unspecialized tissue that can form wood, buds, or flowers. Each year, trees will lengthen twigs and roots, produce flowers and fruit, and grow new buds. The meristem and newly produced tissues are rich with nutrients and are often the target of attack by diseases, insects, and animals. Deer, for example, are Michigan's most significant browser. In areas of high populations, deer can destroy years of growth on small trees and entirely eliminate regeneration.



Most of a tree trunk, branch, or root is dead wood. The living part is only a narrow band on the outside edge. This living layer is produced by thin bands of regenerating tissue called "cambium." Cambium produces new wood on the inside and new bark on the outside. The cambium grows only from the inside out, not up or down the length of a trunk, branch, or root. For awhile, the new wood and bark are living. The wood actively transports many materials up and down the tree and performs other functions. After the wood dies, it still serves as a transport route for several years. Eventually, even that function is diminished and the wood serves primarily as structural support.

Each year the cambium produces TWO distinct rings of tissue. In the spring, a layer of thinner-walled cells are grown. In the summer, a layer of thicker-celled, sometimes larger cells are grown. The layers are called "springwood" and "summerwood," respectively. When counting the age of tree "cookie," either the springwood or summerwood rings can be counted, but don't count both (unless you divide your sum by two!). Most people count the typically narrower and darker summerwood. Tree such as oaks, ashes, and all the conifers produce fairly distinct rings which are easy to count. Other trees, such as aspens, red maple, and birch have less distinct rings. Foresters can count rings without cutting a tree down. A tool called an "increment borer" will extract a thin wood core from the tree, which can be used to age the tree.

Why do leaves change colors in the Autumn?

The short answer is that chlorophyll production drops-off as night length increases. The green part of the light spectrum is no longer reflected and other compounds, chemicals called "**anthocyanins**" (reds) and "**carotenoids**" (yellows), become the dominant pigments in the leaves. The longer answer involves discussions of changing day lengths and weather, and strategies dealing with nutrient loss with the dropping of leaves.

Project: *Have kids collect different colored leaves in the fall. Categorize leaves by species and color. The same species may have many different colors, especially red maple. Also, have kids record the dates when trees at home, at school, or in another selected place begin to change color. Make notes by species and see if any patterns can be observed. It would be interesting to have a "sister" school in a different part of the state to compare color change with.*

What is the story behind Autumn leaf fall?

The purpose of Autumn leaf fall is to prepare for **winter dormancy**. The cold temperatures prevent trees and plants from functioning in at least three ways. Water would freeze in the plant tissues, causing cell rupture. Water in the upper soil layers often freezes, making absorption impossible. Lastly, the low temperatures are far outside the operating windows for the enzymes that control a tree's metabolic processes, such as photosynthesis and respiration. To avoid these environmental limitations, trees prepare for dormancy in the Autumn.

Trees drop leaves because they are too difficult to "winterize" (unlike most conifers that have strategies to maintain their green parts during the winter and needles have a much different structure than broad leaves). Or, in the case of conifers, the needles that have grown old after two to three years, no longer receive as much light, and are shed each Autumn. However, dropping tons of biomass per acre presents the problem of losing significant amounts of valuable nutrients. Much of the sugars and valuable nutrients are resorbed from the leaves, but the annual leaf drop still means the loss of a lot of good "stuff." In our north temperate climates, dropped leaves become part of the "organic layer" on the surface of the soil, to be recycled (in part) by decomposers.

There are two components influencing the Autumn color display, the **timing** and the **intensity**. The timing is usually controlled by lengthening nights and the intensity is strongly influenced by weather.

The most dependable seasonal environmental factor is the change in daylight, or more accurately, the lengthening dark period. Such things as rainfall or temperature might "fool" a tree into retaining leaves too long. For this reason, the timing of leaf-drop is regulated by the consistent movement of the Earth around the Sun. However, a late spring or extremely dry summer can postpone the response to lengthening nights by a week or two. Just "when" a tree begins to turn color varies from species to species, and geographically from north to south. In our northern forests, black ash is the first to change color. Tamarack (a needle-bearing tree) is the last.

The intensity or brilliance of the color change is influenced by weather conditions during the period of declining chlorophyll production. A series of sunny days and cool nights (above freezing) result in a more colorful display. The warm days increase production of both sugars and anthocyanin pigments. Sugars "stranded" in the leaf and greater concentrations of anthocyanins bring out the scarlets and reds, especially the deep purple of northern red oak. Carotenoids yield the yellow and golden colors but tend to remain at fairly constant concentrations regardless of weather.

So, how might weather affect the fall colors?

- Warm Autumn weather will generally reduce the color quality.
- Moist soils following a good growing season contribute to better displays.
- A few warm, sunny days and cool nights (at the right time) will increase brilliance.
- Droughts will usually result in poorer displays.

What causes the leaves to actually fall off?

Wind, most commonly. As nights lengthen, a layer of cells forms in the leaf stem near the twig, called the "**abscission layer**." Abscission means cutting or severing. This layer blocks transfer of materials to and from the leaf. The abscission layer also makes a weakened connection. Eventually, wind, rain, snow, or animals will knock the leaf from the twig.

Sunlight and Tolerance of Shade

It’s commonly known that trees and plants need sunshine to live. However, not all trees need the same amounts of sunlight. Trees that require high amounts of sunlight are sensitive to shade. Foresters call this sensitivity "**shade tolerance**" or just "**tolerance**". The shade tolerance of some tree species will vary with age.

Tree species such as **aspen, cherry, paper birch, jack pine, and red pine** require lots of sun and are not tolerant of shade. That’s part of the reason stands of these species tend to be all about the same age. Seeds of these species that germinate under a canopy of shade do not survive.

Other tree species are more tolerant of shade, such as **sugar maple, beech, balsam fir, hemlock, and cedar**. They can survive as seedlings or saplings under a fairly heavy canopy of shade for many years. When exposed to light, the small trees (not always young trees!) can quickly grow to take advantage of the new light regime.

There are a number of tree species that fall into the moderately tolerant category, such as **red oak, red maple, yellow birch, white ash, white pine, and white spruce**. The may be able to grow under the light canopy of an aspen or paper birch stand, but would not be very successful under the shade of a maple-beech-basswood stand.

Relative Sunlight Requirements For Representative Tree Species	
Paper Birch *Tamarack* *Jack Pine*	☀ ☀ ☀ ☀ ☀
Quaking Aspen *Silver Maple* *Red Pine*	☀ ☀ ☀ ☀
Red Maple *Red Oak* *White Pine*	☀ ☀ ☀
Yellow Birch *Balsam Fir* *White Spruce*	☀ ☀
Sugar Maple *Basswood* *Cedar*	☀

Shade tolerance is key component of forest management systems.

Other Environmental Factors

There are many environmental factors, both living and not living, that influence the growth of trees. This guide has already discussed some of them, such as light, nutrients, and temperature. Many of these factors interact with other. That's part of the reason why forest management can be complex. Tree adaptation to various environmental factors runs along gradients. Some tree species are more sensitive to a particular gradient than others.

Rainfall or Precipitation

Average annual rainfall varies across a wide geographical area. Some tree species can survive with less annual precipitation. As you move north and west, rainfall declines, and so do the number of tree species. More locally, *available* water may vary with microsites. The south sides of slopes will be drier, so will a sandy plain or areas with bedrock close to the surface.

Soil Variability

Scientists have identified over 475 soil types in Michigan. It stands to reason that different tree species have preferences for certain types of soil. Red pine and jack pine are well-known for their ability to grow well on sandier, poorer soils where most other trees grow poorly. Sugar maple and basswood prefer richer soils with lots of nutrients. Other species, such as bur oak and quaking aspen grow well on a wide variety of soils. This variability is largely related to the amount of available nutrients in a soil, the nutrient demand of a particular species, and a tree's ability to extract those nutrients.

Moisture

This is related to both rainfall and soils. The amount of *available* moisture varies during the year. High moisture levels during the dormant season will not help trees. Or usually hurt them. Saturated conditions from spring runoff or flooding does not hurt most trees because they are not actively growing. Some tree species are more tolerant of short periods of flooding during the growing season, such as bur oak or silver maple. Oddly enough, white cedar is quite sensitive to rapid changes in moisture, either wetter or drier. Northern swamp tree species grow on small, dry microsites. They don't usually grow in the water.

Biotic Factors

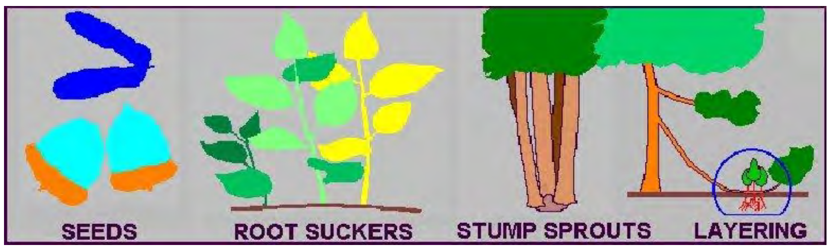
These are the living parts of an ecosystem that trees interact with. Other plants will impact forests. Insects and diseases play a major role in forests. Animals like white-tailed deer, porcupines, and squirrels also have prominent roles. Not all of these impacts are negative. Many are beneficial. Insects pollinate tree flowers. Soil animals loosen soil. Birds eat lots of insects. And of course, humans manage forests for a wide variety of reasons.

Mycorrhizae

Pronounced *"my-core-HI-zee"*, these are beneficial fungi to trees. The fungi are associated with tree roots in a **symbiotic** relationship. That's where both partners benefit from each other. The mycorrhizae increase a tree's ability to absorb water and nutrients. The tree supplies the mycorrhizae with a share of photosynthate. Sometimes, species of mychorrizae are only associated with a particular species of tree. The lack of proper mycorrhizae in the soil can prevent a tree from growing well, or maybe from surviving at all. It may be one of the factors that limit trees to a certain range. Scientists are learning more about these special fungi.

Tree Regeneration Strategies

There are four ways Michigan trees regeneration themselves.



- Seeds
- Root Suckers
- Stump Sprouts
- Vegetative Layering

All trees can reproduce by seeds. Each species has a unique set of requirements for seed production and germination. Seed dispersal strategies vary widely, from wind-driven seed to seeds carried by certain species of animals.

Sprouts and suckers are similar, in that dormant buds "come alive" to form new shoots of parent trees. Sprouts are shoots from stumps or the base of a tree. Suckers are shoots that originate from buds on the root systems. Often times, sprouts and suckers will not grow until the parent tree dies or becomes very sick. The buds are held in dormancy by hormones produced in the leaves. When these hormone levels drop below a certain point, the dormant buds will grow.

Vegetative layering is uncommon, occurring mostly in white cedar and Canada yew (which most would not consider a tree!). When branches or stems come in contact with the soil, cambium tissue sometimes form roots. In this way, former branches of a fallen cedar might become trunks of several "new" trees.

Tree Longevity

Trees do not live forever, therefore cannot be "preserved." A forest condition, or forest type might be preservable (if managed), but not individual trees. While people know that all living organisms eventually die, often times this is not taken into account when people consider forests.

Tree longevity varies from about 70 years to over 1000 years, depending upon the species. Most trees do not live past 50 years (or 10 years, for that matter), if you consider attrition from the time of germination. Short-lived species tend to be **successional "*pioneers*"**, or trees that first colonize an unforested site. Aspens, paper birch, cherries, jack pine are examples of short-lived tree species. They also tend to be intolerant of shade. Long-lived tree species tend to be more shade tolerant, occupy later stages of succession, and employ more "conservative" survival strategies. Sugar maple, basswood, beech, and white cedar are good examples.

Succession: The orderly and predictable series of vegetation type changes over time. Primary succession begins with bare soil, or nearly so. Secondary succession begins at some point earlier in the process than what was present before. Succession is a critical concept in developing *forest management systems*.

Note: "Succession" is further explained in another chapter in this guide and is one of the most important concepts in forest ecology.

Most Common Michigan Tree Species (by volume) and Their Expected Lifespans (in years)
Note: Maximum lifespans may exceed the ages listed.

Sugar Maple	200-300	Balsam Fir	70-100
Red Maple	125-150	White Oak	400-500
Quaking Aspen	60-90	Eastern Hemlock	400-500
Cedar	400-600	Jack Pine	80-100
Northern Red Oak	200-300	Yellow Birch	200-300
Red Pine	200-250	Black Cherry	150-200
Bigtooth Aspen	75-100	White Ash	unavailable
Basswood	125-175	American Beech	300-400
Paper Birch	70-100	White Spruce	150-200
White Pine	250-300	Black Spruce	200-250

Winter Adaptations of Trees

Trees must have adaptations to survive the cold and drying conditions of winter. Trees cannot change their location or behavior like animals can, so they must rely on physiological and structural adaptations.

The height advantage of trees becomes a liability in the winter, as tissues are exposed to the weather. There are four basic strategies that trees employ.

1. Either leaf drop or adaptations for leaf retention.
2. A physiological acclimatization process.
3. Resolution of water issues.
4. Methods of reducing mechanical damage.

Stomate: Small openings in leaves that permit the passage of air for respiration and photosynthesis. Leaves have the ability to open and close stomates.

Broadleaf trees (hardwoods) drop their leaves during the winter, avoiding the problems of maintaining foliage in cold and dry conditions. Conifers (softwoods) retain foliage and have special adaptations in order to do so (better stomate control and a waxy coating called cutin).

All trees go through an acclimatization process. Like leaf drop, the process is initiated by changes in photoperiod and is controlled by hormones and other chemicals. The process also exploits the physical properties of water.

Winter conditions make finding sources of liquid water and transporting water a challenge. Water loss is minimized in several ways. Water can be obtained from the ground, within the tree, or from the subnivean (under snow) micro-environment. Conifers have special cell adaptations to facilitate water transport whenever temperatures allow it.

Snow and ice accumulation can cause breakage, especially under windy conditions. Conifers have growth patterns that minimize the chances of damage occurring. Dramatic loss in vegetation from animal consumption increases pressure on woody tissues, especially foliage, buds, and bark. Browse damage can be significant in many regions of Michigan. Lastly, pollutants from highways, particularly road salts and exhaust, can damage trees, especially those more vulnerable to these chemicals.

A More Detailed Explanation of Winter Adaptations of Trees

Trees must have adaptations to survive the cold and drying conditions of winter. Trees cannot change their location or behavior like animals can, so they must rely on physiological and structural adaptations.

The height advantage of trees becomes a liability in the winter, as tissues are exposed to the weather. There are four basic strategies that trees employ.

1. Either leaf drop or adaptations for leaf retention.
2. A physiological acclimation process.
3. Resolution of water issues.
4. Methods of reducing mechanical damage.

Leaf Drop

Leaves are a major source of water loss and are difficult to protect from winter conditions. Most trees drop leaves in the autumn to avoid these problems. Conifers are the exception and will be looked at in the next section.

Annual leaf and flower expansion requires tremendous inputs of water and nutrients. Trees must produce and store a sufficient amount of reserves during the four to five month period when leaves are photosynthesizing. Buds are usually set by the end of July. Above-ground growth also ceases in late summer.

Physiological processes, including leaf drop, are stimulated largely by changes in photoperiod. The lengthening dark period changes the production rates of a number of chemicals and hormones. The most important is probably the increase in abscisic acid (AA). AA slows protein and RNA (ribonucleic acid) production. Both are keys parts of growth. AA also increases cell membrane permeability, which is important in the acclimation process.

Chemical breakdown of the green chlorophyll molecules reveal the pigmentation of the yellow and orange carotenes and xanthophylls. The scarlet colors are enhanced by hard frosts affecting residual sugars and anthocyanins.

Abscission layers between the leaf stem and the twig are formed. Cells along this line expand at different rates, and enzymes degrade tissue. As a result, a physical line of weakness develops. Scar tissue is formed over the attachment point that prevents water loss. Gravity and wind cause leaves to drop.

Not all trees lose their leaves at the same time. Black ash is usually the first to drop leaves. Some species will retain brown leaves well into the winter, especially oaks, ironwood, and beech. In May of each year, leaf growth can be tracked by species. Black ash and bigtooth aspen are among the last tree species to leaf-out.

Adaptations For Leaf Retention

In the north temperate forest, all broad-leafed trees lose their leaves. Each year conifers also drop leaves, similar to broad-leafed trees, they just don’t shed them all. Most conifers retain needles for two to three years before shedding them. Although conifers require the resources to produce new needles each year, they gain a large measure of economy by using a set of needles for more than one year. The coniferous exception to this needle-retention strategy is the genus Larix, the tamaracks and larches.

Conifer needles have a thick, waxy coating of cutin that significantly reduces water loss. Needles also have much tighter stomatal closure. Stomata are the pores that allow air and water to pass in and out of the needle. Lastly, tissues undergo an acclimation process, similar to other living tissues in trees.

Retaining needles allows trees to extend the length of the photosynthetic season. It also potentially allows trees to take advantage of winter thaws and, perhaps, even to permit slow rates of photosynthesis during cold weather. However, needle retention presents serious challenges in terms of water loss, water re-supply, and snow-loading.

Acclimation

Loosely analogous to animal hibernation, trees undergo changes that allow them to survive the cold, dry conditions of winter. This process occurs at the cellular level and exploits the physical properties of water.

All trees have a measurable "killing temperature", the temperature where ice crystals form within cell structures resulting in cell death. Killing temperatures vary among different species, between populations of the same species, and even among different tissues. In some cases, killing temperatures are limiting factors for species ranges.

Tree Species With Northern Ranges Limited By Killing Temperatures	Tree Species With Killing Temperatures Below Average Low Temps	Tree Species With Adjustable Cold Tolerance
Northern Red Oak	Eastern Hemlock	White Pine
American Beech	Northern White Cedar	White Ash
Black Cherry	Black Spruce	Green Ash
Sugar Maple	Balsam Fir	Red Maple
Yellow Birch	Tamarack	
Musclewood	White Pine	
White Ash	Jack Pine	
Ironwood	Red Pine	
	Eastern Cottonwood	
	Quaking Aspen	
	Black Willow	
	Paper Birch	
	Basswood	
Source: Marchand (1996).		

Like leaf-drop, acclimation is prompted by changes in the photoperiod. Abscisic acid (AA), once again, plays a key role. Physiological changes include:

1. An increase in AA production.
2. Lipids (soluble fats) unsaturate.
3. Lipid concentration within cells increases.
4. Proteins de-polymerize.
5. Cell membrane permeability increases.

Solute concentrations within cells increase, slightly reducing the freezing point. Therefore, as temperatures drop, water outside cells freezes first. Freezing water releases small amounts of heat energy, which in turn, helps cell fluids remain unfrozen. Twig temperatures actually rise several degrees during this process. Water moves out of cells attracted to the ice crystals in the pore spaces. This process effectively reduces the freezing point of cell water to the killing temperature. Colder temperatures will begin to result in cell freezing and death.

Water Loss

Water is lost primarily from above-ground biomass. Bark and buds are fairly water-tight. Drastically lower levels of photosynthesis and respiration reduce water demand and subsequent loss. Conifers, however, have huge surface areas of living tissue in their needles. Any photosynthesis that might occur will increase water demand and risk of loss.

Water vapor moves from areas of high concentration to low concentration. Concentrations are usually higher inside needles, so the tendency is for water to be lost from foliage. Needles have advanced structures to present a barrier to water loss, but cannot eliminate it. In addition to tight stomatal closure and cutin, reduced air movement around needles will contribute to lower vapor gradients. Air “boundary layers” act like insulation. The dense foliage of conifers, especially stands of conifers, serves to mediate micro-environmental conditions somewhat. The fuzzy undersides of evergreen broad-leaf shrubs serve to increase this zone of “insulation”.

Oddly enough, warm, sunny days present the greatest water retention challenges for conifer foliage. Dark needle coloration readily absorbs heat and raises needle temperatures significantly above ambient air temperatures. Metabolic rates rise and internal vapor pressure increases. Despite thicker air boundary layers, the net effect is greater water loss.

Cloudy, windy days are actually better for conifers. Clouds block warming solar energy and wind readily removes heat from the needles, reducing the vapor pressure gradient.

Water Supply

Conifers have larger winter water demands than most broad-leaf trees (some hardwoods have photosynthetic bark and branches, which increases water demand). Without re-supply sources, trees would die from water loss. However, freezing temperatures and frozen water would make re-supply seem impossible.

There are three potential sources of water; 1) the soil, 2) internal tree reservoirs, and 3) subnivean (below snow) vapor absorption.

Soils are not always frozen. In fact, much of Michigan's soil remains unfrozen for all or part of the winter. The insulating effects of snow can result in ground thaws or prevent freezing in the first place. This means that liquid water is available. Transportation above-ground becomes an issue, discussed later.

The sapwood of trees and branches contains water. Oftentimes, this water is frozen and unavailable. However, differential warming (solar insolation) and winter thaws can melt the sapwood water, making it available for transport.

Lastly, conifer branches below snow-level might benefit from higher water vapor concentrations *outside* the foliage. Potentially, this absorbed water could be transported to other locations in the tree.

Water Transport

Given that liquid water sources exist during the winter, the problem of transport remains. Water cannot be moved while frozen, so temperatures along a transport line from source to sink must be near or above freezing.

Water is moved within a tree through the xylem, which consists of cells that make up long tubes, called tracheids. The strong cohesive properties of water permit continuous columns of water to be "pulled" through the tracheids. If a water column is broken, it is virtually impossible to restore the column.

When tracheid water freezes, two things potentially break the water column. Ice crystals stop the flow. More importantly, as ice forms, dissolved gases are expelled and form gaps in the column. Upon thawing, these air gaps remain, rendering the column unusable for water transport. Hardwood (broad-leaf) trees grow new xylem cells in the spring to re-establish the water transport system.

Conifers have some fascinating adaptations that overcome the problem of broken water columns.

Within the transport tubes, conifers have tiny "check valves" between each tracheid. Ice formation and volume expansion increase pressure within a water column causing the "float" within the check valve to seal the ends of each tracheid making up a tube. The float is called a "torus". The expelled gas is held under pressure within the tube by the incredibly strong tracheid walls. Measurements have demonstrated that the tracheids can hold pressure up to 900 psi. When the ice crystals melt, the gas is forced back into solution, pressure returns to normal, the tori migrate back to the middle of the check valve, and the water column is restored.

Water column restoration in conifers can occur multiple times during the winter during warm periods or when solar insolation is high. Foliar water stress caused by those warm, sunny winter days can be alleviated by restored water columns supplying water from any of the available water sources.

In addition to the clever adaptations of conifer xylem cells, there is evidence suggesting that water can also be diffused from cell to cell via the phloem, in both hardwoods and softwoods (conifers). Diffusion is slow but may be sufficient to meet the water demands of dormant hardwood species that appear to have no other winter water transport system. This may help explain why some hardwood species, such as paper birch, can survive winter conditions right up to the treeline.

Other Winter Season Challenges to Survival

Conifers have higher leaf densities than hardwoods. This means snow can quickly accumulate to the point of stem and branch breakage. Ice storms can be even more detrimental. To offset this snow-loading problem, conifers display alternative growth and branching patterns.

Conifers have a single leader or main stem (determinant growth), as opposed to the many leaders of hardwoods (indeterminant growth). The subsequent cone shape more effectively sheds snow. Conifer branches grow at more obtuse angles to the main stem. This allows branches to reach snow-shedding angles with less bending. Longer wood fibers also generally provide more flexibility.

Denser conifer foliage offers greater wind resistance, potentially leading to breakage, especially when foliage is loaded with snow and ice. Trees on the perimeter of conifer stands take the brunt of wind damage, but the dense foliage also protects those individuals internal to the stand. This factor creates typical stand shapes in mountainous terrain, but is not as pronounced in Michigan. However, Michigan conifers sometimes do display “flagging” in the direction away from prevailing winds. Tall white pine are particularly noteworthy in this regard.

Many conifer species become targets for animal browsing during the winter. Foliage contains some of the better sources of nutrients, although they are poor compared to summer food availability. In many parts of Michigan, high deer densities have eliminated the regeneration of most tree species (hardwoods and softwoods), along with other plant forms. High moose densities have had tremendous impacts on the vegetation of Isle Royale.

Porcupines, rabbits, and mice find sustenance in the living bark and phloem tissue of trees. If the bark is chewed all the way around the stem, the girdling will kill the tree beyond that point. Girdling is an especially severe problem in certain conifer plantations and young trees in old fields.

Many birds feed on the rich flower buds of trees. Ruffed grouse are particularly well-known for their affinity for the male flower buds of quaking aspen. However, flower bud browsing has seldom, if ever, resulted in significant damage. Plantations grown for fruit or seed production may be an exception.

The final winter challenge for trees is human-caused. Trees along major roads may eventually show signs of poisoning from road salts and vehicle exhaust. Some species are more resistant to these pollutants. The more vulnerable species include; white pine, red pine, hemlock, basswood, ironwood, sugar maple, and red maple.

WINTER ADAPTATION REFERENCES

Guillion, Gordon W. 1984. Managing Northern Forests for Wildlife. The Ruffed Grouse Society. Coraopolis, PA. 71 pages.

International Society of Arboriculture. 2001. Website [http://www2.champaign.isa-arbor.com/].

Marchand, Peter J. 1996. Life in the Cold. University Press of New England, Hanover and London. 304 pages.

Raven, Peter H., R.F. Evert, and H. Curtis. 1976. Biology of Plants. Worth Publishers, New York, NY. 685 pages.

Salisbury, Frank B. and C.W. Ross. 1978. Plant Physiology, second edition. Wadsworth Publishing Company, Belmont, CA. 422 pages.

Winchester, A.M. 1969. Biology and Its Relation to Mankind. Van Nostrand Reinhold, New York, NY. 717 pages.

CMG GardenNotes #141

Plant Physiology: Photosynthesis, Transpiration, and Respiration

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

- **Photosynthesis** – The process of using chlorophyll to capture light energy and convert it to energy stored in sugars. Photosynthesis uses light energy, carbon dioxide (CO2), and water (H2O) to generate glucose with a byproduct of oxygen.
- **Transpiration** – The loss of water vapor through the stomates of leaves.
- **Respiration** – The process of metabolizing (burning) sugars to yield energy for growth, reproduction, and other life processes. Respiration uses glucose and oxygen to generate kinetic energy, with a byproduct of carbon dioxide and water.

Photosynthesis

A primary difference between plants and animals is the plant's ability to manufacture its own food. In photosynthesis, plants use carbon dioxide from air and water in the soil with the sun's energy to generate photosynthates (sugar) releasing oxygen as a byproduct. [**Figure 1**]

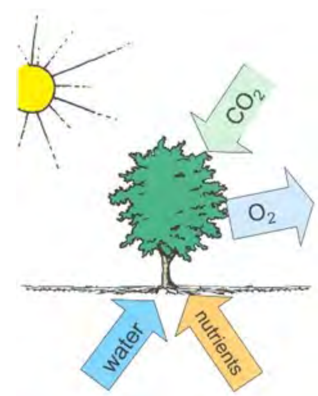


Figure 1. Photosynthesis

Photosynthesis literally means to put together with light. It occurs only in the **chloroplasts**, organelles contained in the cells of leaves and green stems. The chemical equation for photosynthesis is

$$\text{carbon dioxide} + \text{water} + \text{light energy} = \text{glucose} + \text{oxygen}$$

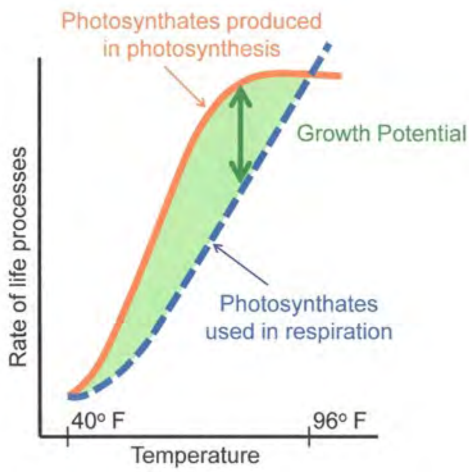
$$6CO_2 + 6H_2O + \text{light energy} = C_6H_{12}O_6 + 6O_2$$

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

In a tightly closed greenhouse, there may be very little fresh air infiltration and carbon dioxide levels can become limiting during the day while photosynthesis is actively occurring, thus limiting plant growth. Large commercial greenhouses may provide supplemental carbon dioxide to stimulate plant growth.

The rate of photosynthesis is temperature dependent. In general, warmer temperatures increase the rates of photosynthesis, but only up to a point. At high temperatures, enzymes used in photosynthesis become less efficient. Furthermore, respiration increases with temperature as well. For example, when temperatures rise above 96 degrees Fahrenheit in tomatoes, the rate of food used by respiration rises above the rate of food manufacture through photosynthesis. Plant growth comes to a stop. Most other plants react similarly. [**Figure 2**]

Figure 2. In the tomato plant, rates of photosynthesis and respiration both increase with increasing temperatures. As the temperature approaches 96°F, the rate of photosynthesis levels off, while the rate of respiration continues to rise.



Transpiration

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

Transpiration serves three essential roles:

- **Movement of dissolved nutrients and minerals** up from the roots (via xylem) and sugars (products of photosynthesis) throughout the plant (via phloem). Water serves as both the solvent and the avenue of transport.
- **Cooling**. 80% of the cooling effect of a shade tree is from the evaporative cooling effects of transpiration. This benefits both plants and humans.
- **Turgor Pressure**. Water maintains the turgor pressure in cells much like air inflates a balloon, giving form to the non-woody plant parts. Turgidity is important so the plant can remain stiff, upright, and have a competitive advantage when it comes to light. Turgidity is also important for the functioning of the guard cells that surround the stomates, regulates water loss, and carbon dioxide uptake. Turgidity also is the force that pushes roots through the soil.

Water movement in plants is also mediated by osmotic pressure and capillary action.

Osmotic pressure is defined as water flowing through a permeable membrane in the direction of higher salt concentrations. Water will continue to flow in the direction of the highest salt concentration until the salts have been diluted to the point that the concentrations on both sides of the membrane are equal.

A classic example is pouring salt on a slug. Because the salt concentration outside the slug is highest, the water from inside the slug's body crosses the membrane that is its skin. The slug dehydrates and dies. Envision this same scenario the next time you gargle with salt water to kill the bacteria that are causing your sore throat.

Fertilizer burn and dog urine spots in a lawn are examples of salt problems. In moderately salty soil, the plant can draw water into its roots less efficiently than from soils not affected by salts. In severe cases, the salt level is higher outside the plant than within it, and water is drawn from the plant.

Capillary action relies on the property of water that causes it to form droplets (hydrogen bonding). Water molecules in the soil and in the plant cling to one another and are reluctant to let go. You have observed this as water forms a meniscus on a coin or the lip of a glass. Thus when one molecule is drawn up the plant stem, it pulls another one along with it. These forces that link water molecules together can be overcome by gravity and are more effective in small diameter tubes ("capillaries"), in which water can move opposite gravity to considerable height.

Respiration

In **respiration**, plants (and animals) convert sugars (photosynthates) back into energy for growth and other life processes. The chemical equation for respiration shows that the photosynthates are oxidized, releasing energy, carbon dioxide, and water. Notice that the equation for respiration is the opposite of that for photosynthesis.

$$\text{glucose} + \text{oxygen} = \text{energy} + \text{carbon dioxide} + \text{water}$$
$$C_6H_{12}O_6 + 6O_2 = \text{energy} + 6CO_2 + 6H_2O$$

Chemically speaking, the process is similar to the **oxidation** that occurs as wood is burned, producing heat. When compounds are oxidized, the process is often referred to as "burning." For example, athletes burn energy (sugars) as they exercise; the harder they exercise, the more sugars they burn so they need more oxygen. This is why at full speed they are breathing very fast. Athletes take in oxygen through their lungs.

Plants take up oxygen through the stomates in their leaves and through their roots. Like animals and microorganisms, plants respire to generate the energy they need to live, thus requiring both oxygen and carbon dioxide in order to survive. This is why waterlogged or compacted soils are detrimental to root growth and function, as well as the decomposition processes carried out by microorganisms in the soil, oxygen is not available.

Comparison of Photosynthesis and Respiration

Photosynthesis	←→	**Respiration**
Produces sugars from energy.		Burns sugars for energy.
Energy is stored.		Energy is released.
Occurs only in cells with chloroplasts.		Occurs in all living cells.
Oxygen is produced.		Oxygen is used.
Water is used.		Water is produced.
Carbon dioxide is used.		Carbon dioxide is produced.
Requires light.		Occurs in dark and light.

NCF-Envirothon 2024 New York

Forestry Study Resources

Key Topic #2: Field Skills and Identifications

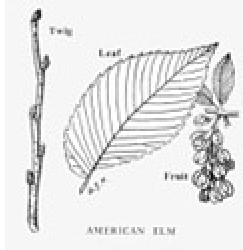
4. Identify common trees of Northeastern forests (common and scientific name) by leaves, bark, branching patterns, buds, fruit, and other characteristics without the use of a key.
5. Apply common forestry tools and procedures to field scenarios.
6. Utilize and make common forestry measurements in field scenarios.

Study Resources

Resource Title	Source	Located on
Know Your Trees	*J. A. Cope and F. E. Winch, Jr., 2002*	Pages 36-41

Study Resources begin on the next page! ➡

AMERICAN ELM:



white elm

Ulmus americana Linnaeus

American elm is one of the most beautiful, graceful, and best known forest trees in New York. It occupies a wide range of sites, though typically a tree of the bottomlands, and grows to be one of the largest trees in the state. (The Gowanda elm had a basal circumference of 39 feet.) The wood is heavy, hard, strong, tough, coarse-grained, difficult to split, and light brown in color; largely used for veneer, barrel staves and hoops, crates and wheel hubs. The graceful symmetry of the crown makes the elm highly prized for ornamental planting. However, this species has nearly disappeared from our parks and streets because of the lethal Dutch Elm disease. Improved resistant strains have been developed and planted ornamentally and in the wild in hopes that this majestic species can regain its former widespread occurence.

Bark - dark gray in color, divided by irregular up-and-down furrows into broad flat-topped ridges, rather firm or occasionally in old trees flaking off; inner bark in alternate layers of brown and white.

Twigs - slender, smooth, reddish brown in color, not mucilaginous (like glue) when chewed.

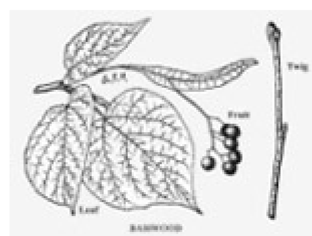
Winter buds - winter twig obviously ends in leaf scar, hence larger bud near end of twig not truly terminal; lateral buds somewhat smaller, ovate, pointed, light reddish brown in color, smooth, 1/8 inch long.

Leaves - simple, alternate, 4 to 6 inches long, oblique at the base, margin doubly serrate, at maturity dark green in color above, lighter beneath, midrib and parallel veins prominent; upper surface of leaf somewhat rough to the touch, although not so pronounced as in slippery elm.

Fruit - flat, winged, deeply notched at the end, 1/2 inch long, containing one small seed; in clusters, ripens in early May as the leaf buds unfold, falling soon thereafter.

Distinguishing features - zigzag twigs; inner bark not mucilaginous, having alternate layers of brown and white; leaf slightly rough on upper side only; with oblique base.

BASSWOOD:



linden, whitewood

Tilia americana (Ventenat) Linnaeus

Basswood is a moderately common forest tree in New York State. It has rapidity of growth and a wide range of uses for its lumber. It does best in the deep, moist soils of the woodlot sections but is generally distributed except in the high Adirondacks and Catskills. The wood is soft, even-grained, light, and fairly strong, and used for boxes, crates, cheap furniture, woodenware, and paper pulp; often used as a substitute for white pine.

Bark - on young stems smooth, dark gray in color; on older trunks firm but easily cut, becoming furrowed into rather narrow flat-topped ridges; on still older trunks furrows deeper, ridges more rounding and broader, surface scaly.

Twigs - rather slender, smooth, bright red or greenish in color or covered by a gray skin, zigzag, slightly mucilaginous when chewed; fibers of bark on twigs very tough, may be used as rope.

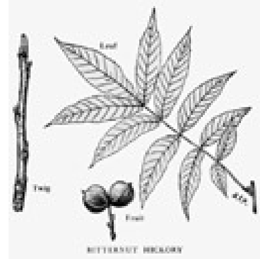
Winter buds - terminal bud absent; lateral buds large, smooth, sometimes lopsided or humped, bending away from the twigs, dark red or sometimes green in color.

Leaves - simple, alternate, heart-shaped, 5 to 10 inches long, sharp-pointed, coarsely serrate along margin; leaf base is asymmetrical.

Fruit - a nut, round, woody, about the size of a pea, borne singly or in clusters, with a common stalk, attached midway to a leafy bract, ripening in late fall but sometimes remaining on the tree into the winter. The bract acts as a sail to scatter the seed.

Distinguishing features - often found in clumps; usually large, heart-shaped leaf; hump-backed bud on zigzag twig; fruit a pea-like nut attached to a slender "parachute."

BITTERNUT HICKORY:



swamp hickory, water hickory, tightbark hickory

Carya cordiformis (Wangenheim) K. Koch

Bitternut hickory is occasional in most sections of the state except in the higher Adirondacks or Catskills. It is by preference a bottomland tree growing on wet sites in pastures, fields, and along streams, though it is occasionally found on hillsides and ridgetops in small moist depressions. It grows well on moist, rich soil such as is found in many farm woodlots. The wood is heavy, very hard, strong, tough, and dark brown in color with paler sapwood. It is inferior to that of the other hickories but is used for practically the same purposes.

Bark - thin, close, with shallow furrows and narrow regular ridges, usually does not scale or shag off, light gray in color.

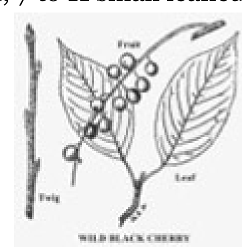
Twigs - slender, often yellowish in color, hairy toward the end; grayish or orange-brown in color during the first winter; pith brown and unlike any other hickory in this respect.

Winter buds - long, flattened, blunt-pointed, covered by 4 sulfur-colored scales; terminal bud 1/3 to 3/4 inch long.

Leaves - alternate, compound, 6 to 10 inches long, with 7 to 11 long, narrow, sharp-pointed leaflets which are smaller and more slender than are those of other hickories.

Fruit - a nearly round nut, thin-husked, brown in color, 3/4 to 1 inch long, without ridges. Kernel - bitter, not edible. Husk - clings to the nut after falling. Shell is so thin that it can easily be crushed between the fingers.

Distinguishing features - smooth bark and usually straight stem; sulfur-colored bud; 7 to 11 small leaflets.



BLACK CHERRY

Prunus serotina Ehrhart

Black cherry is the largest and most valuable of the cherry trees in New York State. It prefers rich bottomlands and moist hillsides, but is found also in drier situations. It is common in most sections of the state, though seldom found above an altitude of 3000 feet in the Adirondacks. Its wood is light, strong, hard, close-grained with pale reddish brown heartwood and is much in demand for cabinetmaking, interior finishing, tools, ties and fence posts. It is a valuable fast-growing timber and wildlife food tree and should be encouraged in woodlots.

Bark - at first smooth, reddish brown in color, marked with easily seen, long, white breathing pores; with age becoming much roughened by irregular, close, dark scaly circular plates with upturned edges.

Twigs - slender, smooth, reddish brown in color, having bitter almond taste which is characteristic of all cherries.

Winter buds - smooth, ovate, 1/8 to 1/6 inch long, sharp-pointed, chestnut brown in color; terminal bud present.

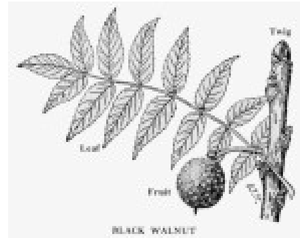
Leaves - alternate, simple, 2 to 5 inches long, lanceolate, broader than are those of pin cherry, fairly long-pointed, margin finely serrate, tufts of hair along midrib on undersurface of leaf.

Fruit - a single-seeded juicy fruit, about 1/2 inch in diameter, grouped on very short stems, in long scattered, drooping clusters, purplish black when ripe in late summer. Birds and animals eat the fruit, though its flavor is decidedly bitter.

Distinguishing features - long white pores on young bark; dark scaly, circular, saucer-like plates in older bark; hairy midrib below on leaf; fruit in short-stemmed clusters.

Sweet cherry or bird cherry (*Prunus avium* Linnaeus) is an escaped cultivated cherry found in abandoned fields and hedgerows. Its shiny red bark and thick twigs are its outstanding features.

BLACK WALNUT:



Juglans nigra Linnaeus

Black walnut is a valuable timber tree native to some areas of New York State. It can reach a large size and produces highly prized wood and large edible nuts. It is common at low elevations in rich, well-drained bottomlands northward to Saratoga and Jefferson Counties and west to Lake Erie. The wood is heavy, hard, strong, durable, rich dark brown in color, easily worked, and takes a fine polish. It is largely used in cabinetmaking, interior trim, and for gunstocks. It deserves protection and planting in suitable locations.

Bark - thick, dark, deeply furrowed with rounded ridges between; grayish brown in color; inner bark dark chocolate brown in color.

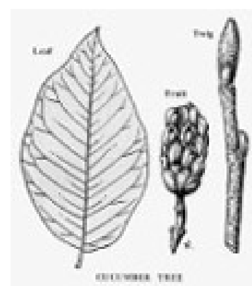
Twigs - at first hairy, later smooth, stout, brittle, orange brown in color, cream-colored chambered pith.

Winter buds - terminal bud pale, downy, scarcely longer than broad, blunt-pointed, less than 1/3 inch long; lateral buds less than 1/6 inch long.

Leaves - alternate, compound, with 13 to 23 leaflets; leaflets 3 to 4 inches long, sharp-pointed, serrate along margin, usually stalkless; leaves up to 2 feet in length.

Fruit - a round nut, 1 1/2 inches in diameter, black, the surface roughened by rather coarse ridges, enclosed in a yellowish green, fleshy husk, usually solitary or in clusters of 2, ripening in October. Kernel - sweet, edible, and when properly cured somewhat easier to extract than the butternut. It is necessary to remove the outer husk if nuts are to be stored.

Distinguishing features - large round nut; cream-colored, chambered pith.



CUCUMBER TREE:

Magnolia acuminata Linnaeus

Cucumber tree, so called because of its cucumber-like fruit, is the only magnolia that is at all common in this state outside of Long Island. In rich woods, on moist slopes, and along stream courses, from the central part of the state westward and southward, it is found locally. The wood is light, soft, close-grained, brittle, and light yellowish brown in color. It resembles that of yellow poplar and besides wood-carving, has much the same uses. Because of its yellowish green flowers, its large leaves, its rapid growth, and its red seeds, it is often grown in lawns and parks.

Bark - grayish brown in color, with long narrow furrows separating into rather loose, scaly, flat-topped ridges.

Twigs - brittle, brown in color, smooth or shiny, aromatic odor.

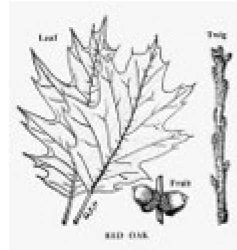
Winter buds - terminal bud oblong, somewhat curved, thickly covered with pale, silky hairs, pointed, about 1/2 inch long; lateral buds smaller, blunt, also hairy.

Leaves - alternate, simple, ovate, pointed at the tip, 4 to 10 inches long, entire margin. One of the few species of the state that has an entire-margined leaf.

Fruit - a cone-like or cucumber-like, cylindrical mass, often curved, about 2 1/2 inches long, containing a large number of scarlet, pea-like seeds which dangle from the ends of short, white threads when ripe in the early autumn.

Distinguishing features - smooth margin of large leaf; aromatic odor of twigs; oblong terminal bud; branching like that of pear tree, fruit like cucumber.

NORTHERN RED OAK:



Quercus rubra Linnaeus

Northern red oak is the fastest growing and largest of all the oaks native to New York State. It shows adaptability to a wide variety of soil conditions and ranges farther north than any other oak common to the state. The wood is heavy, hard, strong, light reddish brown in color, and is used for furniture, interior finish, ties, piling, ships, and general construction, though less durable than white oak.

Bark - on young trees smooth, gray green in color; with age tardily breaking into rather regular, firm, elongated, flat-topped ridges with shallow furrows between. The smooth ridge tops are markedly lighter in color than are the furrows. On very large trees, this characteristic is lost at the base but is evident higher up the trunk. Inner bark is red in color.

Twigs - stout or slender, reddish to greenish brown in color.

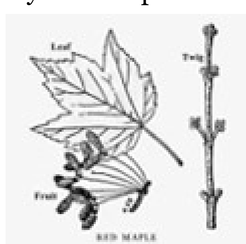
Winter buds - clustered at ends of twigs, oval, sharp-pointed, 1/4 inch long, generally smooth (particularly on the lower half).

Leaves - alternate; simple, 5 to 9 inches long, 4 to 6 inches wide, with 7 to 9 lobes; lobes sparsely toothed, bristle-tipped; wide rounding clefts extending halfway to midrib. At maturity thin, dark, shiny green in color above, paler and smooth below.

Fruit - an acorn, borne solitary or in pairs, either with or without stalk, maturing in the autumn of the second year; one of our largest acorns. Nut - chestnut brown in color, 3/4 inch long, only 1/5 enclosed in a wide, shallow cup. Meat - pale yellow in color, bitter.

Distinguishing features - reddish inner bark; leaf balanced (no heavier at outer than inner end); large fat acorn with flat cup. In thick woods, lower branches usually are self-pruned to more than half the height of tree.

RED MAPLE:



swamp maple, soft maple

Acer rubrum Linnaeus

Red maple derives its name from its brilliant autumn foliage. While common in swamps all over the state, it is also abundant on moist slopes and increasingly common in partially cut woodlots. It is an extremely rapid-growing tree, furnishing a fairly strong, close-grained wood, extensively used for cheap furniture, in the manufacture of baskets and crates, for mine props, railroad ties, and fuelwood.

Bark - on young trunks smooth, light gray in color, often resembling beech; with age becoming darker and roughened into long ridges, often shaggy or scaly on surface; bark character extremely variable on different trees in the same stand.

Twigs - rather slender, bright or dark red in color, without odor when cut or broken.

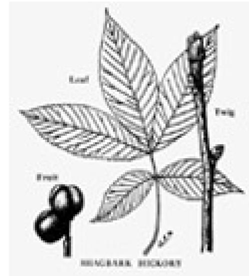
Winter buds - broad, blunt-pointed, clustered, short stalk, red in color; terminal bud slightly larger than lateral buds; numerous large, plump flower buds along the twig.

Leaves - simple, opposite, 3 to 4 inches long, fully as wide, usually 3-lobed; the clefts between lobes shallow and sharp angled as contrasted with deep clefts of silver maple; margins of leaf lobes coarsely serrate; at maturity leaves light green in color above, pale greenish white below.

Fruit - maple samaras, in clusters on long stalks, ripening in May or early June. Seeds -joined more or less end on end. Wings - diverge at wide angles.

Distinguishing features - red buds and twigs; sharp angle between leaf lobes; leaf margin with teeth.

SHAGBARK HICKORY:



scalybark hickory

Carya ovata (Miller) Koch

Shagbark hickory is the best known and most valuable of the hickories in this state. It is common in deep, moist soils throughout New York though rare in the higher Catskills and Adirondacks, and is not reported from the pine barrens of Long Island. In the forest it is a tall straight-branched tree but in open fields and along hedgerows where it often grows it usually forks near the ground into stout ascending limbs. The wood is very heavy, tough, elastic, close-grained, and is used chiefly for handles, vehicles, agricultural implements, and fuel. The fruit is important for wildlife.

Bark - light gray in color, smooth and seamy, becoming shaggy with age and peeling off into long strips which are loose at both ends and attached in the middle, thus giving rise to the name "shagbark hickory."

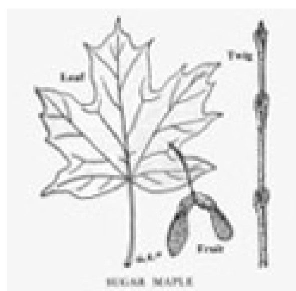
Twigs - covered with numerous light dots, extremely tough and pliable, reddish brown to gray in color.

Winter buds - large, ovate, blunt-pointed, with papery, dark brown, loose bud scales, the outer scales much darker, persistent through the winter; terminal bud usually more than 1/2 inch long.

Leaves - alternate compound, 8 to 14 inches long, with 5 to 7 leaflets, the 3 upper ones being by far the largest.

Fruit - a smooth, white, 4-angled nut, enclosed in a thick, round husk that splits into 4 sections as the nut falls after heavy autumn frosts. Kernel - large, sweet.

Distinguishing features - large terminal bud; 5 to 7 leaflets, outer 3 much larger; bark peeling in long plates.



SUGAR MAPLE:

hard maple, rock maple

Acer saccharum Marshall

Sugar maple is a magnificent forest tree abundant everywhere in the state outside of Long Island. It is the official state tree of New York. Besides providing beautiful borders to many miles of highway, and hundreds of thousands of gallons of maple syrup from the many thousands of sugar bushes in all parts of the state, it yields a wood of high grade. It is hard, strong, close-grained, and tough, with a fine, satiny surface, and is in great demand for flooring, veneer, interior finish, furniture, shoe lasts, rollers, and as a fuelwood of the best quality.

Bark - on young trees dark gray in color, close, smooth, and firm, becoming furrowed into long irregular plates lifting along one edge.

Twigs - slender, shining, the color of maple sugar.

Winter buds - very narrow, sharp-pointed, brown in color, the terminal buds much larger than the laterals.

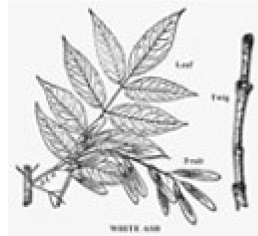
Leaves - simple, opposite, 3 to 5 inches long and fully as wide, 3 to 5 shallow lobes with wide-spaced coarse teeth, dark green in color above, paler below; the clefts are rounded at the base.

Fruit - maple samaras, in short clusters, ripening in September. Seeds - join each other in a straight line. Wings - turn down almost at right angles.

Distinguishing features - rounded cleft between lobes of leaves; leaf lobes lacking small teeth; sharp-pointed, brown buds; brown twig.

WHITE ASH:

Fraxinus americana Linnaeus



White ash is a valuable and rapid-growing tree in the woodlots of New York State. It is common throughout New York and is found up to an altitude of 2000 feet in the Adirondacks. It prefers to grow in rich moist woods, and is common on abandoned agricultural lands. The wood is heavy, hard, strong, close-grained, and tough. Large quantities of it are used for agricultural implements, tool handles, oars, furniture, and sporting goods. In some locations, especially open edges and roadsides, branch dieback and tree mortality are common.

Bark - dark grayish brown in color, deeply furrowed with narrow flat-topped firm ridges which on older trunks are somewhat scaly; ridges in some instances tend to run together, enclosing diamond-shaped fissures.

Twigs - very stout, smooth, shining, grayish brown in color, brittle, flattened at leaf bases (nodes); leaf scar is notched.

Winter buds - plump, blunt-pointed, dark brown or nearly black in color; terminal bud 1/5 inch long, larger than lateral buds; last pair of lateral buds almost on level with terminal bud.

Leaves - opposite, compound, 8 to 15 inches long, with 5 to 9 leaflets; leaflets sharp-pointed, 3 to 5 inches long, with slightly and sparsely serrate margins; borne on short stems, by this characteristic may be distinguished from black ash leaflets, which are stemless.

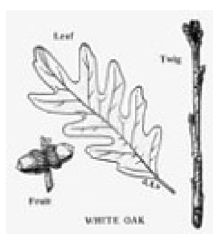
Fruit - a winged seed, 1 to 2 inches long, broadly paddle-shaped with the wing occupying the position of the blade; borne in long, open, drooping clusters, ripening in September, often not dropping off until early winter.

Distinguishing features - thick twigs; compound leaves with stemmed leaflets; brown buds; ashy-gray, older bark.

Green ash (*Fraxinus pennsylvanica* Marshall var. *lanceolata* (Burkhausen) Sargent) is frequently confused with white ash. The former has narrower leaflets with more noticeable serrations which extend farther toward the base; the leaflets are greener beneath; the terminal bud is more pointed; and the leaf scar is not notched. It has the same uses as white ash.

WHITE OAK:

Quercus alba Linnaeus



White oak is an important forest tree in the southern two-thirds of the state, growing to large size and producing lumber of high grade and value. It is found in moist as well as in dry locations, and was once particularly abundant on what are now the best farmlands of the Genesee Valley. The wood is hard, heavy, strong, and durable. It is highly prized for furniture, flooring, implements, ties, and in general construction where strength is required, especially in piling and ships. White oak acorns are an important food for wildlife.

Bark - ashy gray in color, broken by shallow furrows into long, irregular, thin scales which readily flake off; on old trunks furrows frequently become deep.

Twigs - medium in thickness, greenish red to gray in color, smooth, sometimes covered with a bloom.

Winter buds - clustered at end of twigs, blunt, reddish brown in color, 1/8 inch long.

Leaves - alternate, simple, 5 to 9 inches long, with 5 to 9 rounded lobes, generally deeply cleft toward midrib, dark green in color above, paler below, frequently staying on tree over winter.

Fruit - an acorn, either with short stalk or stalkless, maturing in one year. Nut - light brown in color, 3/4 inch long, 1/4 enclosed in the cup, falling in September, frequently starts sprouting in late autumn. Meat - white, slightly bitter.

Distinguishing features - ashy gray, flaky bark; deeply cleft lobes in leaves; acorn 1/4 enclosed in cup.

NCF-Envirothon 2024 New York

Forestry Study Resources

Key Topic #3: Forest Management

7. Apply Forest Management planning and the incorporation of treatment methods to meet landowner objectives.
8. Evaluate stand conditions utilizing stand and stocking tables.

Study Resources

Resource Title	Source	Located on
What is a Silvicultural System?	*US Forest Service, Tongass National Forest, 2016*	Pages 43-47
Forest Regeneration Assessment Series, Chapters 2 and 3	*Jim Finely, Leslie Horner, Allyson Muth/The Center for Private Forests at Penn State, 2023*	Page 48-59
Evolution of Silviculture and Creating Desired Conditions	*Dennis E. Ferguson, Victor J. Applegate, Philip S. Aune, Clinton E. Carlson, Kathleen Geier-Hayes, Russell T. Graham, Glenn L. Jacobsen, Theresa B. Jain, David C. Powell, Wayne D. Shepperd, John P. Sloan, Andrew Youngblood, Interior West Silviculture Group, US Forest Service, 1997*	Page 60-61
How to Use a Stocking Guide	*North Carolina State University/Woodland Stewardship on YouTube, 2016/*	Page 62

<u>Study Resources begin on the next page!</u> ➡

United States Department of Agriculture

***This handout was developed from the March 2003 Silvicultural Handbook for British Columbia, British Columbia Ministry of Forests. The BC Ministry of Forests has a tremendous volume of information available on-line that is very applicable to the work we do on Prince of Wales Island.**

What Is a Silvicultural System?

A silvicultural system is a planned program of silvicultural treatments designed to achieve specific stand structure characteristics to meet site objectives during the whole life of a stand.

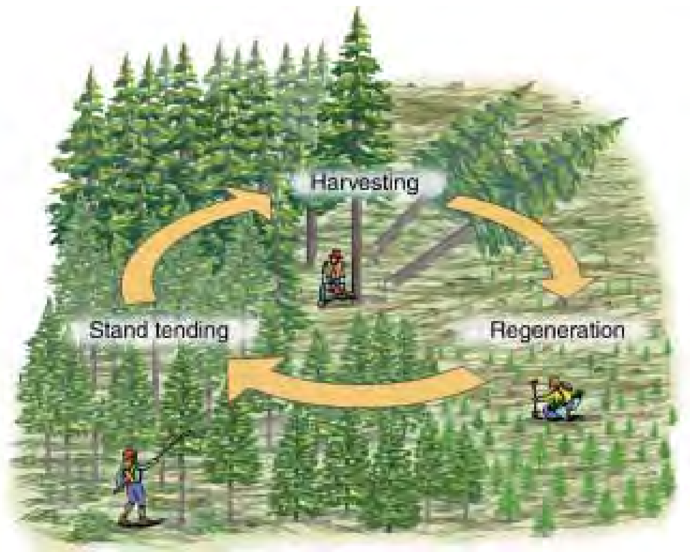


Figure 2.1-1

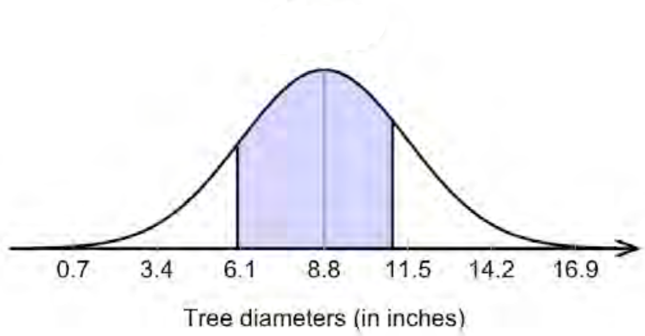
This program of treatments integrates specific harvesting, regeneration, and stand tending methods to achieve a predictable yield of benefits from the stand over time. Naming the silvicultural system has been based on the principal method of regeneration and desired age structure.
Silvicultural systems on most sites have been designed to maximize the production of timber crops. Non-timber objectives, such as watershed health and wildlife production, have been less common. Recently, ecological considerations and resource objectives have increased. A silvicultural system generally has the following basic goals:

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

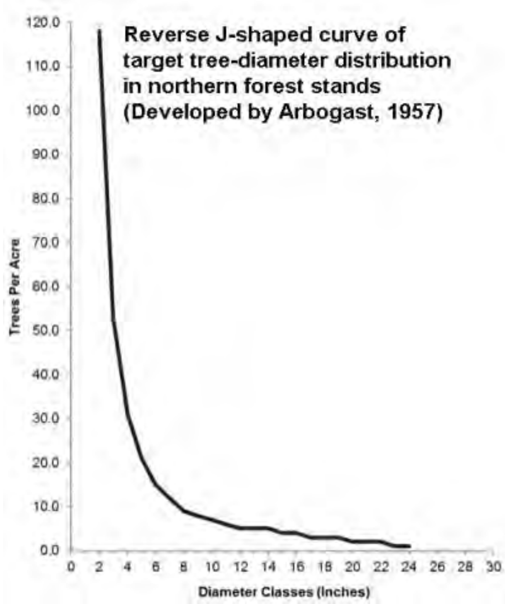
Even-aged and Uneven-aged Stands

Even-aged stands generally have one age class, although two age classes can be found in some two-layered natural or managed stands. These stands generally have a well-developed canopy with a regular top at a uniform height.
Pure even-aged stands generally have a nearly bell-shaped diameter distribution. This means that most trees are in the average diameter class. However, diameter distributions should be viewed cautiously since diameter can be a poor criterion for age. The smallest trees in natural even-aged stands are generally spindly, with vigor suppressed by the overstory.

Figure 1. Diameter distribution curve



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



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

Integrating “Reserves” within a Silvicultural System

Reserves are intended to satisfy management objectives, requiring that the stand be maintained for a long period. Reserves are forested patches or individual trees retained during harvesting, or other forestry operations, to provide habitat, scenic, biodiversity, or other values, for at least one rotation. Reserves are areas that are to be maintained for a long time, such as more than 100 years. Any incidental seed or shelter to the regenerating stand and site that reserve trees supply is secondary to their purpose as reserve trees. Seed or shelterwood trees are not reserves, since they are removed as soon as a new crop is established. Where trees are not retained for the long term, they are not reserves.
Areas that are deferred from harvest only until the adjacent area is greened up are not reserves, simply areas of deferred harvest.
Use of reserves can be compatible with any silvicultural system, under appropriate stand and site conditions. When reserves are combined with a silvicultural system, they are incorporated into the name of the system as in *clearcut with reserves*.
To protect the structural integrity of reserve patches, there will generally not be any harvest entries. However, in limited cases, harvest entries may be required to address safety concerns or a management objective such as forest health. Treatments can be done on reserves for non-timber objectives. The treatment may involve cutting trees. Where a harvest entry occurs, predetermined stocking standards must be met.

1. **Riparian** –as described in the *Riparian Management Area Guidebook*. Typically objectives are to minimize or prevent impacts of forest and range uses on stream channel dynamics, aquatic ecosystems, and water quality of all streams, lakes, and wetlands.

2. **Wildlife** – wildlife tree management strategies can range from the retention of existing wildlife trees, as scattered individuals or in patches, to the creation of new wildlife trees.
Many approaches can be applied within a single cutblock, though reserving patches is usually recommended as the priority approach. Wildlife tree requirements apply to the use of all silvicultural systems.

3. **Other** – a catchall for reserves that provide for objectives other than the first two categories.
Each type of reserve can be further described as a patch or as dispersed. A patch is a group of trees important enough to be mapped at the scale being used. Dispersed is the appropriate description when trees are being reserved individually or in groups too small to be mapped.
Any reserve that is not a patch, is by definition dispersed.

The Clearcut System

The clearcut system manages successive even-aged stands by cutting the entire stand of trees at planned intervals (the rotation) then regenerating and tending a new stand in place of the old.
The clearcut system is the most straightforward and easiest system to use, and has been applied around the world. While it has been successful for pure timber management, especially for valuable shade-intolerant species, concern over aesthetics, habitat impacts, and watershed impacts have prompted interest in alternate systems in many areas.

A “clearcut” means a silvicultural system that removes the entire stand of trees in a single harvesting operation from an area that is about two acres or greater; and at least two tree heights in width, and is designed to manage the area as an even-aged stand.

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

A “clearcut with reserves” means a variation of clearcutting in which trees are retained either uniformly or in small groups, for purposes other than for regeneration.

Patch Cut System

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

Retention System

The **retention system** sustains the major ecological conditions and processes characteristic of a forest by maintaining a level of stand structure, complexity, and diversity.

The retention system is a silvicultural system that is designed to: a. retain individual trees or groups of trees to maintain structural diversity over the area of the cutblock for at least one rotation, and b. leave more than half the total area of the cutblock within one tree-height from the base of a tree or group of trees, whether or not the tree or group of trees is inside the cutblock.

A harvested area is not a clearcut if the major ecological conditions and processes characteristic of a forested environment remain more or less intact (Kimminis, 1992). Forest influence extends from residual trees into a harvested area.

One tree height is used as an administrative way to get at the concept of influence. A retention silvicultural system is where the resulting stand/area has retained trees (aggregate, edge, patch, or single) distributed throughout the cutblock, such that if a person were to conduct a random sample (of 20 samples or more) of the area actively harvested, they would find that greater than 50% of the cutblock is within one tree height of retained trees (i.e., under the influence of retained trees).

The retention system is differentiated from the clearcut with reserves system by the distribution of leave trees and the influence of edge effect. The retention system requires individual trees or groups of trees to be distributed over the block, with edge effect influence covering at least 50% of the opening. The clearcut with reserves system is not bound by a 50% edge influence requirement, nor the distribution over the block.

The retention system requires retained trees to be left in various locations across the whole cutblock, not concentrated in a few areas. The trees can be left singly, in groups of various sizes, or some combination of the two. There can also be a range in the amount and pattern of the retention. Retention objectives are unique to the individual area or landscape unit, and can include, but are not limited to, biodiversity, wildlife habitat, or aesthetic values. Regeneration can be accomplished by either natural or artificial methods.

Seed Tree System

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

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

Shelterwood System

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

The primary intent of this system is to protect and shelter the developing regeneration.

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

Selection System

Selection systems remove mature timber either as single scattered individuals or in small groups at relatively short intervals, repeated indefinitely, where an uneven-aged stand is maintained. Regeneration should occur throughout the life of the stand with pulses following harvest entries.
These systems depend on recruitment of trees into successive age classes over time and the predictable yield from merchantable age classes. Yield will be obtained by thinning clumps, by harvesting individual trees, or by harvesting whole groups of the oldest age class to create small openings scattered throughout the stand.
The selection system can be complex. Three variations of selection systems are used.

Group Selection

Group selection systems also promote uneven-aged stands with clumps of even-aged trees well distributed throughout the cutting unit. Unlike single tree selection, however, these small even-aged groups are large enough that they can be tracked within the stand (see Figure 2.1-6).

Figure 2.1-6

Forest Regeneration Assessment Series- Chapter 2
Why Your Forest May Not Be at a Point of Regeneration

This sugar maple seedling is an example of natural regeneration, which is essential to sustaining the state's hardwood forests.

In the *Forest Ecology: How a Forest Grows* publication, you were introduced to the process of stand development – stand initiation, stem exclusion, understory reinitiation, and complex/mature forest.
Forests that are in the stand initiation or stem exclusion phases of development often don't have regeneration considerations – they are either already a young forest (stand initiation) or they are a closed canopy (stem exclusion) with little light reaching the forest floor. The latter condition can persist for decades. However, whether by natural forces or human- induced disturbance, at some point openings will occur in a closed canopy.

Examples of when you might need to be concerned about forest regeneration include:

- creating young forest for wildlife,
- preparation for overstory removal harvest,
- long-term income (planning for the next forest for sustainable forest management),
- risks associated with severe storms, ice damage, and fire.

Planning for establishing, or releasing already-established, regeneration is not without risks. Recognizing and addressing those risks benefits from assessing current conditions and threats and developing a plan that will increase the likelihood of success. This publication series will prove useful in conducting an assessment, finding assistance, and sustaining your woodland ownership values.

Regardless of where your forest is in its development, it is important to be aware of potential ecological threats that will not only compromise regeneration, but also overall health and resilience of existing forest: deer and competitive plants. Choosing the extent of current control/treatment directly connects to planned future practices. As you read this publication, be aware that your forest may not yet be at a place where you need to have concern about forest regeneration; however, if you intend to ensure a healthy, working forest continues for generations, at some point there needs to be concrete action taken to assess, plan, and act to create forest regeneration. This publication series will assist you in that process.

What's Getting in the Way of Your Woodland's Potential to Regenerate?

Natural regeneration is essential to sustaining Pennsylvania's hardwood forests and the many values they provide. Sustaining the state's forests, nearly 17 million acres, depends on the development of "the next forest" from the trees already growing and creating the high canopy seen across the landscape. This is not a planted forest. Rather, it is a forest that depends on trees naturally following trees. To have this happen, it is essential that the state's forests accumulate advance regeneration in the understory to ensure that the next forest is there and ready to grow. True, some seeds lay dormant in the forest leaf litter waiting to germinate under desirable conditions, but this is not as common as believed. As well, in the past, some species such as oak successfully contributed to regeneration through stump sprouts; however, larger trees are less likely to sprout, and white-tailed deer often prefer browsing sprouts. Our forest's future depends on ensuring that our management and use practices foster adequate advance regeneration.

US Forest Service forest inventory reports for Pennsylvania repeatedly find naturally occurring forest regeneration lacking across much of the state. Recognizing that light is a driving factor in initiating and sustaining forest regeneration, that research specifically focuses on stands where canopy disturbance (59% or less closed) from harvesting or natural events should encourage seedling development. The most recent report from 2014 found that 50% of the state's forests, public and private, have canopy density or openness that should favor regeneration.

However, under these canopies, things are not going well. The Forest Service inventory divides regeneration into three seedling and sapling species groups[1]: Desirable, Commercial, and All Woody[2]. If the evaluation includes all the species listed in the All Woody species group, 68% of the forest has sufficient regeneration to establish a new forest. Some of these species provide wildlife food and cover, and depending on landowner values and objectives, are acceptable in the forest; while other species suggest concerns about future forest composition. Stepping back to the Commercial species group, the projected capacity of forest replacing forest drops to 59%. This too might be acceptable to some woodland owners; although, several species offer little economic or wildlife value (e.g., birch, beech, elm, and black locust). Finally, for the Desirable species group (admittedly those more favored for economic value), only 40% of the forest has sufficient regeneration to replace the existing forest canopy.

Interpreting these findings, the Forest Service notes that species not listed as preferred white-tailed deer browse fare better than those favored for browse; more shade tolerant species are expanding over shade intolerant species as they respond better in small canopy gaps resulting from partial cutting. As well white-tailed deer browsing preference further influences species success in small openings. Specifically, deer do not preferentially browse sweet birch and beech, and both species respond well to small canopy gaps. Further the survey findings suggest that harvests often focus on removing specific species or trees in larger size classes. For example, harvests focused on oak species, which are difficult to regenerate, remove or greatly reduce desirable seed sources, and sweet birch and red maple then come to dominate these disturbed forests.

Reasons for not attaining adequate regeneration are complex and may often include more than one impediment; however, frequently the problem involves 1) plant competition, 2) white-tailed deer, and 3) light-related conditions. Beyond these three obvious issues, there are site-related conditions (e.g., sites that are either too wet, dry, or stony) often reflecting site changes as a result of the canopy disturbance event.
Setting a course for successful forest regeneration or stand replacement is an often overlooked or a poorly understood forest stewardship goal. This publication will provide a tool for evaluating individual forest stands and provide basic insights into management options that may increase potential for developing conditions designed to foster successful regeneration.

Openings in the canopy and a low deer population create good conditions for these young oaks to thrive.

1 Seedlings and saplings include all trees from established seedlings to 5 inches DBH (i.e., Diameter at Breast Height).

2 Desirable: Black cherry, Oak, Sugar maple, Red maple, Conifer, Hickory, Yellow-poplar, Ash, Basswood, Cucumber, Walnut, Butternut; Commercial (Desirable plus): Birch, Beech, Black gum, Elm, Black locust; Hackberry, Aspen; All Woody (Desirable and Commercial plus): Honey locust, Sassafras, Ironwood, Shadbush, Mountain ash, Blue beech, Hawthorn, Dogwood, Redbud, Pin cherry, Striped maple, Hercules club, Scrub oak, Chokecherry.

Looking for Forest Regeneration: Assessing Your Woodland

Understanding the need to establish and foster adequate tree regeneration is the primary role of this publication. This understanding begs the question: “What conditions exist in my woodlands?” Answering this question depends on conducting a systematic evaluation or assessment of stand level conditions. Looking ahead, publication number 3 in this series, *Evaluating Stand Conditions: Implementing and Interpreting the Regeneration Assessment*, presents specific protocol and methods for collecting data and guides your understanding of existing conditions using a stand-level decision tree to determine what level of regeneration exists in your forest. At that point, before undertaking any actions, you should consult with a resource professional to thoroughly consider appropriate management actions.
The remainder of this publication will explore how the intersection of light, competition, and white-tailed deer set the stage for achieving successful stand-level forest regeneration. This is important as success or failure sets the stage for forest development for many years into the future.

Initial Assessment

Forest Ecology: How a Forest Grows, the first publication in this series, introduced several terms and concepts important for beginning to assess forest conditions. Recall that a “stand” is a contiguous, distinguishable group of trees of similar age distribution, species, structure, site, and history such that it is recognized as a unit. A landowner might even recognize and name these areas as the hemlocks, the old orchard, the oak ridge. Taking the time to outline your stands on a property sketch or aerial photograph printed from the internet starts the process of assessing woodland conditions.

Deciding on preliminary stand boundaries is challenging. For smaller properties, there is a tendency to define many small units; while, on larger properties, the opposite is often true. In the latter case there is the risk of large stands overwhelming an owner’s capacity to embark on necessary management activities. Know, though, that work within larger stands can target activities and result in sub-stand units.

PROTOCOL: Mapping assists with identifying important or valued woodland places. Stand Area guides sample size selection (i.e., number of plots to estimate existing conditions).
Do not lose track of the point that this assessment activity focuses on regeneration conditions. The development stage informs stand level understanding about the need for regeneration. Therefore, it is a good starting point. See Table 1 for a refresher on stand development stages. Clearly under ideal conditions there is seldom need for regeneration in the Stem Exclusion stage of stand development; however, this is not always the case. It is relatively easy to find situations where some competitive and/or invasive plant species are present in this development stage and this does not bode well for normal stand development. This is a condition to be aware of in the assessment. A second situation may occur where canopy gaps have developed because of cutting or invasive vines killing desirable saplings and larger trees. The role of competitive plants in stand development is a major concern even in the Stem Exclusion stage. Either while drawing the stand map or during an early visit to each stand, predetermine the stand development stage.

PROTOCOL: Stand Development stage assists in categorizing stand-level conditions that aid in understanding if regeneration is important at this time.

Table 1. Stand Development Stages and What You May See

Stage	What you may see	What is happening
Stand Initiation Stage	Herbaceous plants, young shrubs, and young trees densely packed, brushy appearance. “Legacy trees” from the past stand may remain (for example, large individual trees, low quality trees often called “culls.”	A disturbance (natural, or from a harvest) occurred recently, creating new growing space for seedling establishment or for release of advance regeneration. Growth will continue until all growing space is occupied resulting in a low canopy without gaps.
Stem Exclusion Stage	Heavy or full understory shade, no new shrub or herbaceous growth. Trees crowns small, canopy closed. Competition among small crowns, overtopped trees dying beneath same-age taller trees.	This development stage is long – 15 or more years. Trees from 5 to 12 inches relentlessly compete for light, space, and other resources. Some individual trees grow taller, faster, and thrive; less competitive trees die. Surviving trees expand crowns into the now-vacant space.
Understory Reinitiation Stage	Some small gaps in the canopy. Herbaceous plants, shrubs, and tree seedlings may appear. Some standing dead trees, uprooted trees, or large woody debris.	Some larger trees are gradually dying, leaving canopy gaps. Limited light resources initiate understory development, which may include tree seedlings. Shade tolerance may limit species diversity and success.

Complex Stage (Mature)	Large diameter living and dead trees. Groups of seedlings and saplings present. Foliage is continuous from the ground to upper canopy/ may be across the stand.	Individual tree death continues, leaves scattered larger openings spurring understory tree release or recruitment of more shade tolerant species, depending upon opening size. Seedling and sapling competition select for strongest individuals. This mature woodland stage has the most complex structural features, with plants of various heights and gaps in the canopy.

Adapted from:
Oliver, C.D. and Larson, B.A. 1996. "Forest Stand Dynamics, Update Edition." Y*ale School of Forestry & Environmental Studies Other Publications*. https://elischolar.library.yale.edu/fes_pubs/1/

Assessing Light

As noted several times before, light is the principle concern driving plant recruitment during forest stand development in Northeastern forests. A critical threshold appears where canopy structure is such that about 40 to 50 percent of the canopy is open. Said another way, if about half of the canopy has "blue sky," this should lead to understory plant development. At this level, sufficient light consistently reaches the forest floor to initiate plant development. The second stand-related assessment variable is a determination of canopy openness.

PROTOCOL: Estimate canopy openness to preliminarily prioritize stands for assessment. Measure actual closure using plot protocol

Competition: Assessing Species

In many forest stands, competition with regeneration occurs at various levels in the stand – from the canopy to the vegetation covering the forest floor. Start with the plants that comprise the canopy: do they represent expected species diversity? Do you have species that you do or do not want in the future forest? It is common in developing forest stands to lack species diversity, which subsequently may affect forest resilience (i.e., the ability to withstand issues that specifically affect one species such as emerald ash borer (ash), gypsy moth (oak), hemlock woolly adelgid (hemlock)) or stands may have undesirable species present (e.g., tree of heaven (*Ailanthus*), buckthorn, striped maple).

Simply, competitive plants compete for resources, especially light. Some plants, though, have the capacity to limit competition for light and other resources using chemical inhibitors through a process called allelopathy. Examples of species found in woodlands are black walnut and tree of heaven, which use exudates to inhibit development of other plants. Other plants, such as native hayscented, New York, and bracken ferns create dense shade layers close to the ground. Forestry research has found that shade within 25 feet of the forest floor is especially problematic; therefore, many woody native plants can create light-constrained situations. The species listing of All Woody regeneration contains numerous examples: sassafras, ironwood, shadbush, blue beech, striped maple as well as mountain laurel, spicebush, and American beech root suckers. With the exception of *Ailanthus*, all of these species are native and often become problematic because of preferential browsing by white-tailed deer.

PROTOCOL: Estimate mid-canopy percent cover and list composition.
Competitive plants from other places, often called exotic invasive species, are often more problematic than most of the competitive native species as they have several competitive advantages. First, they tend to leaf out sooner in the spring and retain their capacity to photosynthesize later in the autumn than native plants. These extended growing seasons provide a significant edge. Second, native herbivores, most notably white-tailed deer tend not to browse on many exotic invasive species. There are a few notable exceptions such as multiflora rose; however, browsing tends to focus only on succulent young shoots. Finally, many of these exotic invasive species are prolific seeders and readily dispersed by wind, water, and songbirds. The scenario that develops from these advantages easily gives many of them the ability to germinate in understory conditions and to then expand their foothold.

PROTOCOL: Identify native and exotic woody plants. Identify native and exotic herbaceous plants.

Assessing White-tailed Deer Impact

Some woodland owners and hunters fail to recognize that white-tailed deer can adversely affect forest composition and development. Deer numbers have in places and at various times exceeded cultural carrying capacity and have, through selective and intensive browsing, shifted plant species composition. These changes have and continue to affect wildlife habitat quality for deer as well as other species.

Deer clearly prefer specific tree species. Browsing may contribute to problems regenerating all oak species and maple, especially sugar maple. As well, selective deer browsing may greatly reduce or even eliminate some wildflower species such as Canadian mayflower, trillium, Indian cucumber, and lady slippers. Some ecologists consider the lack of some of these wildflowers as important indicators of excessive browsing. On the other hand, predominance of some native (e.g., New York, hayscented, and bracken ferns, American beech root suckers, striped maple) and exotic invasive plants (See Appendix A) are an additional indicator as deer reduce some species to the benefit of those they choose not to browse.

Forest structure and appearance also provide insights into sustained or past deer impacts. Park-like appearances across a stand, where little understory develops is one example as browsing eliminates understory structure. Do not confuse the profusion of non-preferred species as a positive indicator of low deer impact.
Non-preferred tree species seedlings cropped by repeated browsing is another good indicator (e.g., American beech, black birch, red maple stump sprouts). Clear and evident browse lines where vegetation below five feet in height is eliminated or heavily browsed is another indicator. This is often very evident along woodland edges.
The below referenced Aviddeer website provides an excellent summary of deer impacts assessment.

- No Impact – only in well-maintained exclosures
- Low Impact – preferred woody regeneration abundant with varied height. Spring indicator wildflowers present, flowering, producing seeds
- Medium Impact – preferred woody regeneration present, all one height, herbaceous plants rare, non-preferred plants noticeably common.
- High Impact – preferred woody regeneration absent. Any seedlings heavily browsed. Wildflowers heavily browsed or absent. Ferns and invasive plants may be common.
- Very High Impact – even non-preferred seedlings reduced or heavily browsed. Ferns and competitive or invasive plants common and dominate forest floor or forest floor bare.

Admitting that deer are an issue is challenging for many woodland owners. For the purpose of this assessment, use two scales: Low and High. Low would be as stated above, and High is anything above that threshold as intervention is necessary to increase forest and regeneration resiliency. If deer impact is Low, you would need a weighted average count of 15 seedlings on the 1/1000th acre plot to adequately regenerate. If deer impact is High, you would need a weighted average count of 50 seedlings on the 1/1000th acre plot to adequately regenerate.
PROTOCOL: Assess if deer impact is Low or High.

Summary

Obviously, understanding and assessing forest conditions and their effect on regeneration is complicated. At this point, three conditions serve as the basis for conducting an assessment: Light, Competition, and White-tailed Deer. The intent in this publication is to frame the rationale for addressing the regeneration challenge and encourage landowners to undertake an assessment by considering their individual stands. The next step in this process is to conduct detailed data collection to arrive at specific impediments to achieving desired future conditions. Once this is done, the hope is that an informed landowner will prioritize activities and seek assistance in developing a plan to ensure successful stewardship of their woodlands – at least as it relates to achieving forest regeneration.

Forest Regeneration Assessment Series- Chapter 3

The second publication in this series, *What's Getting in the Way of Your Woodland's Potential to Regenerate?* provided the background for understanding the need to establish and foster adequate tree regeneration. This understanding begged the question: "What conditions exist in my woodlands?" Answering this depends on conducting a systematic evaluation or assessment of stand-level conditions. This third publication in this series presents a specific protocol and methods for collecting data to guide your understanding of existing conditions using a stand- level decision tree to reach a determination.

As a reminder in the second publication, specific **PROTOCOLS** were highlighted. It may prove useful to refer back to these to understand the reason for collecting specific data.

The assessment described here uses "plots" to collect data to answer questions related to:

- Light conditions
- Competitive plants
- Deer impacts

This information will then feed into a decision key designed to suggest apparent reasons for regeneration success or failure in chosen stands and across woodlands. Recall, again, that the stand is the assessment unit. A "stand" is a contiguous, distinguishable group of trees of similar age distribution, species, structure, site, and history such that it is recognized as a unit. A landowner might even recognize and name these areas as "the hemlocks", "the old orchard" or, "the oak ridge."

Take the time to outline stands on a property sketch or aerial photograph printed from the internet. Having done that, you can begin to fill in the first few lines of the Assessment Tally Sheet. Specifically,

1. the name or number you have given the stand,
2. how many stands you have identified, and
3. approximate acres each stand represents.

Assessment Procedures discussed:

Before data is collected, a walk through the chosen stand is done to consider the size of the area and the variability in both the overstory and understory vegetation. This will help determine how many plots (data collection points) to take.

If the chosen stand is large and more variation is observed than was anticipated, a forester may consider dividing the stand into sub-stands of similar conditions and conducting a separate assessment in each sub-stand. For example, if one area has a high proportion of oak and a carpet of small oak seedlings, another has a high proportion of beech/hemlock and scarce regeneration, these areas are separate stands.

Within each individual stand, a determination is made as to how many plots (data points) to take. Taking more plots increases the reliability of the results. Foresters usually take more plots to obtain an accurate assessment of overstory and understory conditions from which to develop silvicultural prescriptions. Often, the number of understory plots is twice the number of overstory observations since understory conditions frequently are more variable than overstory conditions. Confidence in the assessment results and the accuracy of information will increase as we increase the number of plots.

Plot location: *Routes* are chosen that space the plots evenly throughout the stand. Foresters do not "choose" *plot locations*. If they did, this would bias the results. Also, plots are excluded if they include existing road, forest edge, or anything that makes the plot unique or, does not represent the variation in the stand.

Statistical reliability does require a minimum number of plots. There are various tests for determining the minimum number and the optimum number of data points that should be taken but, that is not the subject of concern for now.

At each plot, the same plot center may be used for a combined understory and overstory plot. If twice as many understory plots are to be taken then a plot center for that is added between each combined plot. At each plot the stand characteristics are observed and recorded. See Figure 1 for understanding the layout of one method (Fixed Radius Plot) of data collection.

→ Walk into the stand to an area that looks similar to what you see across the stand or to your pre-established plot location.

→ Mark the plot center with a stick and flagging.

Take care not to step on seedlings on the 1/1000th acre plot. This is the area you will use to assess advance regeneration.

1/1000th acre plot (milacre plot)

- Regeneration assessment (weighted number of seedlings)

1/10th acre plot

- Canopy density (% canopy openness)
- Coverage of fern, grass, and sedges (% area)
- Coverage of interfering woody plants (% area)

Landscape

- Deer impact (Low/High)

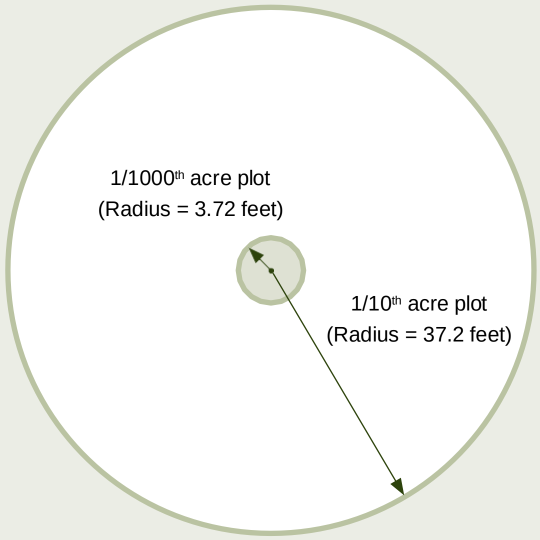
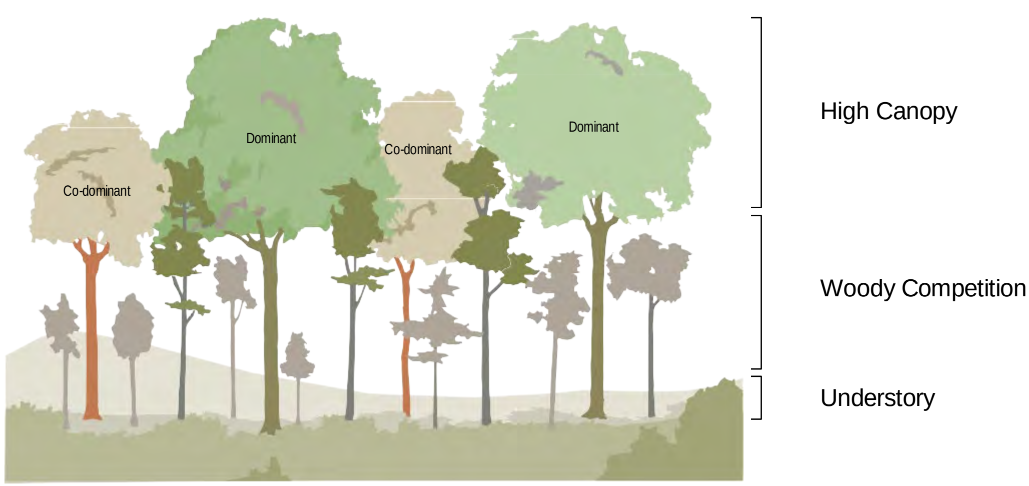


Figure 1.

Stand Structure and Composition assessment considerations:

Stand *structure* and *composition* are two components used to describe forest conditions. *Structure* relates to the vertical and horizontal arrangement of trees within a stand or across a forest, as shown in Figure 2. Structure can provide insights into light distribution. A stand with only a high canopy lacks vertical structure and, depending on the horizontal distribution of trees, this influences canopy closure and thus light distribution. As vertical structure increases or is more complex, lower trees or plants intercept more of the light resource, and the horizontal structure can affect light patterns lower in the structure or on the forest floor.

Figure 2. Vertical Structure of a Stand



Adapted from: Kays, J., Downing, A.K., Finley, J. et al. 2015. The Woods in your Backyard, 2nd Edition. Plant and Life Sciences Publishing, New

York.

Composition provides a description of species. Starting with the high canopy, species provide information on how the structure developed (e.g., tolerance and competition for light), past management activities (e.g., what is there and what is missing), and seed source potential.

The Woody Competition structural layer describes a point where shade density has a larger impact on light resources (i.e., the umbra and penumbra light conditions, see Stand Structure and Composition in *Forest Ecology: How a Forest Grows*). Again, understanding species composition reflects on how this structural layer developed and its effect on regeneration. In many stands, the impact of exotic species is increasingly apparent. To help focus on this challenge, it may prove helpful to separate and identify native and exotic woody species during stand assessment.

It is also important to determine what you want to consider as competitive or desirable woody structure in this layer. For example, foresters would consider any striped maple and American beech root suckers competitive and include them in this competitive assessment. Depending on the landowner's interest, crabapple or juneberry might be desirable and not considered competitive. This point will carry forward into the regeneration tally on the 1/1000th acre plot.

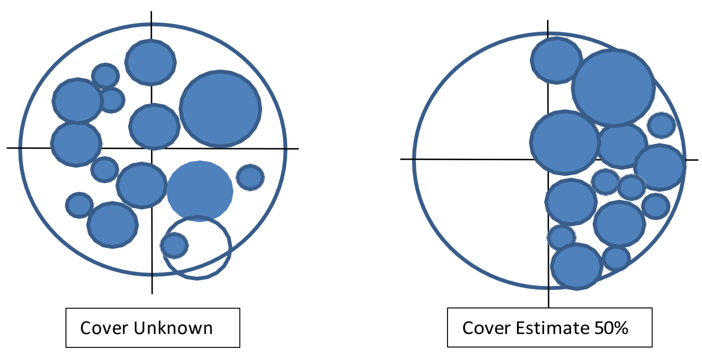
The final layer in the vertical structure is the understory, which considers three components that have the capacity to create low shade: ferns, grass/sedges, and herbaceous plants. Not all ferns are a concern. The intent here is to identify and assess ferns that spread through rhizomes, which results in individual separate fronds, not groupings. Fern species of concern are New York, Hayscented, and Bracken. Grasses and sedges combine into one competitive layer. For identification, grasses have round stems and sedges have "V" or triangular shaped stems. Knowing the difference relates to soil moisture and the potential for water to increase on the site following disturbance – sedges indicate elevated soil moisture or its potential. Herbaceous plants (i.e., soft tissue annual, biennial, or perennial broadleaf plants) do create impactful shade and increasingly these are non-native species. Consider noting the percentages of native and exotic during the assessment.

New York, Hayscented, and Bracken fern species can quickly cover large areas of the understory.

Action Steps taken during a stand assessment:

1. Assessment of canopy closure by calculating the percentage of blue sky that would remain if tree crowns were to be aggregated into quadrants (the example in Figure 3 has 50% blue sky, or 50% canopy closure). There is also a tool that can aid in this task, called a Spherical Crown Densiometer

Figure 3. Example of Calculating Canopy Closure



2. Looking at the midstory (the area 1 to 30 feet above the ground), the same closure calculation is done on the mid-canopy as was done on the high canopy, determining the percentage of the plot that has midstory coverage. It might be important to note whether these are native or exotic species and in what percentage of the mix, they exist.

3. Then by ocular estimate a recording of the percentage of the 1/10th acre plot that has fern, grass/sedges, or herbaceous cover is recorded and a note to species is often helpful.

All of the variables in this portion of the assessment involve estimating percent cover. It is a practice that becomes a skill with practice and the exactness of the number recorded is seldom if ever, critical.

Figure 4 shows an example of how data entries might be made.

Regeneration Assessment
Plot Data

Plot 1 of 5 Stand Name or Number: Good Oak

1/10th Acre (37.2 foot radius) Stand Structure and Composition:

Canopy Closure: 50 % closed

High Canopy Composition: red oak, white oak, sugar maple, red maple

Woody Competition (1 to 30 feet): Total 20 % covered (Optional: 15 % native, 5 % exotic)

Native Woody Composition: striped maple, spicebush

Exotic Woody Composition: Japanese barberry

Fern Cover: 15 % Grass/Sedge Cover: 5 %

Herbaceous Cover: 50 % (Optional: 5 % native, 45 % exotic)

Native Herbaceous Composition: cohosh

Exotic Herbaceous Composition: garlic mustard

Figure 4. Example of 1/10th acre Plot Data Entries

Regeneration Assessment Procedure

Having collected stand structure and composition data on the 1/10th acre, the assessment shifts to the 1/1000th acre (i.e., milacre plot). These are small plots and the data collected on them expands to reflect stocking at the acre and then the stand level. Because of this expansion, the regeneration is carefully tallied. However, note that the regeneration tally does not differentiate species. It is therefore important to establish desirable and undesirable regeneration definitions, where the latter is captured in the woody competition layer assessment discussed above.

Regeneration assessment is challenging, as it is sometimes difficult to know if a tiny plant is desirable or undesirable or even if it is a tree. Again, it is a skill that is developed in time. The research that backs up this practice was done by careful stem count and species identification. Stems are recorded in height groups and multipliers are provided to produce weighted result. Broad ranges of grouped data eventually showed that estimating is as useful and, far more time efficient when collecting data, with essentially the same results.

The next important question is Deer Impact, which is either High or Low. The actual score is then reduced to an "X" indicating adequate regeneration is occurring on the plot, or left blank indicating inadequate regeneration on the plot. The goal is to have 70% of all plots showing an adequate regeneration rating. And in the case of perhaps five plots, err on the conservative side and expect four to have adequate stocking. It is unnecessary to record species however, it is good to note those species considered desirable in the tally. In general, it is the group of tree species considered desirable for timber yields that are also desirable to deer, as food.

Data Summary

Indicate the Stand Development Stage as identified by stand traits. As a refresher, take a look at Table 1 on page 5 of *What's Getting in the Way of Your Woodland's Potential to Regenerate?* Assess white-tailed deer impact and record high or low impact, based on observations. Low indicates the existence of varying heights of preferred woody regeneration and spring indicator wildflowers are present, flowering, and producing seeds. High impact is anything above that threshold (leaving little existence of preferred species).

Upon completing data collection on the assessment plots in a given stand, data is summarized and a stand level understanding of present conditions and future potential can be assessed. Recall too, that deer impact is a stand level measure.

Interpreting the Data Summary

Deer Impact: This is either Low or High. This measure sets the stage for interpreting regeneration adequacy determined by the Regeneration Score.

Regeneration Score: The summary provides a way to assess regeneration distribution or evenness across the stand. The goal is to have 70% or more of the plots meet or exceed the score based on deer impact.

Percent Canopy Density: The average canopy density calculated again reflects light distribution and evenness across the stand. The threshold for this measure is 50%. If the average is above 50%, then canopy openness is generally insufficient to initiate or sustain regeneration of tree species classified as intermediate or intolerant of shade. It is possible to retain some shade tolerant species under more than 50% crown density.

Competitive Plants: The summary average for each of the competitive plant types (i.e., Woody, Fern, Grass/Sedge, Herbaceous) provides one assessment measure, where a value of 30% or more is a significant concern.
First, it occupies at least a third of the site, and with increased light, these species have the capacity to expand as they are seldom desirable white-tailed deer browse species.

Interference Sum: This provides a way to assess the sum impact of all competitive plant types by summing across plot rows on the data sheet. The threshold of concern is 30%. If any of the rows sum to 30% or more, then it is a positive factor of Any Interference and this is a concern. As stated above, 30% coverage by competitive plants suggests significant competition for light and raises concern there is the possibility that competitive plants are now an impediment to regeneration.

Clearly there are trade-offs in achieving desirable regeneration. Suppose all of the measurements (i.e., ferns, grass/sedge, herbaceous, and woody) are low and below the 30% concern threshold. This is in principle good; however, if all of them are present and close to the threshold, caution is warranted as increased light will certainly spur their expansion, especially if the regeneration score is already low.

Interpretation Dichotomous Key

This dichotomous key, shown in Figure 8, walks you through the stand conditions as summarized and indicates where problems might occur. Recommended actions based on observations are color-coded in the rightmost column. Note that many of the situations end in a yellow or red square, indicating that the challenges to obtaining successful regeneration are great. As you work your way through the key and the next Taking Action section, you'll see that there are actions you can take to help create regeneration. It just will take some intervention

Figure 8. Interpretation Dichotomous Key

Item	Description	Go to:
1	Deer impact is high	Go to 2
	Deer impact is low	Go to 7
2	Regeneration is adequate	Go to 3
	Regeneration is inadequate	Go to 4

3	Canopy closure is >50% (light inadequate)	Open canopy to release established regeneration. Monitor impacts of deer and competing vegetation and control as needed. Seek assistance.
	Canopy closure is <50% (light adequate)	Monitor impacts of deer and competing vegetation.
4	Canopy closure is >50% (light inadequate)	Go to 5
	Canopy closure is <50% (light adequate)	Go to 6
5	Interfering vegetation is >30%	Control deer or exclude from the stand. Control competing vegetation prior to opening the canopy to attempt to establish regeneration. Seek assistance.
	Interfering vegetation is <30%	Monitor competing vegetation. Control deer or exclude from the stand prior to opening the canopy to attempt to establish regeneration. Seek assistance.
6	Interfering vegetation is >30%	Control deer or exclude from the stand. Control competing vegetation. Lots of hard work ahead. Seek assistance.
	Interfering vegetation is <30%	Control deer or fence to exclude from the stand. Monitor competing vegetation. Assess potential seed source. Seek assistance.
7	Regeneration is adequate	Go to 8
	Regeneration is inadequate	Go to 9
8	Canopy closure is >50% (light inadequate)	May need to open the canopy to release the established regeneration. Monitor deer impact and competing vegetation. Control plants and deer as needed. Seek assistance.
	Canopy closure is <50% (light adequate)	Monitor deer impact and competing vegetation. Control deer and plants as needed.
9	Canopy closure is >50% (light inadequate)	Go to 10
	Canopy closure is <50% (light adequate)	Go to 11
10	Interfering vegetation is >30%	Control plants prior to opening the crown. Retain overstory species diversity as seed source. Monitor deer impacts. Seek assistance.
	Interfering vegetation is <30%	Create light conditions that will allow regeneration to establish by opening the canopy. Monitor competing vegetation and deer impact. Control deer and plants as needed. Seek assistance.
11	Interfering plants are >30%	Control competitive vegetation. Monitor for deer impacts. Seek assistance.
	Interfering plants are <30%	The lack of regeneration is likely a site-related variable, e.g., soil quality, soil moisture. Seek assistance.

Green = Sustainable	Yellow = Caution and Seek Assistance	Red = Stop and Seek Assistance

Openings in the canopy and a low deer population create good conditions for these young oaks to thrive.

What Do You Want?

What you want is an interesting question and it warrants consideration by every woodland owner, whether the ownership encompasses hundreds of acres or a wooded house lot. Research has repeatedly found that woodland owners want to do well by their land – they want to be stewards.

Taking care of a woods involves planning, developing more than a cursory understanding of forest ecology, investing time and resources in addressing management (i.e., care), which are driven by what you value about your woodland and what is important to you. Again, research finds that woodland owners express diverse values. Among the most frequently mentioned are solitude and privacy, wildlife, recreation, aesthetics, hunting, estate and legacy, and relatively far down the list is income production.

Attaining and sustaining any and all the common values expressed by woodland owners requires retaining desirable forest conditions. It is often difficult to appreciate how dynamic forests are and how they change slowly but continually. Individual trees die, which is obvious, but understanding the process through which trees replace trees and the time scale required involves thinking at spatial and temporal scales that extend over several human lifetimes, especially with the hardwood forests common across Pennsylvania.

If these ideas resonate with a woodland owner, the need for regeneration Is easily understood. More problematic is describing what is missing from a forest. It is important to assess and document regeneration conditions and to appreciate the interactions of competition among plants, the requirement for appropriate light conditions, and the role of white-tailed deer in shifting or sustaining plant communities.

Finally, attaining forest regeneration is a process. That is, it does not generally happen quickly or as the result of one decision. For example, harvesting does not mean regeneration will just appear; rather, creating appropriate light conditions, conserving desirable seed-producing tree species, managing competing vegetation, and keeping deer populations in balance with ecological conditions prior to a harvest, might result over time in successful regeneration – even then, there is no guarantee. Assessing conditions, regeneration development, and planning for management activities all contribute to successful outcomes. Failure to plan and assess conditions is more likely to result in poor outcomes.

EVOLUTION OF SILVICULTURE

The profession of silviculture has evolved for nearly 100 years from emphasis on individual trees to emphasis on the components and processes of forests.

Early silvicultural practices in this country focused on individual trees because of their economic and social importance. Fernow (1916) defined silviculture as the production of wood crops. The economic production of wood for society was the goal of silviculture. Silviculture research investigated the silvics of commercial species, natural and artificial regeneration, tree growth, and relationships between the environment and tree growth. Research logically started with the emphasis on individual trees, but gradually there was increasing research on insects, diseases, fire, non-tree vegetation, soils, and other components of forests.

The advances in knowledge about silvical characteristics of species and growth of trees allowed emphasis to shift to stands of trees. Tourney (1928) and Baker (1934) expanded the definition of silviculture to include methods for establishment and development of forest stands for sustained production of wood crops. Now the emphasis was on stands of trees, but the goal was still wood production to benefit society.

Next, silviculture was defined as the theory and practice of producing and tending a forest that best fulfills the objectives of the owner (Smith 1962). It was no longer assumed that the landowner's objective was the production of wood. This important shift in emphasis recognized that landowners have a wide variety of objectives. Silviculturists developed prescriptions to meet many objectives, which could be as diverse as creating habitat for wildlife, providing clean water, or using genetically improved trees for wood production. The role of silviculture research expanded to use ecological community classifications (for example, habitat types and successional plant communities) that become available in the Interior West (Daubenmire and Daubenmire 1968; Pfister and others 1977; Wellner 1989). Forest growth models were developed, and they were being linked to models that predicted other forest attributes such as shrub cover, impact of insects and diseases, and wildlife (Edminster and others 1990; Moeur 1985; Stage 1973; Teck and others 1996). Silviculture researchers started integrating more ecosystem processes into their studies.

Today, silviculture is defined as "the art and science of controlling the establishment, growth, composition, health, and quality of forests and woodlands to meet the diverse needs and values of landowners and society on a sustainable basis" (SAF 1994). Silviculture is the management of vegetation and creation of forest conditions to meet landowner needs and objectives. Silviculture researchers now explore forest ecosystem processes, structures, and functions. Where is silviculture in terms of its evolution? Interestingly, silviculture has progressed to meeting the intent of its original definition. The root word 'silva' is Latin for an area of woodland or forest (Glare 1968). The literal translation of silviculture is forest culture. Silviculturists prescribe management for all components of the forest to achieve a wide variety of objectives. The current evolution in silviculture to fully implement forest culture in the Interior West is possible because of the collective experience, tools, and scientific knowledge developed over the past 100 years.

CREATING DESIRED CONDITIONS

If silviculture is the art and science of controlling the establishment, growth, composition, health, and quality of forests and woodlands, how does the silviculturist influence the vegetation to meet needs and values? The answer is that vegetation is managed directly and indirectly to favor the desired outcomes. The kind, amount, intensity, and duration of vegetation manipulation depends on the objective.

Silviculturists create and maintain forest structures and processes that result in the desired forest conditions. Forest conditions result in products. Traditionally, products have been wood, water, wildlife, range, and recreation. Products can be easily quantifiable, like the traditional products, or products can be values such as biodiversity, scenery, and spiritual values. Today's silviculturists are dealing with a wide array of products that the public demands.

Silviculturists create desired conditions across the landscape and over time. They develop knowledge and tools for managing forest vegetation. The job of a silviculturist is to integrate knowledge from many disciplines (ecology, pathology, entomology, mensuration, wildlife, watershed, recreation, genetics, soil science, sociology, economics, and so on) to develop prescriptions that produce desired conditions. Not only are silviculturists skilled at creating desired conditions, they are also trained to understand how historic conditions have shaped current forests and how forests will change over time -- 10, 20, 50, and 100+ years into the future. This knowledge can help create desired conditions for today and for decades to come.

VOLUNTARY AND INVOLUNTARY SILVICULTURE

An important point about little or no silvicultural management is that forests are involuntarily changed by human activity. A lack of planning for the future care, development, and replacement of forests becomes a kind of rudderless drifting (Smith 1962). Humans have changed natural cycles in forests, especially wildfires in the west. Cultivation of land adjacent to forests and extinguishing wildfires have changed the frequency and intensity of fires. Human activity has also affected atmospheric

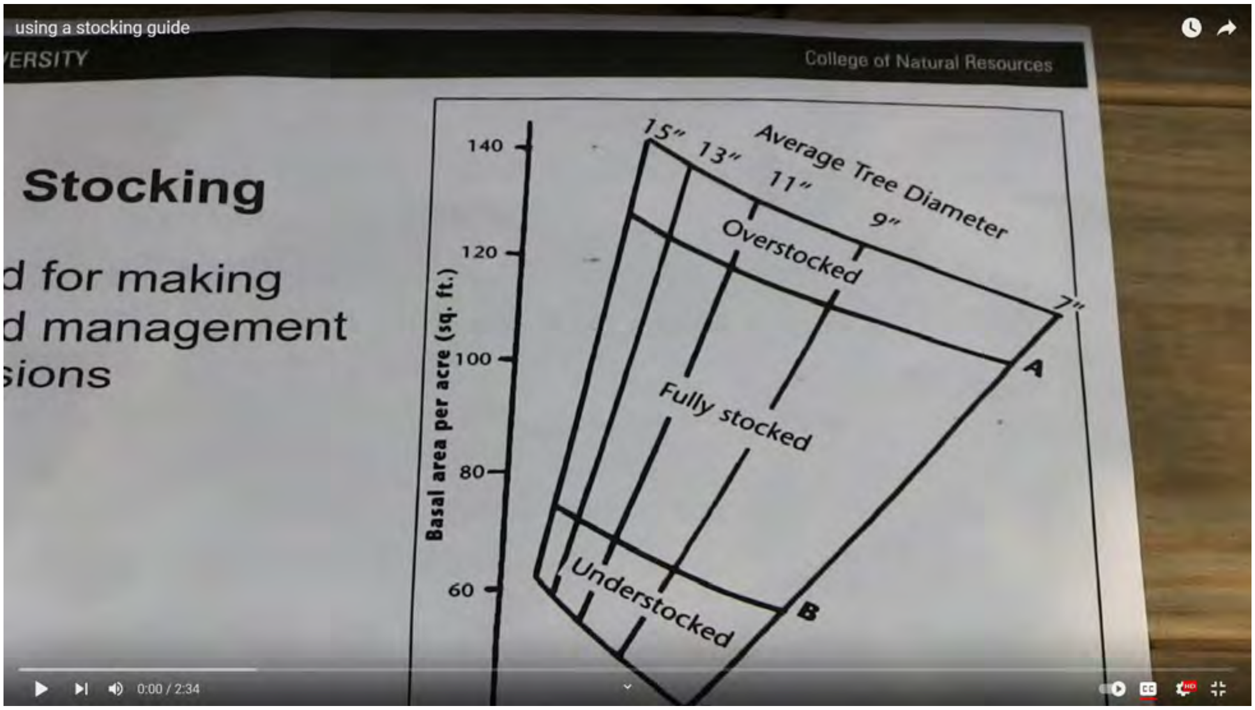
CO_2, high altitude ozone, air temperatures, air quality, wildlife migration routes, gene flow, and the introduction of exotic species of insects, diseases, and plants. We cannot dismiss the existence of involuntary silviculture. It exists and it does have unintentional effects on forests.

Natural resource professionals must consider all consequences of alternative ways that forests can be managed. An example of clear thinking is the discussion about the supply and demand for wood, wood alternatives, and how local and national demand for wood is linked to global supplies (Dekker-Robertson, these proceedings).

America is a net importer of wood and Americans use wood at a rate nearly 3.5 times the global average. Alternatives to wood (steel, aluminum, brick, concrete, and plastic) are expensive, consume large amounts of energy during the manufacturing process, and result in CO_2 release into the atmosphere. When demands for wood are not met locally or nationally, forests in other parts of the world are harvested. Ecologically sensitive tropical rainforests or forests in Siberia are much less productive than forests in the United States. In addition, environmental laws in many foreign countries are weak.

Even if the American people decided not to harvest wood from public lands, there are major health concerns for forests. Ecosystems are constantly changing; they do not and cannot remain static. More wood grows per acre per year in forests than can be decomposed by natural processes (Oliver and others 1994; Olsen 1963). The right combinations of moisture and temperature do not exist long enough each year for wood to decompose as fast as it grows. Fires, insects, and diseases are the disturbance agents that historically recycled excess biomass.

Large amounts of fuel are present in western forests because of fire suppression efforts that began in the early part of this century. Forests that historically burned with low intensity ground fires are now experiencing stand replacing fires. Unacceptable loss of resources and lives are an added expense of fighting wildfires and rehabilitating burned forests. The choices are to manage forests before wildfires or after wildfires; doing nothing is an example of involuntary silviculture.



https://youtu.be/nWUZ7-d-UOY?si=QDX09y6THLnmSpmm

In this 2 1/2 minute video, the instructor explains how to use a Stocking Guide

Woodland Stewardship (FOR 620) is a distance education course offered at NC State university. This channel is of videos used in the course. The course is an introduction and overview of non-industrial private forestry in the Southeast United States with emphasis on active forest management. Topics include history of human impact on forests, evolution of forest, forestry practices, timber and non timber management objectives, financial aspects of forest land management, and management planning.

NCF-Envirothon 2024 New York

Forestry Study Resources

Key Topic #4: Economic Benefits and Ecosystem Services of Forests and Urban Trees

9. Describe the ecosystem services provided by forests and urban trees, including benefits to water quality and wildlife.
10. Describe the social and communal benefits of trees and forests to humans.
11. Describe management strategies for non-timber Forest Products including mushrooms, ginseng and other wild foods, maple products, wildlife, and recreation.

Study Resources

Resource Title	Source	Located on
Benefits of Trees	*International Society of Arboriculture, 2021*	Page 64-65
Wildlife and Forestry in New York Northern Hardwoods	*Audubon New York, 2022*	Page 66-70
The Healing Powers of Trees	*Arbor Day Foundation, 2014*	Page 71-77
Maple Syrup Production	*Penn State University, 2010*	Page 78-80
Farming Exotic Mushrooms in the Forest	*USDA Forest Service, 1999*	Page 81-84
American Ginseng Production in Woodlots	*USDA Forest Service and USDA Natural Resources Conservation Service, 1999*	Page 85-88

<u>Study Resources begin on the next page!</u> ➡

Benefits of Trees

Trees provide social, communal, environmental, and economic benefits.

Trees provide benefits that promote health, social well-being, and even help your home. Trees serve many purposes in your local community and throughout the entire world.

Social Benefits

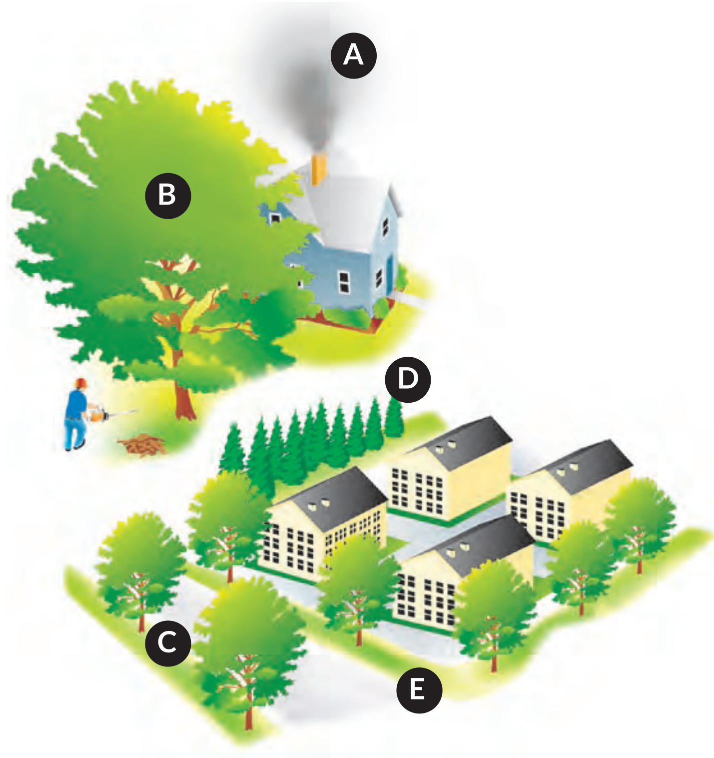
- Trees provide beauty and help people feel serene, peaceful, restful and tranquil.
- Trees significantly reduce workplace stress and fatigue and decrease recovery time after medical procedures.
- Trees may help reduce criminal activity.

Economic Benefits

- Property values of landscaped homes are 5%– 20% higher than non-landscaped homes.
- Individual trees have value that is affected by size, condition, and function. In general, the larger the tree, the greater the value.
- Air conditioning costs are lower in a tree-shaded home; and heating costs are reduced when a home has a windbreak.
- Well-maintained trees can add value to a home.

Communal Benefits

- City trees often serve architectural and engineering functions by providing privacy, emphasizing views or obstructing objectionable views.
- Trees may reduce glare/reflection or direct pedestrian traffic.
- Trees may soften, complement, or enhance architecture.
- Trees bring natural elements and wildlife habitats into urban surroundings, all of which increase the quality of life for residents in the community.



Environmental Benefits

(See figure above)

A: Leaves filter the air we breathe by removing dust and other particles; absorbing carbon dioxide and various air pollutants such as ozone, carbon monoxide and sulfur dioxide; and release oxygen.

B: Deciduous shade trees cool homes in the summer and allow the winter sun to heat homes when they lose their leaves.

C: Trees help cool the environment, working as a simple and effective way to reduce urban heat islands (pavement and buildings in commercial areas cause higher temperatures by absorbing the sun's heat).

D: Trees can serve as a windbreak. The more compact the foliage on the group of trees the more effective the windbreak.

E: Trees intercept water, store some of it and reduce stormwater runoff.

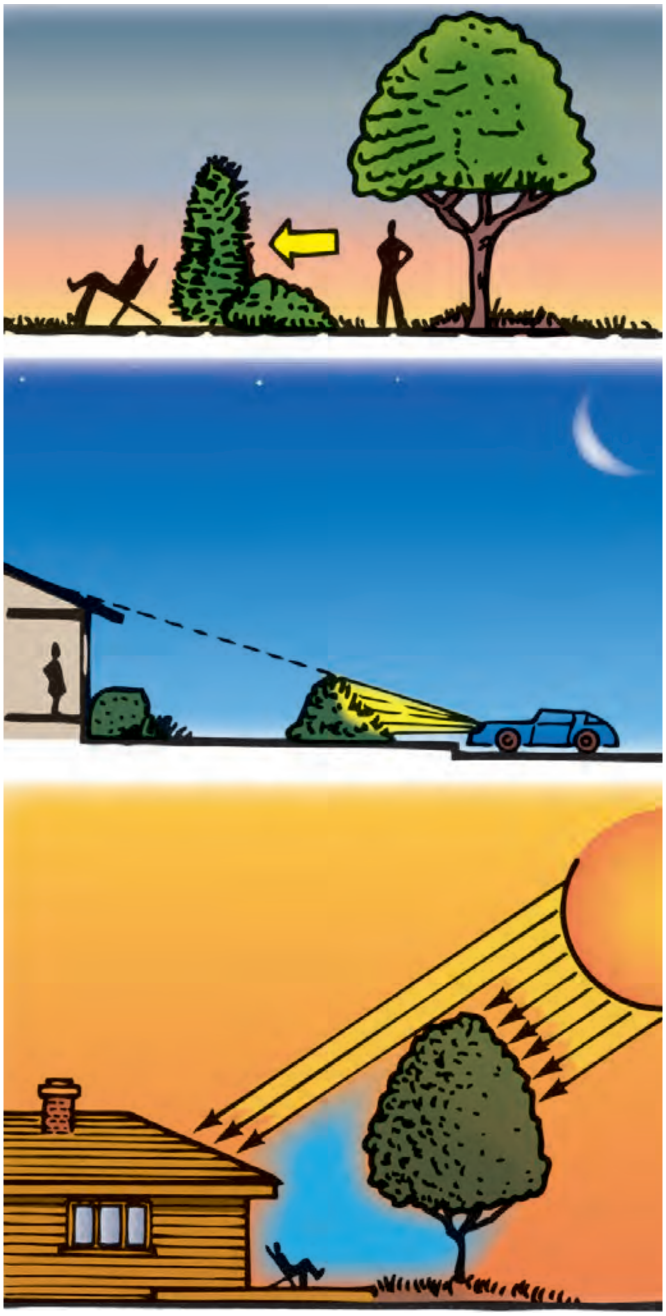
Trees Require an Investment

Trees provide numerous aesthetic and economic benefits, but can have costs. The costs associated with large tree removal and replanting with a smaller tree can be significant. In addition, the economic and environmental benefits produced by a young replacement tree are minimal when compared to those of a mature specimen.

Extending the functional lifespan of large, mature trees with routine maintenance can delay these expenses and maximize returns.

An informed home owner can be responsible for many tree maintenance practices. Corrective pruning and mulching gives young trees a good start. Shade trees, however, quickly grow to a size that may require the services of an arborist.

Your local garden center, university extension agent, community forester, or consulting arborist can answer questions about tree maintenance, suggest treatments, or recommend qualified arborists. ISA Certified Arborists® have the knowledge and equipment needed to prune, treat, fertilize, and otherwise maintain a large tree.



Selecting the right form (shape) to complement the desired function can significantly reduce maintenance costs and increase the tree's value in the landscape.

What Is a Certified Arborist?

ISA Certified Arborists are individuals who have proven a level of knowledge in the art and science of tree care through experience and by passing a comprehensive examination developed by some of the nation's leading experts on tree care.
ISA Certified Arborists must also continue their education to maintain their certification. Therefore, they are more likely to be up to date on the latest techniques in arboriculture.

Finding an Arborist

Visit TreesAreGood.org for free tools:

- The "Find an Arborist" tool can help you locate an arborist in your area.
- The "Verify a Credential" tool enables you to confirm whether an arborist has an ISA credential.

Be an Informed Consumer

One of the best methods to use in choosing an arborist is to educate yourself about some of the basic principles of tree care. Visit TreesAreGood.org to read and download all brochures in this series.

ISA TREES ARE GOOD® www.treesaregood.org

www.isa-arbor.com • www.treesaregood.org

Through research, technology, and education, the International Society of Arboriculture promotes the professional practice of arboriculture and fosters a greater worldwide awareness of the benefits of trees.

PART 1. HOW ARE ANIMAL COMMUNITIES RELATED TO FOREST CONDITIONS?

What is habitat?

The kind of environment where a particular animal spends most of its time is referred to as its habitat. Any large pond will provide habitat for bullfrogs; a large tract of older forest is likely to be habitat for birds such as Barred Owl; a young regenerating forest is excellent habitat for many songbirds. Some animals use different habitats throughout the day, week, or year. White-tailed deer can as easily be found deep in the woods as out in an open field, and it's not unusual to find them running across a large, shallow wetland or browsing through a suburban back yard. Deer may need to spend much of their time in a mature conifer forests to survive severe winter weather conditions and they love to forage in farmers' crop fields during the summer and fall.

As the above examples demonstrate, wildlife relies on habitat for survival and to meet basic needs. These basic needs include food, water, cover, and space sufficient for them to be sheltered from the weather, reproduce and raise young successfully, and avoid predators. Different animals have different needs and specializations, which determine what habitats they tend to prefer and how they use their habitat. Some wildlife require large spaces—whether open or wooded—while other species may spend most of their life within a few feet of where they were born. Often this relates to factors such as their size (a moose requires more space than a mouse!), but it also has to do with how they make their living. Do they move actively through the forest to hunt for food, or do they mostly sit in one place and wait for food to come to them? Does a species feed on abundant plant material, or do they eat other animals that are relatively uncommon? Each wildlife species—whether it is a bird, bat, butterfly, deer, or brook trout—has its own preferred habitat, and each uses its habitat differently to find food, water, or cover, and meet its other needs such as attracting a mate, raising its young, or spending the winter somewhere safe.

How do forested habitats differ?

Forests come in many shapes, sizes, types, and ages. Some forests are dominated by certain types of trees, such as "hardwoods" (like maples, beech, and birch) or "conifers" (like pine, spruce, and hemlock). The *species composition* of a forest (what tree species are present or dominate a forest) can have a strong influence on the type of wildlife that is found there. The wildlife community you would expect to see in a typical hardwood forest will differ predictably from what you would find in most coniferous forests.

Just as tree species composition influences the type of wildlife found in an area, so does the structure of the forest. Some forests have thick, brushy understories with little or no canopy. Others have a closed overhead tree canopy that provides for shade and moisture. Still other forests have a mixture of plant layers including herbs, shrubs, understory and canopy. Different species of wildlife use forests of different forest structures, or conditions, for their habitat.

Forests change quite predictably over time, as they age. This process of change in plant communities over time is known as *succession* (see Figure 1.1). When natural events like intense fires, hurricanes, landslides, or floods occur, they may leave an area

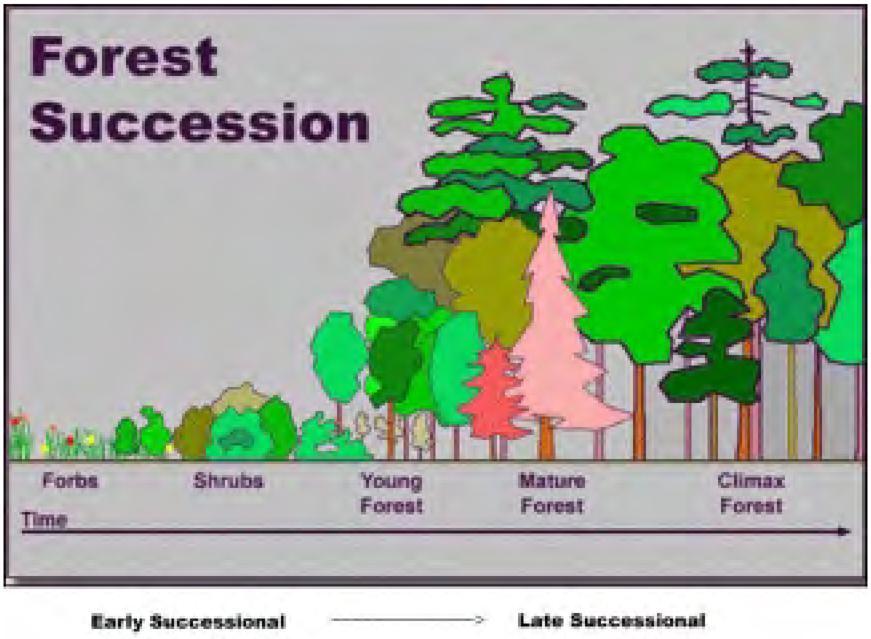


Figure 1.1 Typical forest succession over time.

quantity and quality of food, water, cover, and space changes. Young, early-successional forests, for example, often have an abundance of berry-producing shrubs and brushy cover but few hard mast (acorns, hickory nuts) or cavity trees. As a result, species that feed on berries (e.g., Gray Catbird) and/or require dense cover for safety (e.g., Ruffed Grouse) do well there, but species that eat acorns (e.g., squirrels) or nest in large decaying trees (e.g., Pileated Woodpeckers) are more abundant in older, more mature forests. Some species of wildlife, including the white-tailed deer and Wild Turkey, prefer a combination of plant succession stages. Deer need the cover provided by thickets of shrubs and saplings but they also feed extensively on acorns found under trees in a mature forest and seek out succulent green vegetation and grains in agricultural fields.

completely devoid of vegetation. Likewise, land cleared for agricultural or other uses might also be left with very little vegetation. Over time, left undisturbed, certain plants will tend to reoccupy an open area first and dominate it for some time. They may be species that spread easily or grow rapidly, and these traits give them a competitive advantage over other species. Over time, however, these "*early successional*" plants tend to die off and be replaced by other kinds of plants. This may happen because the fastest-growing plants tend to be short-lived, but it may also be due to changing environmental conditions there over time. The rate of forest succession on any one property is difficult to predict and may vary depending on many different factors like soil type, climate, terrain, natural disturbances, and past land uses including previous timber harvests. Typically however, if undisturbed, an open field over time will be colonized by shrubs and seedlings, which in turn will be replaced with saplings, young trees, and eventually a mature forest. Even mature forests change as small and large disturbances (e.g. a tree dies) occur from time to time. Our forests are constantly changing.

Forest succession affects the plant species that are present in the forest, as well as the forest structure. Likewise, the abundance and kinds of wildlife also change as a forest changes over time, and the

Whether you wish to manage your land for a variety of wildlife species or for a single species, understanding what stage(s) of forest succession each species depends on for food and cover can help you to understand the effects of your forest and wildlife management decisions.

How do forest conditions affect wildlife?

To find the answer to this question Audubon New York conducted research to describe the wildlife communities in many recently harvested forests. The intent was to look at forests that had been managed by various methods to better understand how certain wildlife are related to the forest conditions those methods leave behind. The Audubon research included forests of many different conditions, from clearcuts where almost no trees were left standing, to partial harvests with some trees standing, to unharvested stands with many or all large trees remaining.

This study was carried out in the Adirondack and Catskill regions of New York and in the

"Appalachian Plateau" that extends west from the Catskills along the "Southern Tier" border with Pennsylvania and north towards (but not including) the Finger Lakes region. The research took place in the northern hardwood forest type, because this type represents about 70% of all forests in New York State. Northern hardwood forest is usually made up mostly of sugar and red maple, American beech, yellow birch and, to a lesser extent, black cherry and white ash. Other tree species that are fairly common in northern hardwood forests include eastern hemlock, basswood, red oak, and white pine. It was important to focus on one forest type, because forests of different types (e.g., oak-hickory stands, spruce-fir stands, or mixed stands that include combinations of any of the species above) tend to have different wildlife communities.

Which groups of wildlife were studied?

The study focused on three different groups of non-game wildlife: birds, amphibians, and carrion beetles. Birds were studied because they are one of the most diverse groups of animals in New York State. Different species of birds use forest habitats in different ways to take advantage of all three dimensions of forests, from the ground to the very top of the forest canopy, and from the trunks of trees to the tips of their branches. Therefore, the management and structure of different forests affect which species can live there. Also, birds are popular with landowners, who appreciate them because they are attractive, interesting to watch and, compared to many other animals, birds are easy to see, hear, and enjoy.

Amphibians are recognized as important indicators of habitat conditions and disturbance. Though small and often unnoticed these animals are very abundant in forests. Hidden under the logs and leaf litter of the forest floor often there are at least three salamanders per square meter. Because of their abundance and size amphibians serve as food for others and are effective and efficient predators themselves. They feed on invertebrates that inhabit the forest floor, which in turn affect the rate that nutrients are cycled in the soil. With their semi-permeable skin and unprotected eggs, amphibians are also good indicators of environmental health and water quality.

Carrion beetles were also studied, in part because they are a type of insect which is by far the most diverse and abundant group of animals in the forest. Unlike most insects, carrion beetles are large and colorful which makes them easy to identify and thus handy for scientific studies. Carrion beetles can play an important role in the rate of forest nutrient cycles because they speed up the process by which the bodies of dead animals are broken down. This is because they lay their eggs on pieces of dead tissue, which they bury in the soil, to nourish their developing young. Nutrient cycles regulate how large and how fast trees grow in a forest, which obviously affects the kind of wildlife habitat found in a place over time. Because of their close association with dead animals, the numbers and kinds of beetles in an area have been shown to be related to the total amount (or biomass) of animals in a given forest.

John McKeith

Hardwood partial harvest site - Malone, NY.

What are forest condition categories?

In this study forests were sorted into four different groups (see Figure 1.2) based on the similarities in the numbers and sizes of trees and other aspects of their habitat structure. These groups can be referred to as forest condition categories. The four categories were:

- Mature or very lightly thinned
- Moderate partial cuts
- Heavy partial cuts
- Clearcuts

In mature or lightly thinned forests only a small percentage of the largest trees, if any, were removed. Many kinds of timber harvests are intended to regrow a new forest of young trees, but a thinning is not. Thinnings are meant to "tend" the existing trees, just as you would thin a garden. Mature or lightly thinned stands had a high canopy (the leafy crowns of the tallest trees) that was mostly closed and an understory that was relatively open. There was relatively little ground cover (e.g., ferns, wildflowers, other herbaceous plants, and tree seedlings) in these forest stands.

Moderate partial cuts also have a high forest canopy that is mostly closed. However, they typically have had 20-30% of their timber volume removed. Stands in the more mature category were made up mostly of sawtimber and large sawtimber trees, whereas stands in the moderate partial cut category included mostly poletimber (6-12 inches diameter at breast height [DBH]) sized trees. The biggest differences between these two categories was in the sizes of trees that made up these stands and increasing ground cover in moderate partial cuts due to more light reaching the forest floor and generating pockets of new growth.

Heavy partial cuts included stands that had most of their sawtimber and large sawtimber removed, resulting in much more open conditions than the first two categories. However, all of these stands had some remaining large trees scattered throughout, or small patches of mature trees. This category included a variety of different kinds of management, including some group selection cuts that included both open patches and portions of the stand that were relatively undisturbed, mature forest. It also included heavy "shelterwood" cuts, with relatively few large trees remaining in the canopy, and a dense shrubby understory of young trees and raspberry bushes.

The fourth forest condition category is recent clearcuts. Clearcut stands had very few large trees

My forest doesn't look like that....

Some readers will own or be familiar with other kinds of forests, which do not fall into one of the four forest condition categories discussed in this manual. That is because we focused only on older mature forests and recently-harvested stands. The structure of any forest changes over time and we focused on certain points in time. Virtually all clearcuts and old fields and pastures eventually will turn into a mature forest given sufficient time. However, they will go through a long period of development to arrive there and during this time will not resemble stands in *any* of the four forest condition categories we described.

Clearcuts are a very temporary habitat. The initial shrubby, open conditions that we studied only last for a few years. Within 10-15 years of clearcutting most stands will form a dense thicket of small (1-5" DBH) trees. This young forest will slowly mature as trees grow in height and diameter. As it does it will pass very gradually through different structural phases. However, during this entire 20-40 year process it will not resemble any of the stands in our study as we looked only at *recently harvested* or *older, mature* forests, which had not been cut for some 75 years. We do not discuss younger, developing forests in depth in this manual, though these habitats are used by some wildlife, and landowners do have options in terms of how they manage them. For more information on other forest conditions see the final section, which briefly presents some considerations about other types of forests.

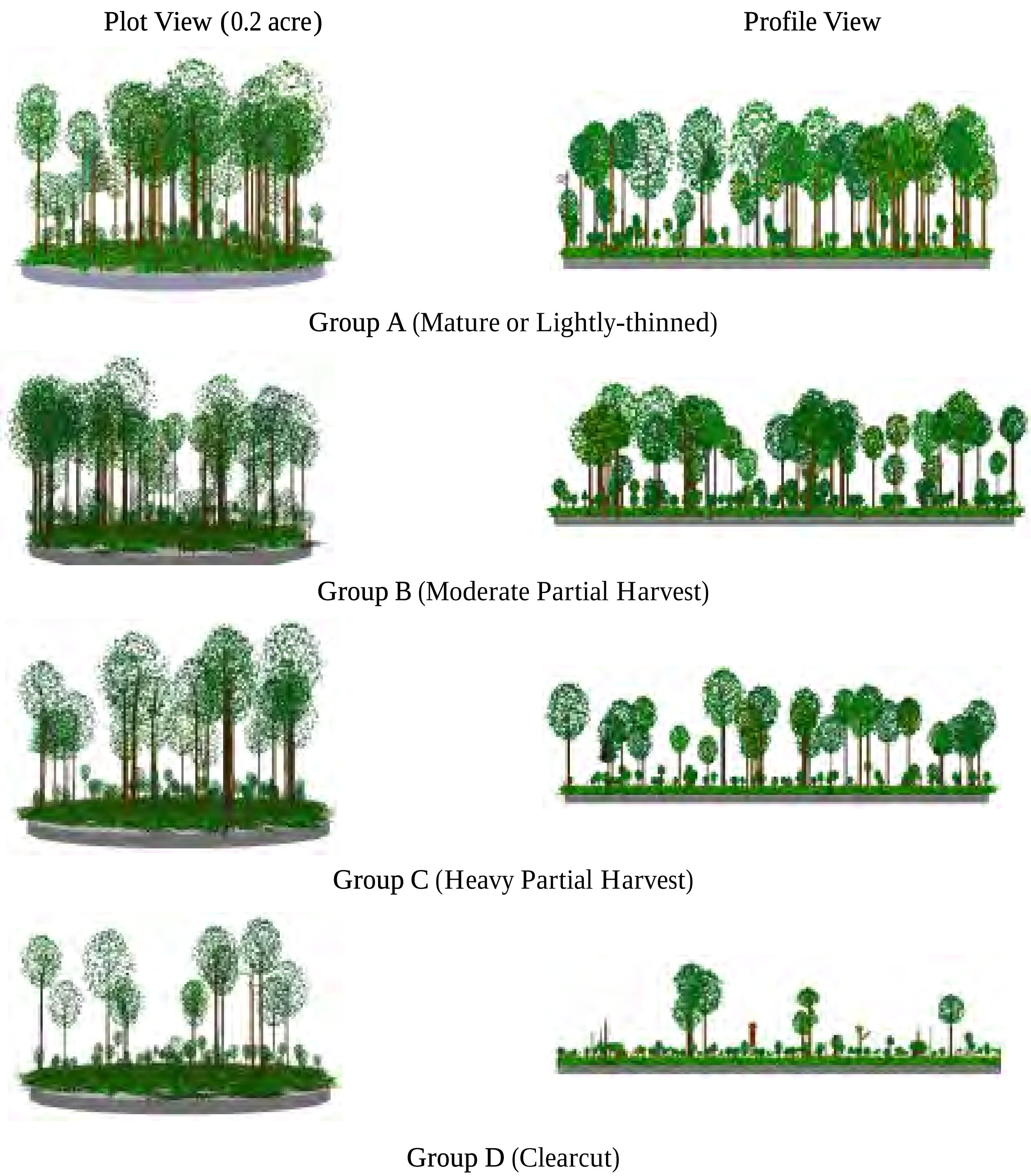


Figure 1.2 Four forest conditions for northern hardwood stands studied in New York.

left uncut. Such stands are dominated by dense, shrubby vegetation such as raspberry bushes and dense stands of small trees.

All four of these condition categories might be expected to differ in terms of tree canopy, understory, ground cover, temperature and moisture, in ways that could affect the habitat for wildlife.

The Healing Power of Trees

TREE CITY USA® BULLETIN

No. 71 Editor: Dr. James R. Fazio • $3.00

An emotional attachment to trees is deeply ingrained in the human spirit. Whether it is a spiritual connection with something larger and unseen or a practical way to reduce stress and live a healthier life, urban foresters and tree boards would do well to recognize and build upon these important benefits.

Who is not familiar with the good feeling that comes from a pleasant walk in the woods?

The noises of streets and people are left behind. The cares of work or personal problems are eased as focus shifts to the majesty of trees and their sweet essence fills the air. It is at once an escape and a refreshment of mind and spirit, the very meaning of 're-create' in recreation. The Japanese have another term for the leisurely woodland walk – 'forest bathing' – and research suggests that it goes beyond being an emotional experience or providing the benefits of exercise. It actually has a physiological effect that can bolster the immune system.

John Muir said of the woodland walk that it is "the clearest way into the universe" and promised that when you go to the forest "Nature's peace will flow into you as sunshine flows into trees." Muir and philosophers throughout the ages saw the healing potential of trees, whether in a wilderness, a sacred grove, an urban park or, like the poet Joyce Kilmer observed – a single tree "that looks at God all day, and lifts her leafy arms to pray."

Although most of us are not philosophers or poets, we all have a favorite tree or special remembrance of it. It was likely to have been part of a life-shaping experience in youth or part of treasured family memories. It may still be a place of solace or relaxation. In the pages that follow, read about what science is telling us of these connections with trees and green spaces – and how they can actually help heal us physically and mentally.

Arbor Day Foundation®
100 Arbor Avenue • Nebraska City, NE 68410

From Intuition to Scientific Fact

Humans have recognized a special connection with trees since the dawn of history. Every major religion includes trees in its earliest stories. The Egyptians had their sacred groves and the Bible mentions trees no less than 120 times. The Celts saw magical powers in trees that varied by species. Philosophers like Rousseau and Thoreau proclaimed moral value or goodness that comes from associating with trees and the outdoors. So did J. Sterling Morton, founder of Arbor Day, who said, “Children reared among trees and flowers growing up with them will be better in mind and in heart than children reared among hogs and cattle.”

As parks began to be established in American cities in the nineteenth century, efforts began at the same time to define just what these intrinsic values might be. Pioneering landscape architect Frederick Law Olmsted believed they improved the mental health of urbanites as more and more people left the more healthful countryside to reside in cities. But he also felt that the topic was “too complex, subtle and spiritual...to be checked off, item by item, like a jeweler’s or a florist’s wares.” In other words, it defied research and understanding.

Social scientists today would disagree with Olmsted. Hundreds of studies worldwide have established a relationship between trees, green spaces and myriad mental health benefits. In a 1963 essay, psychology professor Robert Greenway even coined the term ‘ecopsychology’ and in the Spring/Summer 2009 edition of *Taproot*, a publication of The Coalition for Education in the Outdoors, Denise Mitten succinctly listed the psychological-emotional values of spending time in nature (of which trees are a major component):

- Mental restoration
- Stress reduction and its impacts
- Attention restoration
- Improved mood states
- Reduction of depression
- Reduction of anger and anxiety
- Enhanced feelings of pleasure
- Increased mental acuity
- Reduced mental fatigue
- Improved problem solving-ability
- Improved concentration
- Improved body image for women
- Increased feelings of empowerment
- Encouragement of nurturing characteristics
- Decreased risk of seasonal affective disorder (SAD)
- Mitigation of the impact of dementia

To this list might be added important spiritual and religious benefits.

istockphoto.com/Kevin Russ

THERAPY AND HEALING – SOME DIFFERENCES

THERAPY is the treatment of disease or disorders, as by some remedial, rehabilitating, or curative process.

HORTICULTURAL THERAPY is the engagement of a person in gardening and plant-based activities, facilitated by a trained therapist, to achieve specific therapeutic treatment goals.

HEALING GARDEN or THERAPEUTIC GARDEN is a space in which a person can build on or find inner strength. This is a space anyone can create or use and, by extension of the meaning, can include special places with trees. It is designed to meet the physical, psychological, social and spiritual needs of the people using the garden as well as their caregivers, family and friends. These spaces are typically found around hospitals, nursing homes, assisted living residences and retirement communities.

HORTICULTURAL HEALING GARDEN is a space professionals use to encourage active involvement of clients or patients. The therapist matches plants and chores with the needs of individuals that are challenged physically, emotionally or socially.

Some Amazing Relationships

Research is showing some strong correlations between trees and the green spaces around them and human health consequences.

HOSPITAL RECOVERY

Studies by Dr. Roger Ulrich gained world-wide attention and made a huge impact on the idea that the healing power of nature is real. Dr. Ulrich tracked the recovery rates of 46 hospital patients who had gall bladder operations. Half were assigned to recovery rooms facing a brick wall. The other half could see a small stand of trees outside their windows. He found that patients who could see trees spent 8.5 percent fewer post-operative days in the hospital and needed fewer pain-killing medicines than patients viewing the brick wall. The study has been replicated many places and with similar results.

Paul Mattaco

At Sacred Heart Medical Center at RiverBend in Springfield, Oregon, doctors as well as patients and their families find peace and restoration in the wooded grounds behind and beside the hospital. Here a doctor takes advantage of the natural view while enjoying a break at the cafeteria. Urban foresters and tree boards have an opportunity to encourage and assist with institutional landscaping that provides emotional/psychological benefits as well as eco-services.

THE WORKPLACE

Stephen and Rachel Kaplan were also modern pioneers who looked at human-nature relationships, including office workers and their surroundings. As with many studies that have followed theirs, they found that workers with windows looking out at green elements were more satisfied at work and had more patience, less frustration, increased enthusiasm for work, and fewer health problems than their colleagues in windowless offices. Similar relationships have been shown to reduce absenteeism and increase efficiency.

INNER CITY GIRLS

Work by Drs. Ming (Frances) Kuo and William Sullivan have uncovered a trove of amazing relationships. One famous study showed the positive social effects of landscape around public housing projects. Another focused on young girls living in Chicago apartments. They found that girls in apartments with greener, more natural views scored better on tests of self-discipline than a matched group of girls with more barren views. The young ladies fortunate to have green views showed better concentration, less impulsive behavior and were better able to postpone immediate gratification. This means they can better handle things like peer pressure, sexual pressure and can generally do better in school and prepare more responsibly for later life.

istockphoto.com/digitalskillet

Some Amazing Relationships Continued

CHILDREN

istockphoto.com/ArtisticCaptures

The Dimensions Educational Research Foundation is the repository for scores of studies that show the positive influence of unstructured outdoor play. Trees, of course, are a large part of the spaces that make this possible. The studies of these benefits point out that, in addition to physical benefits, outdoor play opportunities help make children "smarter, better able to get along with others, healthier and happier." And then there are those who are challenged with Attention Deficit Hyperactivity Disorder, or as it is often called in shorthand, ADHD. With over 2 million children in the U.S. diagnosed with ADHD, considerable attention has been focused on how natural settings might be of help. These studies have come to the same conclusion – children with ADHD show reduced symptom severity when they live in more natural settings or have "green time" during the day.

PREGNANT WOMEN

One of the most amazing recent studies was led by Dr. Geof Donovan in Portland, Oregon. In short, the researchers found a strong relationship between leafy neighborhoods and the health of newborn babies. First they carefully controlled for factors such as income and then looked at tree canopy density within 164 feet of the homes of pregnant women. For each 10 percent increase in tree canopy in this zone around a house, the rate of undersized newborns decreased by 1.42 per 1,000 births.

SENIOR CITIZENS

In a Dutch study that controlled for income and other factors, the proximity of nature was found to affect the health of the elderly. In a greener environment, people reported fewer poor health symptoms and perceived better health in general. The researchers concluded that "10% more green space in the living environment leads to a decrease in the number of symptoms that is comparable with a decrease in age by 5 years."

MORE STUDIES

Links to more studies and to the authors of findings mentioned on these pages are provided at the website shown on page 8.

istockphoto.com/Steve Cole

How Does it Work?

The Druids and other ancients attributed the healing power of trees and other plants to magic. At first glance, one may conclude they were right. But now science is looking more closely not only at the relationship between nature and mental health, but the cause(s) behind the consequences.

Some writers have argued that human affinity for trees – and resulting benefits – stems from our genetic base. That is, it is somehow linked to our primordial past. This is difficult to test and affirm or deny. The spiritual aspect of trees is equally murky. At this level of what might be called tree worship, the theory has been suggested that trees help us become more aware of our connection with something larger than ourselves. In her book, *Between Earth and Sky: Our Intimate Connections to Trees*, Dr. Nalini Nadkarni adds that trees put us in a state of "mindfulness," or "the need to be aware of and compassionate towards one's surroundings."

For those who want more concrete evidence of the healing power of trees, there is a growing body of knowledge. Brain chemistry is certainly involved. Perhaps it is as simple as greenery stimulating a dopamine pulse, the neurotransmitter that sends signals to other nerve cells, including the so-called pleasure centers of the brain. But it is probably more than that. Research has focused on a number of physical effects of being around trees, gardens and other green or natural surroundings. For example, environmental psychologist Terry Hartig did an experiment using 112 young adults. They were assigned a variety of stressful tasks and then some were placed in a windowless room and some were exposed to tree views and walked through a nature preserve. He then measured blood pressure and found that the latter group showed blood pressure declining and better feelings commencing sooner than in the control group.

Japanese enjoying the 'forest baths' (walks in the woods) mentioned on page 1 were found to benefit from lower pulse rates, lower blood pressure and lower concentrations of cortisol, a chemical that, among other unhealthy things, suppresses the immune system.

THE KEY

The bottom line that explains the healing power of trees points to stress reduction. Stress is our nervous system giving our body the so-called 'fight-or-flight' response to various stressors. While this was useful to cave dwellers – and still is in many circumstances – it is not so good as a reaction to the workplace, domestic situations, grief, brain fatigue and the other unavoidable circumstances of modern life. Stress triggers higher heart rates, muscle tension (and subsequent headaches), a weakened immune system, sweating and other unhealthy physical responses.

According to Dr. Marc Berman, as reported in *The Wall Street Journal*, trees and other components of nature engage our attention as something interesting and that do not require intense focus. They are something pleasant and give our minds and bodies time to restore themselves. In an experiment, Dr. Berman found that his subjects performed 20 percent better on memory and attention tests after they paused for a walk through an arboretum. Subjects that strolled down a busy street showed no cognitive boost on the tests.

A SUMMARY OF BENEFITS

Dr. Kathleen Wolf sums up the benefits of exposure to nature in cities saying that the urban forest "can help us to calm and cope, to recharge our ability to carry on." The healing – and preventative – effects of trees and green space on human health include:

- PHYSICAL ACTION or the eco-benefits that come from filtering air and water pollutants and reducing heat.
- PHYSICAL ACTIVITY by providing settings that encourage people to engage in walking, jogging and other outdoor exercises.
- SOCIAL SUPPORT by providing inviting places that promote social interaction, a sense of inclusion, and that can lead to reducing social annoyances and preventing crimes.
- RESTORATION, the result of reducing stress and helping people restore their cognitive functions and ability to cope with the demands of life.

If a greener environment can play a role in managing ADHD (Attention Deficit Hyperactivity Disorder), few, if any, studies have explicitly examined whether the converse is also true: that ADHD may be a set of symptoms initiated or aggravated by lack of exposure to nature…

If that's the real ailment, a walk in the woods would be the ideal treatment: It's not stigmatizing, has no serious side effects, and it's free. But such reliance on greenery would underscore the need to scale back industrialism, redesign cities, and expand access to nature – which can't be encapsulated in a pill, but could be equally powerful medicine.

– **Richard Louv**, Author of *Last Child in the Woods* and six other books, and quoted in the Attention Deficit website, ADDitude

What it Can Mean to Urban Forestry

The human health benefits resulting from trees and green spaces are significant. They have even been called the 'green vitamin,' or Vitamin G. And this powerful medicine rests in the hands of urban foresters, tree boards and other stewards of trees and green spaces in our cities and towns.

HOW TO USE THIS INFORMATION

- ☑ PLANT TREES! With 80 percent of our nation living in stressful urban situations, residents in all neighborhoods need the healing power of trees.
- ☑ GAIN SUPPORT The data developed by research can be a powerful tool in gaining the support for urban forestry by city councils, potential donors and grant organizations.
- ☑ BROADEN YOUR AUDIENCE Expand beyond traditional partners by showing health care providers and insurance companies the benefit of trees. For example, based on the Portland study of tree canopy density and healthy babies mentioned on page 4, the findings suggest that by increasing tree cover by 33 percent, there would be 3 fewer undersized newborns per 1,000 births. More trees would lower the costs of health care in this and many other ways.
- ☑ CREATE HEALING GARDENS AND TREE GROVES Spaces designed for this purpose will gain public attention and appreciation. Parks and other public land can be dedicated as healing spaces. Guidance for the creation and maintenance of these places can be provided to hospitals, care centers and similar institutions.
- ☑ HAVE A MEMORIAL TREE PROGRAM If your community does not have a way for residents to donate funds for a memorial tree, find out how these programs elsewhere provide a source of funding for trees while at the same time providing a humanitarian service.
- ☑ SPONSOR A NATURE EXPLORE CLASSROOM These carefully designed outdoor spaces not only connect children with nature, they can provide a place for family bonding. Domestic violence centers are among the many institutions using this means to provide solace to troubled children and parents.

Growth Award
TREE CITY USA

Activities to initiate or expand the use of trees to take advantage of their healing power may qualify for points needed to earn the Tree City USA Growth Award. For more information, visit **arborday.org** and navigate to the Growth Award section.

istockphoto.com/simonox

MEMORIAL TREES AND GROVES

The Grove of Remembrance is a program of the New Jersey Tree Foundation. The memorial grove is an 11-acre tract at Liberty State Park where 750 trees were planted in remembrance of the terrorist attack of September 11, 2001. Planning and development of the grove included involving the victims' families, an important element when considering a memorial grove. Besides the trees, features of The Grove of Remembrance include planting beds, donated shrubbery, and walkways that lead to a circular area with a plaque containing the names of all New Jersey residents who were lost on that fateful day.

Trees provide the psychological benefits described throughout this bulletin as well as eco-services such as cleaner, cooler air and stormwater retention. But they also offer one additional opportunity. When death occurs in a family or tragedy strikes on a larger scale, loved ones are often at a loss as to how to memorialize or properly celebrate the life of the deceased. Planting memorial trees can help – in two ways. First, it truly continues the contributions of an individual beyond his or her lifetime, and at the same time it provides an uplifting avenue of action for the bereaved.

A community program that enables donations for memorial trees usually takes one of several forms:

- A special tree is planted somewhere in town or on an institution's grounds where it is needed, paid for with donations, and identified with a plaque or marker. The latter is sometimes flat on the ground or surrounded by mulch to address maintenance issues.
- Same as above but in a place designated for memorial trees such as along bike paths or in greenways, cemeteries, or arboreta.
- In both cases, the addition of individual trees is ongoing as the need arises and should be publicized with specific costs, rules and opportunities clearly spelled out in a brochure. Distribution of the brochure should include all funeral directors and churches in the area.
- A memorial grove might be created for the commemoration of a person or event. This usually entails the dedication of a piece of land for the purpose and the addition of infrastructure such as walks, lighting and appropriate signage.

AN ADDED DIMENSION TO ARBOR DAY

Each year tree boards are faced with the question about where to plant trees and hold an Arbor Day celebration. When planning, consider using trees to meet the emotional/psychological needs of people in your community. Consider retirement homes or convalescent homes, hospitals, and similar spaces, or start a memorial grove where trees can be added in the future.

With a little thought, there may be other ways to get 'extra duty' from Arbor Day trees. Here is what the 2012 Arbor Day tree means to the residents of McCall, Idaho: A few years earlier a beautiful young spruce tree was spotted by resident Janet Meckel at a local tree farm. It was then marked with a ribbon as "Janet's Tree" and she planned to have it moved to her yard. But life for Janet took an unexpected turn and she found herself fighting for her life against acute myeloblastic leukemia. After a grueling bone marrow transplant and a long but successful struggle with the disease, Janet's family decided to have "Janet's Tree" donated to the city's park as part of the 2012 Arbor Day celebration. In a letter published in McCall's *Star-News*, Janet wrote that when she first saw the tree that she wanted for her yard, she saw it as "…as a beautiful and grand symbol of life and second chances. Now, where it stands in the middle of Legacy Park, our hearts celebrate knowing its branches will provide to everyone comfort in the heat and shelter in a storm, just as the arms of this community did for us. It is our prayer and desire that the tree will stand as a monument of gratitude and as a symbol of hope for generations to come."

A special Arbor Day tree is lowered into place by Troy Berheim of Meckel Excavation in McCall, Idaho's Legacy Park. The tree was donated by a family grateful for the recovery of a loved one from a life-threatening disease.

AGRICULTURAL
ALTERNATIVES
PENNSTATE agalternatives.aers.psu.edu

Maple Syrup Production

Production

Site and Tree Selection

The best species of maple for syrup production in Pennsylvania is sugar (often called hard or rock) maple (*Acer saccharum*). However, red, silver, and Norway maples may be used. Generally, the sugar content of the sap of these species is not as high, requiring more sap to produce syrup. Also, red and silver maple will break bud (swelling of the buds) sooner than will sugar maple, which shortens the sap-collection season. The best trees to tap have large crowns with no defects. Check with your local extension office or forester if you have questions about the maple species you have.

One of the most important and most often overlooked factors in maple syrup production is maintaining the sugar maple tree in a healthy and productive condition. To maximize tree health and vigor, the soil should be moist but well drained. Sugar maple is a somewhat demanding species as far as soil fertility is concerned. Thinning your sugar bush is likely going to be needed to improve the spacing among your trees. Adequately spaced trees will be healthier and produce larger crowns, which will eventually lead to higher sap production. By working with a professional forester who is familiar with maple sap and syrup production, you can develop a management plan to maximize production while protecting the sugar bush.

When selecting the site of the sugar bush you plan to use, several factors should be considered. The topography of the land is of particular concern. If you plan to use tubing to collect the sap, the ideal site for the sugar bush will be at a higher elevation than the sugar house. This will allow you to move the sap by gravity and eliminate the need to haul the sap from the trees to the sugar house. If this type of site is not available to you, then ease of moving the sap should be considered.

Your annual sap crop will depend to some extent on environmental factors from the previous growing season. Two other factors play major roles in sap production and the amount of sugar found in the sap. Healthy trees with large crowns will normally produce more sap during a season and the sap will have a higher sugar percentage. As you gain experience with making maple syrup, you will likely discover trees that consistently produce more sap and are sweeter. Much of this is genetically determined. The other major factor is the weather conditions at the time the season begins.

Tapping Trees

In the Northeast, sap begins to flow in late January or early February. However, the most productive runs (times when sap flows) will be from mid-February through March (and occasionally into early April). Warm days (temperatures above 40°F) and cold nights (temperatures below 32°F) will normally start the flow of sap. The sap will often quit flowing if night temperatures exceed 32°F and will begin again when nights drop below freezing. Generally, early runs produce lighter syrups. The further you go into the season, the darker the syrup becomes. Light syrups are preferred for value-added products such as maple sugar and maple cream. You should stop collecting sap before the buds begin to swell because such sap produces off-flavored (called "buddy") and less valuable syrup. Useable sap may flow for four to six weeks depending on weather conditions.

Trees may be tapped when they are between 10 to 12 inches in diameter (measured 4.5 feet diameter breast height [DBH] above the ground). Trees up to 18 inches in diameter should have no more than one tap. Trees greater than 18 inches in diameter may receive two taps. Using more than two taps per tree is discouraged. Unhealthy trees or trees of low vigor should not be tapped.

You should move the tap hole at least two inches to the side and twelve inches above or below the hole from previous years. Taps placed close to previous holes are likely not to produce sap. Tap holes will usually close within three years. Careful tapping will not damage trees as there are reports of trees being tapped for 100 years.

You will need a rechargeable drill or brace to begin the tapping process. Use a 5/16 inch bit to drill a hole 1 ½ to 2 inch deep into the white wood at a slightly upward angle. The upward angle will help facilitate sap flow. Take care not to oval the tap hole so the tap (spile) will fit snugly and close quickly. Tap holes should not be drilled into frozen wood.

While drilling the tap hole, check the color of the wood being removed. Cream, as opposed to brown, is the desired wood color. Brown-colored wood shavings indicate rotten or unhealthy wood, and you should move the hole to another location. Clean all shavings from the hole (do not blow, place any sort of sanitizing pellet, or spray into the hole) and insert the spile into the hole and tap it gently to secure it snugly in the hole. Keep in mind that the spile will hold the weight of the bucket and sap during collection. Your spiles should be sanitized before using with a 20:1 unscented household chlorine bleach solution. Make sure they are thoroughly rinsed with hot water after sanitizing. If using plastic tubing, any remaining chlorine bleach solution on the spile is likely to attract squirrels. They will damage the spile and make it unusable.

Commercial spiles are available from suppliers in many styles. The style you choose will depend on your collection method. If you use buckets for collection, you will require a different spile than if you plan to use plastic tubing.

Spiles should be carefully removed at the end of the syrup season. Do not leave the spile in the tree. Tap holes do not need to be plugged; this can interfere with hole closure.

Collection and Storage

If you choose to use buckets for sap collection, purchase new or undamaged, clean, used buckets. Make sure that the buckets you purchased are made of a lead-free material. You will need a lid or covering to prevent dirt, rain, snow, twigs, and other debris from getting into the sap. Before collection begins, you should clean all buckets with a 20:1 chlorine bleach solution and rinse the buckets thoroughly several times with hot water. Capped gallon jugs may also be used. Whatever you use, make sure it is of food-grade material and has not previously contained any hazardous or toxic materials.

Sap should not be left in the collection container for more than two days. After two days microbial action will result in a lower grade of syrup. If the days are warm the sap may spoil. This sap is no longer useful and must be discarded. You will need to plan accordingly to transport, store, and boil the sap as quickly as your evaporation system will allow.

If your site and conditions allow, plastic tubing may be used to collect and transport the sap to the storage facility. Steep slopes are not required as tubing may be used on slopes as low as 2 to 5 percent. It should be noted that wildlife can affect the use of tubing. Squirrels often chew the tubing and deer occasionally knock the tubing from the spile. Because of these possibilities, you need to check tubing regularly during sap flow. Using hot water for several rinses instead of chlorine bleach to clean the tubing at the end of the season will reduce the amount of squirrel damage. If you wish to expand your operation, consider investing in a vacuum system. Vacuum systems increase sap production over gravity systems.

If not using tubing, you will need to consider transportation to your storage tank. Roads or paths will need to be constructed and maintained to transport the sap in all types of weather. Depending on the quality of the road or path, you may use a truck, ATV, or horses and a sled or wagon fitted with a collection tank to haul sap.

The size of the storage tank will be dictated by the size of the operation. You will need to have enough storage capacity to accommodate two days of sap collection for your operation. Allowing for two gallons of sap storage per tap is a good standard to follow. Storage tanks must be of a food grade material and nonporous. Tanks with lead solder are not acceptable. The tanks should be cleaned regularly during the evaporation season using a 20:1 chlorine bleach solution and then triple-rinsed with hot potable water. It is recommended that you have two tanks so sap can still be stored while the other tank is being cleaned.

Evaporation and Boiling

Once you have collected and transported the sap to a central location, you can begin the process of evaporating and producing syrup. Sap should be filtered to remove debris and other foreign material before boiling. Sap is best boiled in a well-ventilated building to allow steam to escape.

You will need several pieces of equipment: a heating source, evaporating pans or continuous-flow evaporator, thermometer, filtering material, and bottles or barrels for storing the syrup. You may be able to make the evaporator yourself, or you may choose to purchase an evaporator from an equipment dealer. You may be able to find good-quality used equipment from a producer who is expanding his or her operation. You should make sure that any used evaporator was constructed of lead-free materials. A hydrometer and hydrometer cup or refractometer is a must. This will help you determine the sugar content of your syrup. Syrup must have a minimum of 66 brix (this equates to 66 percent sugar content) to be considered syrup. Syrup at a lower concentration is more likely to mold or go sour. There is legally no upper limit for syrup, but syrup with sugar content greater than 68 percent is more likely to form sugar crystals in the container.

The heating source is called an "arch" in maple syrup production. For very small producers, this may be an old stove or constructed from concrete blocks and a smoke stack. If you plan to construct your arch from concrete blocks, it should match the size of your evaporating pans. It should be at least two blocks high and be fitted with a smoke stack to remove the smoke and increase heat efficiency. Wood is the most widely used fuel source, so a smokestack will help move the smoke above head level. The evaporation process may be completed by either a batch process or continuous-flow system. The batch process uses flat pans at least 2 inches deep because the sap should be at least 1.5 inches deep in the pan to prevent scorching and at least 12 inches square. The larger the pans you use, the quicker the entire process. Whatever you use as an evaporator, it must be lead free. If you have more than 50 taps, small continuous-flow systems may be purchased from a supplier.

Sap will boil at the same temperature as water and depends on elevation and barometric pressure. On any operating day, determine the boiling point of water and add about 7.5°F for the finishing temperature of syrup. Barometric pressure varies daily and affects the boiling point by a few degrees. A candy thermometer calibrated to the nearest degree should be used to determine the boiling point. While boiling, the sap will roll and foam. A defoaming agent may be purchased from a supplier to decrease the amount of foam. One to two drops per batch should be sufficient.

You should take care during the evaporation process so that your syrup is as close to 66 percent sugar content as possible. Overboiling will cause the syrup to be darker than desired and may cause the syrup to taste scorched or burned. This will greatly reduce the value of the finished syrup. Faster boiling will yield higher quality syrup, so controlling the heat during the finishing process is critical. Many producers do not finish the syrup in the large evaporator. They will draw it off at a lower concentration and then finish the syrup in a smaller pan where the temperature can be better controlled.

When you have finished syrup, you will need to filter it before filling your containers. Commercially available clean wool or orlon is commonly used to filter hot syrup. Paper filters should be used ahead of the wool or orlon filter to extend their useful life. Filtering the syrup is required to remove any "sugar sand," small mineral particles that have precipitated out during the evaporation process. Removing the gritty sugar sand will make your syrup clearer and results in a finished product that looks and tastes good. If you increase in size, you may consider purchasing a filter press designed for filtering syrup. This will make the filtration process much easier and quicker.

Bottling

After filtering the syrup, you are now ready to begin the bottling process. Syrup should be bottled at a temperature between 180 and 190°F. You may use bottles, canning jars, or commercially available containers to store and sell the syrup. An attractive container will do a lot to help you successfully market your product. To prevent breakage, containers receiving hot syrup should be at room temperature. Separate the filled containers slightly while the syrup is cooling. As mentioned earlier, when selling syrup the containers must be labeled as to grade, net contents by volume, and have your farm or business name and address on the container. You can also store syrup in food-grade drums for future bottling.

Agroforestry Notes
USDA Forest Service • USDA Natural Resources Conservation Service

AF Note — 13 July, 1999

Farming Exotic Mushrooms in the Forest

Introduction

One income opportunity derived from forest farming is the production of exotic mushrooms. Many of these edible mushrooms, such as shiitake *(Lentinula edodes)*, maitake *(Grifola frondosa)*, lion's mane *(Hericium erinaceus)*, and oyster *(Pleurotus spp.)* feed on the cellulose and lignin in wood. Although a significant volume of these mushrooms is produced under artificial conditions on a substrate of sawdust, grains and other supplements, production on logs results in firmer texture and more flavor.

Production of high-value mushrooms on small diameter logs of almost any hardwood species enables a private forest landowner to utilize forest thinning residue. In the past ten years or so, markets for shiitake mushrooms have remained stable, with wholesale prices for top quality mushrooms ranging from $4 to $12 per pound, depending on supply and demand.

Exotic Mushrooms Commonly Farmed in the Forest

Shiitake - Gourmet mushrooms that look like many other stalked mushrooms, have a slight garlicky taste, are honey brown to almost black on top with white gills underneath.

Maitake (also called hen-of-the-woods) - Gourmet mushrooms which tend to grow in large masses of overlapping scales, similar to turkey feathers, are brownish-gray in color with light gray to cream edges.

Lion's mane (also called pompom) - Gourmet mushrooms which grow to resemble a pompom, with many "spikey" projections downward on a single large (greater than a six inch) mass, cream to white in color.

Oyster - Gourmet mushrooms which come in a wide array of colors from cream to various pastels, which can grow in a stalked form, like shiitake, or in more of a mass form, like lion's mane.

Materials and Equipment

High speed drill

Use drill bits sized for the kind of spawn or inoculation tool used (see below), and a drill stop to prevent drilling too deeply into the wood.

Spawn

This material comes in two forms, sawdust spawn and dowel spawn. Both include spores of the desired mushroom species which have been "run" through either sawdust or small wooden dowels (about one inch by 3/16 inch). Grain is added to the sawdust mixture as a nutrient and carbohydrate source.

Sawdust spawn is usually sold by the pound and dowel spawn in containers of 100. Standard units (enough to inoculate 10 to 20 logs) cost around $20. A rule of thumb is that shiitake inoculation will cost $1.00 to $1.50 per log. In addition to its two physical forms, shiitake spawn also comes in different varieties - warm season, cool season, and wide range (referring to the climatic conditions under which the strain is most likely to fruit). Growers should consider a cold weather strain for growth in the spring or fall and a warm weather or wide range strain for summer. New growers should experiment with different types to see which work best under their unique conditions. Costs for spawn of different mushroom species vary - spawn for oyster and lion's mane may cost closer to $2.00 per log, and maitake, $3.00 per log. When ordering spawn, it is suggested that at least two strains of spawn be used.

Freshly cut logs

Logs should be cut no more than a few days before inoculating, and the trees from which the logs are cut should be alive at the time of cutting. Inoculating into freshly cut logs should ensure that the fungus which begins the breakdown process of the log is the desired mushroom species and not something else. Recommended log diameters are three to eight inches; recommended lengths are two to four feet. Logs smaller than three inches in diameter can dry out very quickly; logs greater than six inches in diameter can produce mushrooms over a longer period of time but require more inoculation sites per log to compensate for the greater diameter. Maitake can also be inoculated directly into the stumps of freshly cut trees. Mushroom logs require a lot of handling, so it is important to note that a log four feet by eight inches can weigh up to 80 pounds! Oaks have proven to be some of the most productive species for exotic mushrooms, and a wide variety of other hardwood species are also acceptable.

Cheese wax or other food-grade wax

When spawn is inoculated into the logs, the inoculation sites and any other raw wood sites (cuts, branch stubs, scrapes, possibly the ends) should be coated with hot (400 degrees F.) wax. This sterilizes the surface of the site against any competing fungi or bacteria and prevents water loss, maintaining proper moisture content.

- **Heat source for the wax -** anything that will melt the wax and keep the wax hot during the inoculation step. Possibilities include a heavy duty pot on a camping stove or other heat source, or a self-contained electric deep fryer.
- **Applicators for wax -** metal or glass turkey basters work best, ideally with a steel wool screen in the tip. Most paint brushes or similar applicators will melt. Natural fiber brushes can be used, but are more expensive and difficult to find.

Inoculation equipment

Sawdust spawn requires a simple plunger or inoculation tool to pack the right amount into the drilled holes. Dowel spawn plugs are inserted into the logs and usually hammered flush with or just below the surface of the log. Both types need to be waxed.

Labels for the logs

Purchased or handmade labels from aluminum cans work well. It is important to label each log with the date it was inoculated, the tree species, and the type of spawn used.

Growing Process

Obtain logs

Cut or obtain fresh-cut logs during the dormant season when sap is running in the tree and contains the maximum amount of stored carbohydrates—either in the late fall when sap is moving down into the roots, or in the late winter/early spring when it begins to move up to the crown again, roughly Thanksgiving to St. Patrick's Day. During log cutting, it is important to minimize damage to the bark layer.

Inoculate logs

Inoculate the logs by drilling a pattern of holes through the bark and into the sapwood. Drilling adjacent rows offset from the next row makes the classic diamond pattern. Holes within rows need to be six inches apart. The depth of the drill holes depends on the type of spawn and the inoculation tool used. Fill each hole with spawn, seal the inoculation site, and label the log. A rule of thumb is that the number of rows down the length of a log should be one less than the number of inches in diameter at the log's small end. For example, if the log is five inches in diameter, there should be four rows of holes down the log's length. Inoculation should occur within two weeks of felling a tree.

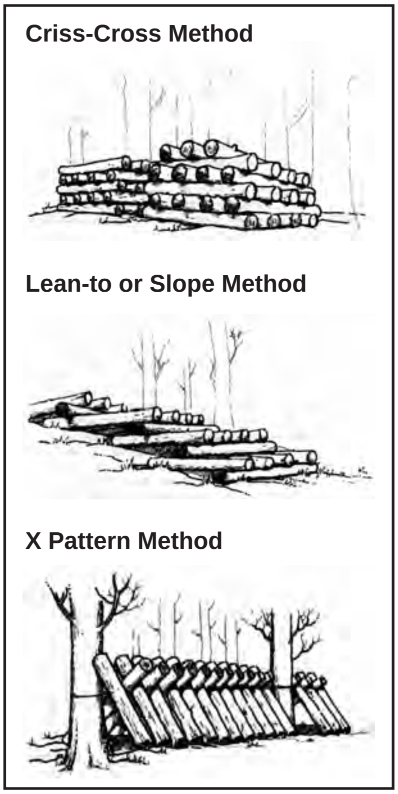


Figure 1: Common stacking methods.

Incubate logs

Incubate the logs until the mycelia of the mushroom (the "root" system of the fungus and really the major body of the organism - mushrooms are simply fruiting bodies of the organism) has had the opportunity to colonize the whole log, a process called the "spawn run." Depending on the strain of spawn used, the specific local conditions, and the care with which moisture content is monitored, the spawn run may take from six to eighteen months, after which the first "fruiting" will occur. During this time, the logs should be in a "laying yard" where they are heavily shaded (75 to 80 percent shade), and where there is a source of water nearby. Logs are often stacked "lean-to" style (one log flat on the ground with three or four logs resting one end against it, and the pattern repeated). This keeps them close to the ground where they can absorb moisture. See Figure 1 for other methods. Some mushrooms (i.e., maitake) produce most effectively when one end of the log is buried in the soil, or when the log length is half-buried in soil, although this stacking style may create a climate for greater contamination of the logs by other fungal and bacterial species. The grower needs to determine the right balance for moisture retention and air circulation when deciding which stacking method to use. The optimum situation is when the bark remains dry to prevent contamination while the inside remains moist.

Monitor moisture content

This should be done on a bi-weekly (summer) or monthly (winter) basis. If the logs dry out, the fungus will die. There are some basic formulae for calculating the appropriate range of percent moisture in the logs based on weight. Simply put, cut a one-inch wide section ("cookie") out at six inches from one end of a log. Weigh the section and the larger end of the log immediately. Dry the cookie overnight in the oven (300 degrees F) and re-weigh. The dry weight of the large log piece can then be calculated from the ratio between the fresh and dry weights of the cookie. The range of weights (fresh to dry of the log section) is what indicates whether or not the logs need watering. The section of the "moisture content" log should be weighed regularly. It is wise to have a moisture content log for every ten or fifteen logs in a pile. If the moisture content logs weigh lower than the midpoint of their range, all logs should be soaked or sprinkled with water equal to one inch of rainfall over a 24 hour period.

Harvesting

Once the spawn run is complete (white mycelia usually show at the ends of the logs) and the weather conditions are favorable (warm and moist — often when the seasons change), the fungi will begin to fruit. If controlled production is desired, the logs can be immersed in water for 24 hours, which will force the logs to fruit about a week later. The flush lasts about a week and the producing logs then need to rest eight to twelve weeks before another soaking. Logs can produce about 10 percent of the wet weight of the original log in mushrooms over their productive lifetime. If the logs fruit at will, they will produce over a longer period of time, and if they are forced, the same total production will occur in a shorter time. Once logs begin to fruit, they will normally produce mushrooms one to several times a year for up to six years.

Mushrooms should be harvested on a daily basis, usually in the afternoon when they are dry. Mushrooms are removed from the log by twisting or cutting at the base when they have opened about 60 to 75 percent. They should immediately be put into cardboard boxes and refrigerated. Refrigeration can extend the shelf life of mushrooms from four to five days to up to two or three weeks. Mushrooms of lower quality or freshness can be dried. Mushrooms can be dried by placing them over dry, warm air, preferably in sunlight which increases vitamin D content. Seven pounds of fresh shiitake mushrooms yields about one pound dried.

Marketing

Be sure to find a market before growing mushrooms although marketing should also take place both during and after growing the mushrooms. Restaurants, farmers' markets, supermarkets, health and natural food stores, and harvest festivals are all good options for marketing exotic mushrooms. When marketing to supermarkets, it is important to arrange for a food tasting demonstration in the market so that consumers can sample the flavor of the mushrooms. Clientele for natural food markets and farmers' markets are more likely to try something new and different, even without first tasting it. Shiitake mushrooms are easily dried and reconstitute well, so marketing by mail is also possible.

How many logs?

A ten-log operation is typical if mushrooms are to be grown for personal use or for family and neighbors. To produce commercially, 200 to 500 logs is a good beginning size, and to produce as a full-time business, thousands of logs are necessary. Management and monitoring are largely labor, rather than equipment, costs. A couple or a family can manage a less-than-500 log farm. When there are thousands of logs involved, hired labor probably will be necessary, especially for cutting logs and inoculating them.

Additional Information

- Eagle Bluffs Environmental Education Center (contact Joe Deden), (formerly Forest Resource Center), 1991 Brightsdale Road, Route 2, Box 156A, Lanesboro, MN 55949. Phone: 507-467-2437
- Fungi Perfecti (contact Paul Stamets), P.O. Box 7634, Olympia, WA 98507. Phone: 206-426-9292
- Northwest Mycological Consultants (contact John Donoghue), 702 NW 4th Street, Corvallis, OR 97330. Phone: 503-753-8198
- Field & Forest Products (contact Joe Krawczyk or Mary Ellen Kozak), N3296 Kozuzek Road, Peshtigo, WI 54157. Phone: 715-582-4997
- Mushroompeople (contact Frank Michael), P.O. Box 220, Summertown, TN 38483. Phone: 931-964-2200
- Mushroom Harvest (contact George Vaughn), P.O. Box 5727, Athens, OH 45701. Phone: 614-448-6105
- "Growing Shiitake Mushrooms." Oklahoma Cooperative Extension Service Publication F-5029.

Author

Dr. Deborah B. Hill, Professor, Department of Forestry, University of Kentucky, Lexington, KY 40546-0073

A partnership of

Contact: USDA National Agroforestry Center, 402.437.5178 ext. 4011, 1945 N. 38th St., Lincoln, Nebraska 68583-0822. *www.unl.edu/nac*

The USDA National Agroforestry Center (NAC) is a partnership of the Forest Service (Research & Development and State & Private Forestry) and the Natural Resources Conservation Service. NAC's staffs are located at the University of Nebraska, Lincoln, NE and in Blacksburg, VA. NAC's purpose is to accelerate the development and application of agroforestry technologies to attain more economically, environmentally, and socially sustainable land use systems by working with a national network of partners and cooperators to conduct research develop technologies and tools, establish demonstrations, and provide useful information to natural resource professionals.

Agroforestry Notes

USDA Forest Service • USDA Natural Resources Conservation Service

AF Note — 14

July, 1999

American Ginseng Production in Woodlots

Introduction

For the past 3,000 years or more the roots of a perennial plant called ginseng have been an important component of traditional Chinese medicine. The roots of wild American ginseng have been harvested, dried, and exported from the United States and Canada to China, since the mid 1700's. Today, American ginseng is also a very important part of traditional Chinese medicine. It is used as an "adaptogen" that allows the body to adjust to various types of stress. It is not used as a specific cure or remedy for any particular ailment but as a component of many medicinal herbal combinations that help people deal with the aging process and related disorders.

Presently there are dozens of over-the-counter herbal remedies, available in local drug stores, which contain ginseng or ginseng extracts. Ginseng has become one of the most popular herbs of the 1990's as Americans and Europeans seek alternatives to prescription drugs. Unfortunately many of the ginseng products available in local stores do not contain any American ginseng. Usually they contain extracts of either Asian ginseng, which is widely cultivated in China and Korea, or so-called "Siberian ginseng" which is a related plant, but not a true species of ginseng. According to the U.S. Department of Commerce, as long ago as 1858 the U.S. exported more then 350,000 pounds of dried wild ginseng roots. American ginseng has been cultivated in the U.S. since the late 1800's, primarily in the northeast, southeast and the midwest.

Types of Ginseng

American ginseng, (Panax quinquefolium) - is a native American herb with a range that extends from Southern Quebec to Northern Georgia and from the East Coast to the Midwest (Figure 1). It grows as an understory plant in the dense shade provided by deciduous hardwood tree species. In the Northeast it is most often found growing under sugar maple while in the Southeast it is often found under tulip poplar or black walnut. In the Midwest it occurs beneath several different hardwood species including oak.

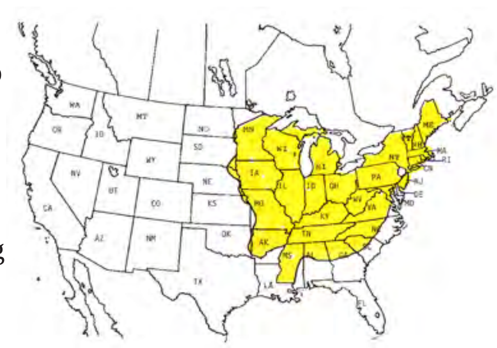


Figure 1 - Shaded area denotes ginseng's present wild range in the United States.

Field cultivated ginseng - is grown in raised beds in fields under artificial shade provided by either wood lathe or polypropylene shade cloth for a period of three to four years. In 1998 there were approximately 8,000 acres of "field cultivated" ginseng in production in North America.
Woods cultivated ginseng - is grown in a forested environment in tilled beds

under natural shade for a period of six to nine years.

Wild simulated ginseng - is grown in untilled soil in forests for a period of nine to twelve years or even longer. The dried roots of wild simulated ginseng closely approximate the appearance of truly wild ginseng.

Wild ginseng – is an internationally protected species. Its collection is either prohibited or strictly regulated in states where it occurs.

In recent years the world market price for field cultivated ginseng has dropped to near the actual cost of production. The prices of woods cultivated and wild simulated ginseng, on the other hand, have risen to levels that can be extremely profitable for landowners with suitable forest stands.

Constraints

Legal - Wild ginseng is an internationally protected plant. In order for it to be legally exported from any state it must be certified as being cultivated ginseng or, if wild plants are gathered, they must be harvested according to the rules and regulations of a state certification program, approved by the U.S. Fish and Wildlife Service. Currently, only 20 states have such a program (Table 1). Prospective growers should contact their local conservation district for information regarding any local rules and regulations that might affect cultivation, including pesticide regulations.

Table 1: States with a ginseng certification program
Alabama, Arkansas, Georgia, Illinois, Indiana, Iowa, Kentucky, Maryland, Michigan, Minnesota, Missouri, New York, North Carolina, Ohio, Pennsylvania, Tennessee, Vermont, Virginia, West Virginia, Wisconsin

Pests - Although woods cultivated ginseng is not often affected by many pest problems, occasionally they do occur. Very few pesticides are registered for use on ginseng in the United States. Introduced exotic or sometimes native slugs can be a major problem in woodland ginseng operations. Prospective growing areas can be surveyed for slugs by using baits made from grapefruit rinds.

Range - American ginseng is native only to the states shown on the map (Figure 1). It may or may not be feasible to cultivate it in forested areas of states other then those pictured. It absolutely requires a cold period during the dormant season equivalent to at least 1,000 hours at temperatures below 50 degrees F, therefore ginseng cannot be grown in the extreme southern U.S. Other obscure, but very important, microclimatic forest conditions also influence the growth of ginseng, even within it’s native range.

Seed Dormancy

Ginseng seed has a complex dormancy requirement and is highly perishable if not properly handled from the time of harvest until it is planted. Typically the seed is extracted from the red, ripe berries in August or September by mashing the berries and floating the pulp off. The seeds are then mixed with moist, clean, coarse sand at a ratio of two parts sand to one part seed. The seed/sand mixture is put in a box with screen on top and bottom and buried underground for approximately one year. The box is dug up one year later and the seed is planted in the late summer or early fall. The seeds sprout the following spring, usually in mid April. Ginseng seed that has been stored for one year under outdoor conditions is referred to as “stratified seed.”

Site Assessment

Perhaps the most crucial aspect of forest ginseng cultivation is choosing a proper site. Ginseng thrives in cool, moist, densely shaded woodlands that have well drained soil. Wild ginseng is typically found in calcium rich forest soils well supplied with organic matter. It is often found beneath mature deciduous trees and will not grow in an exclusively coniferous forest. In the South, Southeast, parts of the Northeast and Midwest, slopes that are north or northeast and of five to 20 percent grade seem to provide optimal orientation and facilitate both air and water drainage. In the far north, for example Vermont and Maine as well as Quebec, south or southwest facing slopes are preferred. The ideal ginseng-growing site is one that has a thriving population of wild ginseng or resembles such a site in terms of tree species and ground plants. Prospective growers would be wise to investigate the ecology of wild ginseng in their region (see references) before beginning. Ginseng is often found growing among other woodland plants that indicate rich, moist soil, high in calcium. Local foresters, soil scientists, and other resource conservationists often can be called on to identify rich, fertile soils within any given region.

Site Preparation

"Woods cultivated" ginseng site preparation begins with a general clearing of understory vegetation, small trees and as many rocks as possible. The next step is to till the soil to a depth of four to six inches either with a rototiller or by hand. Occasionally soil amendments are tilled into the soil if necessary (see maintenance section).

Planting

No fertilizer or lime is applied to potential ginseng beds unless the soil pH is below 4.5. If pH is 4.5 or less, 50 pounds of ground limestone per 1,000 square feet may be tilled in before planting. A one to two inch layer of well-rotted or shredded hardwood leaves from the forest floor may also be tilled in. Stratified seed are planted at the rate of 40 to 50 pounds per acre (one to one and a half pounds per one thousand square feet) in late summer or fall, but before the ground begins to freeze. There are approximately seven thousand seeds per pound. Seeds are randomly broadcast by hand or tediously planted one inch apart in rows spaced six to nine inches apart. Many growers make four to six foot wide beds to facilitate weeding. The seed is covered with a one half to one inch layer of soil, trampled on and mulched with two to three inches of either shredded or intact leaves from the surrounding trees.

Occasionally, one, two, or three-year-old rootlets are planted at a depth of one inch to two inches. These are spaced at one rootlet per square foot of bed. Rootlets for transplanting cost significantly more then stratified seed but save years of time in the production cycle. In New York state in 1998 one year old rootlets cost approximately 25 cents each. Two-year-old rootlets cost 50 cents and three-year-old rootlets cost $1.00.

"Wild simulated" ginseng planting involves similar site preparation without tilling the soil. In most cases the ground cover of decaying leaves and humus is simply raked away and seeds are pushed into the soil, trampled on and the leaf mulch is then raked back.

Maintenance

Annual maintenance of "woods cultivated" ginseng beds consists of hand weeding, removal or suppression of competing shrubbery, spraying of appropriate fungicides if needed, controlling slugs if necessary, and fall thinning of crowded stands to achieve a final population density of one plant per square foot. Weeding is most crucial during the first two growing seasons.

Occasionally calcium is applied in the form of gypsum at the rate of four pounds per 100 square feet, broadcast on top of the beds in early spring, prior to crop emergence, if soil tests indicate less then 1,000 pounds of calcium available per acre. Established ginseng beds should be tested for calcium levels every two to three years. Except for calcium, no fertilizer should be added to woods grown ginseng at any time. "Wild simulated ginseng" is usually left to grow on it's own after one or two seasons of weed control except for annual slug control if needed.

Ginseng roots growing in woodland sites are usually large enough to harvest after six or more seasons of growth. Harvest usually takes place in late summer or early fall. The freshly dug roots should weigh an average of at least one-quarter of an ounce each by that time. There is often great variability in the size and shape of the roots, even those growing next to each other. A “rule of thumb” is that from 100 to 300 dried ginseng roots are needed to produce a pound (dried ginseng loses 2/3 of its fresh weight). Ginseng roots are usually dug by hand, carefully, so as not to damage the root or the fibers that grow from the main taproot.

Harvesting and Drying

Freshly dug roots are washed with a strong stream of water from a hose, but never scrubbed. The roots are dried slowly in a well-ventilated attic or a commercial dryer that never gets warmer than 100 degrees F. They are carefully placed individually without touching each other on screens or in cardboard trays before drying. The drying process may take several weeks depending upon the prevailing weather conditions. Growers should talk to prospective buyers before attempting to dry the roots because some buyers prefer to buy the roots fresh. Freshly harvested and washed ginseng roots will keep for months in a refrigerator if stored in an open plastic bag. Fresh roots are preferred for making certain types of products.

Economics and Markets

Ginseng growing in a forested environment is certainly not a “get rich quick” scheme as it takes a minimum of five to eight years of growth before harvesting can occur. Prospective growers are encouraged to start with a very small investment, perhaps a few ounces of seed plus a hundred rootlets. Expand only if preliminary results are positive. Unlike many “alternative” agricultural commodities the market for ginseng is well established and easily accessed. See AF Note Forest Farming-4 for more information on marketing and the economics of ginseng. All of the references listed at the end of this fact sheet include sources of seed, rootlets for transplanting, ginseng buyers and consultants.

Additional Information

“American Ginseng Production in New York State.” Beyfuss, R.L. Cornell Cooperative Extension of Greene County, HCR 3, Box 906, Cairo NY 12413

“The Practical Guide to Growing Ginseng.” Beyfuss, R.L. RR 1, Box 126 N, Freehold NY 12431

“American Ginseng, Green Gold.” Persons, W.S. Tuckasegee Valley Ginseng, Box 236, Tuckasegee, NC 28783

“The Challenges of the 21st Century, Proceedings of the International Conference-Vancouver 1994.” Bailey, W.G., Whitehead, C., Proctor, J.T,A., and Kyle, J.T. “ Simon Fraser University, Burnaby, British Columbia, Canada

Author

Robert L. Beyfuss, Cornell Cooperative Extension of Greene County, HCR 3, Box 906, Cairo NY 12413.

USDA National Agroforestry Center

A partnership of

Forest Service, NRCS Natural Resources Conservation Service

Contact: USDA National Agroforestry Center, 402.437.5178 ext. 4011, 1945 N. 38th St., Lincoln, Nebraska 68583-0822. *www.unl.edu/nac*

The USDA National Agroforestry Center (NAC) is a partnership of the Forest Service (Research & Development and State & Private Forestry) and the Natural Resources Conservation Service. NAC’s staffs are located at the University of Nebraska, Lincoln, NE and in Blacksburg, VA. NAC’s purpose is to accelerate the development and application of agroforestry technologies to attain more economically, environmentally, and socially sustainable land use systems by working with a national network of partners and cooperators to conduct research develop technologies and tools, establish demonstrations, and provide useful information to natural resource professionals.

NCF-Envirothon 2024 New York

Forestry Study Resources

Key Topic #5: Forest Pests, Diseases, and Invasive Species

12. Identify common New York forest pests and diseases, and describe their impact to forest health and local ecosystems (including the Spotted Lantern Fly, Hemlock Woolly Adelgid, Emerald Ash Borer, Oak Wilt and Asian Long-Horned Beetle).
13. Explain prevention and treatment options for controlling New York pests and diseases.
14. Identify the impacts of climate change on Northeastern forests.
15. Describe the ways in which forests help mitigate the effects of climate change.

Study Resources

Resource Title	Source	Located on
Northeast and Northern Forests Regional Climate Hub Assessment of Climate Change Vulnerability and Adaptation and Mitigation Strategies	*Tobin, D. et al, United States Department of Agriculture, 2015*	Page 90-93
Invasive Species Field Guide	*Finger Lakes PRISM, 2018*	Page 94-97
Tree and Forest Health	*Cornell Cooperative Extension and DEC, 2006*	Page 98-101
Oak Wilt Fact Sheet	*New York State DEC, Bureau of Invasive Species and Ecosystem Health, 2019*	Page 102-103

Study Resources begin on the next page! ➡

Models forecast that species currently near their northern range limits in the region may become more abundant and more widespread under a range of climate futures. These include many oak and hickory species, dogwood, and eastern red cedar. At the same time, observed trends have suggested that other forest species such as balsam fir and red spruce may be more prone to range contraction at southern limits and less able to expand ranges northward (Murphy et al., 2010; Woodall et al., 2013; Zhu et al., 2011). Most species can be expected to migrate more slowly than their suitable habitats will shift (Iverson et al., 2004a; Iverson et al., 2004b; McLachlan et al., 2005). Habitat fragmentation and dispersal limitations could further hinder the northward movement of southerly species despite the increases in available habitat. Pests and diseases such as emerald ash borer, beech bark disease, and Dutch elm disease are also expected to affect some species that are projected to increase. The possibility also exists for nonnative plant species to take advantage of shifting forest communities and unoccupied niches if native forest species are limited (Hellmann et al., 2008). Major shifts in species composition may not be observable until well into the 21st century because of the long time frames associated with many ecosystem processes and responses to climate change.

Changes in Forest Productivity

One of the major implications of climate change is the potential for changes in forest productivity, which will be influenced by complex interactions among the degree of warming, ecosystem water balance, and disturbance events (Campbell et al., 2009; Chiang et al., 2008; He et al., 2002; Ollinger et al., 2008). There is evidence both worldwide and regionally that warmer temperatures and longer growing seasons are partially responsible for observed increases in forest growth and carbon sequestration during the past century (McMahon et al., 2010; White et al., 1999). Likewise, there is evidence that carbon dioxide fertilization has contributed to enhanced tree growth over the past two centuries (Cole et al., 2010; Franks et al., 2013; Norby & Zak, 2011) and may potentially offset some of the effects of drier growing seasons (Franks et al., 2013; Wang et al., 2006).

Although the potential exists for forest productivity to continue increasing under a changing climate, productivity may also be reduced in several ways. In particular, it is uncertain whether the timing and amount of future precipitation will be adequate for overcoming the increased evaporative demand of warmer temperatures. Episodic disturbances such as fires, wind, droughts, and pest outbreaks may also reduce productivity in certain areas over different time scales. Finally, a combined effect of tree species decline and lags in the migration and establishment of more suitable species may result in reduced productivity until a new equilibrium is reached.

4.3. Considerations by Ecoregion

Climate change is expected to have wide-ranging effects on forests, which will vary on the basis of geographic location and local site conditions. Within each ecoregion, climate change will have different effects on the drivers, stressors, and dominant tree species that are characteristic of the forest communities within that particular area. This section presents specific considerations of climate change vulnerabilities for the particular ecoregions located in the Northeast.

New England and Northern New York

The projected changes in climate and the associated effects and vulnerabilities will have important implications for economically valuable timber species, forest-dependent wildlife and plants, recreation, and long-term natural resource planning. Across New England and northern New York, several vulnerability assessments describe potential climate change effects (Manomet Center for Conservation Sciences, 2010, 2012; New Hampshire Fish and Game Department, 2013; Rustad et al., 2012; Tetra Tech Inc., 2013). There are several similar conclusions across these assessments. One of the most consistent findings is the threat of climate change to forest ecosystems dominated by boreal species such as spruce-fir, paper birch, and aspen forests, which are consistently rated as the most vulnerable across numerous vulnerability assessments. Spruce-fir forests are of particular concern under a changing climate because the range of this forest community appears to be largely controlled by the presence of cold temperatures (Manomet Center for Conservation Sciences, 2010, 2012; New Hampshire Fish and Game Department, 2013; Rustad et al., 2012; Tetra Tech Inc., 2013). Likewise, forests that have an abundance of northern species are also rated as more vulnerable. For example, northern hardwood forests dominated by species such as sugar maple, yellow birch, American beech, and eastern hemlock have generally been assessed as being moderately vulnerable to climate change (Manomet Center for Conservation Sciences, 2010, 2012). Declines in the productivity or extent of these forest communities have the potential to dramatically alter other ecosystem components such as dependent wildlife. Wildlife species associated with northern climates and forests, such as the moose, Bicknell's thrush, spruce grouse, fisher, and Canada lynx, may also decrease as boreal conifer species and other key habitat features change (Manomet Center for Conservation Sciences, 2010, 2012; Rodenhouse, 2009).

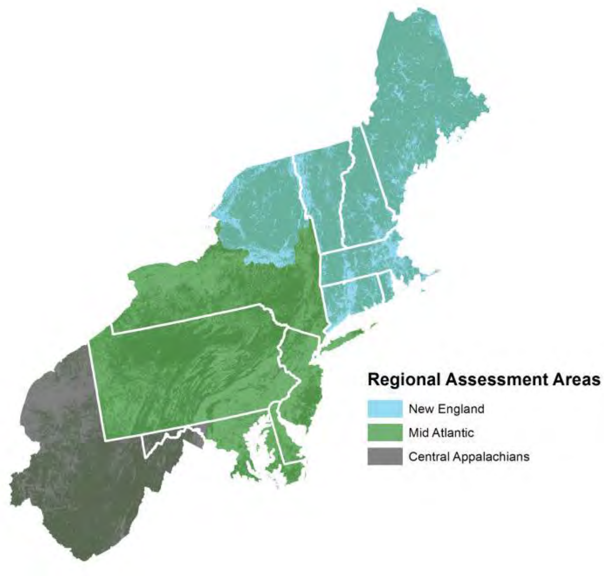


Figure 3: Three ecoregional areas used by the Climate Change Response Framework to assess the vulnerability of forests to climate change. See http://www.forestadaptation.org/.

Climate trends may generally favor hardwood species across the landscape by the end of the century. Forest communities featuring a greater abundance of oak and pine species, such as central hardwoods and pitch pine forest types, have generally been assessed as being less vulnerable to projected changes in climate (Manomet Center for Conservation Sciences, 2010, 2012; Natural Resources Workgroup of the Adaptation Subcommittee to the Governor's Steering Committee on Climate Change, 2010; Tetra Tech Inc., 2013). Results from forest impact models suggest that species such as bitternut hickory, black oak, bur oak, and white oak may have increases in both suitable habitat and biomass, and some deciduous forest types have the potential for productivity increases across the assessment area (Landscape Change Research Group, 2014). Note that forest communities will not be influenced only by shifts in habitat ranges, but also by the ability of species to actually migrate and establish in new areas (Iverson, Prasad, Matthews, et al., 2008; Iverson et al., 2011). Warmer climates are also likely to allow for range expansions of a variety of biological stressors, including insect pests, forest diseases, and invasive plant species (Rustad et al., 2012; Weed et al., 2013).

Changes in forest composition and function resulting from climate change are likely to lead to other changes in the forest sector. Forest industry may face challenges if commercially important tree species decline, particularly if the industry is not prepared for large potential shifts in the availability of commercial species. Shorter winter seasons may also reduce the feasibility of forest harvest operations in some areas (Rittenhouse & Rissman, 2015). Maple syrup production, a regionally important forest product, is already being affected by changes in the climate. In central New England, the start of sugaring season has shifted from mid-March to early February, producing a shorter tapping season and lower-grade syrup (Rustad et al., 2012). Additional changes in climate or declines in sugar maple trees could have substantial economic effects due to reduced maple syrup production (Rustad et al., 2012; Skinner et al., 2010). Likewise, changes in seasonality could also affect forest- and nature-based forms of recreation, such as fall foliage tourism, skiing, and snowmobiling (Rustad et al., 2012; Scott et al., 2008).

Mid-Atlantic

Across the Mid-Atlantic, several modeling efforts and vulnerability assessments describe potential climate change effects on the region (e.g., (Manomet Center for Conservation Sciences, 2012; McKenney-Easterling et al., 2000; Pan et al., 2009)). One of the most consistent findings is the threat of climate change on cool-temperate mixed forests. In general, species and communities adapted to warm, dry conditions are expected to increase, and those adapted to cool, wet conditions are expected to decrease. Forest communities featuring a greater abundance of oak and pine species such as longleaf-slash pine, loblolly-shortleaf pine, oak-hickory, and oak-pine types, have generally been assessed as being less vulnerable to projected changes in climate (Manomet Center for Conservation Sciences, 2012; McKenney-Easterling et al., 2000). Results from forest impact models suggest that species such as post oak, longleaf pine, loblolly pine, slash pine, shortleaf pine, southern red oak, and white oak may increase in importance (Landscape Change Research Group, 2014; McKenney-Easterling et al., 2000), whereas other species including sugar maple, black cherry, northern red oak, beech, birch, and tulip poplar are expected to decrease (Beecher et al., 2013; Landscape Change Research Group, 2014; McKenney-Easterling et al., 2000). It is important to note that forest communities will not be influenced only by shifts in habitat ranges, but also by the ability of species to actually migrate and establish in new areas (Iverson et al., 2004a).

In addition to direct effects on forests, climate change is also expected to affect a number of forest disturbances and stressors. Existing regeneration problems characteristic of many Mid-Atlantic forests are expected to be exacerbated as trees respond to warmer, drier conditions (Beecher et al., 2013). Deer herbivory is already affecting tree regeneration in the region. These effects are expected to increase with warmer winters and reduced snow cover, which could expose vegetation for winter browsing, reduce winter deer mortality, and allow deer populations to grow (Rosenzweig et al., 2001). Warmer temperatures are also expected to result in range expansions and increased effects from insect pests, forest diseases, and invasive plants (Rustad et al., 2012; Ryan & Vose, 2012; Weed et al., 2013). Hemlock woolly adelgid and elongate hemlock scale, beech bark disease, emerald ash borer, Asian longhorned beetle, and sudden oak death will increasingly threaten many tree species across the region, especially when combined with drought and other stressors (Beecher et al., 2013).

Other effects from climate change are particularly important in the Mid-Atlantic region because it has a high density of urban infrastructure, substantial greenhouse gas emissions, and significant heat island effects. These combined effects on urban trees and forests may interact with climate change to present unique challenges in forest management. Forest fragmentation is already a forest stressor in the region; expansion of natural gas exploration into northeastern Pennsylvania and southern New York, and the expansion of pipelines and overhead transmission lines are expected to exacerbate forest fragmentation in years to come (Beecher et al., 2013). Fragmentation may slow or prevent species migration, and the reduced genetic diversity within fragments is likely to hinder adaptive evolution (Anderson et al., 2012). In the New Jersey Pine Barrens, effects from southern pine beetle and fire have the potential to affect both forests and human populations near the wildland-urban interface. For example, a 2007 forest fire scorched more than 15,000 acres in the Pine Barrens, and also damaged homes and forced residents to evacuate (Kutner, 2008).

Central Appalachia

Climate change, including drought, damage from insect pests and diseases, competition with nonnative species, and altered disturbance regimes, is likely to cause similar stress on forests in the central Appalachian Mountains. A forest ecosystem vulnerability assessment completed for the central Appalachians region suggests that some tree species and forest communities may benefit from climate change, whereas others may become more stressed and experience loss of suitable habitat (Butler et al., 2015). Consistent with findings from other regional vulnerability assessments, (Butler et al., 2015) assessed forest ecosystems dominated by boreal species such as red spruce and balsam fir as the most vulnerable to climate change. Spruce-fir forests are of particular concern under a changing climate because the range of this forest community appears to be limited by a cool, moist climate at the highest elevations in the region (Byers et al., 2007; Cogbill & White, 1991). Forests that have an abundance of northern mesic species such as sugar maple, basswood, yellow birch, American beech, black cherry, and eastern hemlock are also expected to be more vulnerable to climate change (Butler et al., 2015; Manomet Center for Conservation Sciences, 2012). Climate change is also expected to negatively affect riparian systems through amplified effects of altered hydrologic regimes, invasive species, and pollution. Declines in the productivity or extent of these forest communities have the potential to dramatically alter other ecosystem components. For example, wildlife species associated with northern hardwoods and spruce-fir forests, such as the Cheat Mountain salamander, West Virginia northern flying squirrel, and northern saw-whet owl, may also decrease as boreal conifer species and other key habitat features change.

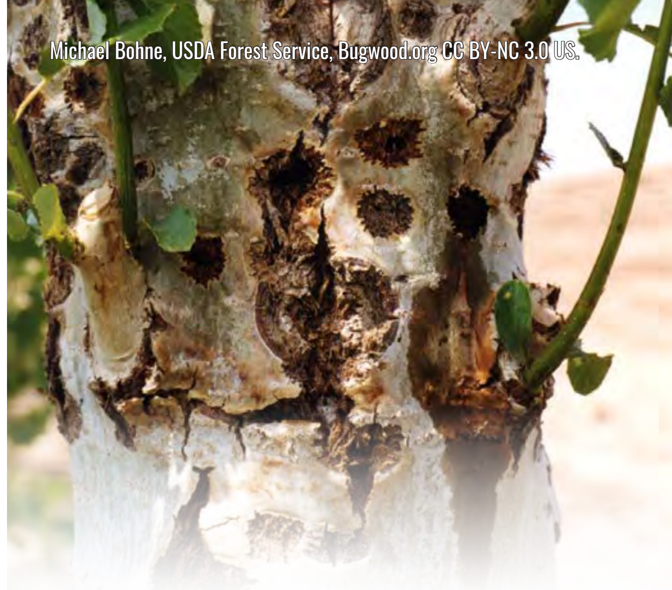
Climate trends may generally favor hardwood species across the landscape by the end of the century. Forest communities featuring a greater abundance of oak, hickory, and pine species have generally been assessed as being less vulnerable to climate change (Butler et al., 2015; Manomet Center for Conservation Sciences, 2012). Habitat for species with ranges that extend largely to the south such as post oak, blackjack oak, southern red oak, and shortleaf pine is expected to increase in the central Appalachians. Loblolly pine, currently only a plantation species, is also expected to fare well under future climates (Landscape Change Research Group, 2014). Many mesic species, including American beech, eastern hemlock, eastern white pine, red spruce, and sugar maple are among those projected to have reductions in suitable habitat, growth potential, and biomass under a high degree of warming over the next century. Note that forest communities will not be influenced only by shifts in habitat ranges, but also by the ability of species to actually migrate and establish in new areas (Iverson et al., 2004a).

Existing forests may also have to compete with undesirable species under warmer future conditions. One example of this is kudzu, an invasive vine that typically transforms invaded forests in the southeastern U.S. by quickly overgrowing and smothering even mature overstory trees. Presently, the northern range of kudzu is limited by winter temperatures but modeling suggests the risk for kudzu invasion could be heightened for many areas under future warming (Bradley et al., 1999; Jarnevich & Stohlgren, 2009). Warmer climates are also likely to allow for range expansions and increased effects of other biological stressors, including insect pests and forest diseases (Ryan & Vose, 2012; Weed et al., 2013).

4.4. Forest Sector Adaptation Strategies

As an increasing amount of relevant scientific information on forest vulnerability to climate change becomes available, managers are searching for ways to realistically use this information to meet the more specific needs of on-the-ground forest management, including management plans and silvicultural prescriptions (Millar et al., 2012). The amount of information available on the anticipated effects of climate change on ecosystems is growing rapidly, putting high-quality scientific information within reach of most natural resource professionals (Seppälä et al., 2009; Vose et al., 2012). At this point in time, many professionals are shifting their requests for more information to requests for practical and efficient ways to focus and apply existing information. The application of this information can help them adjust management, conservation, and restoration priorities and activities to adapt forests to the changes in climate.

Female (middle), male (right) compared to cottonwood borer (left)



INSECTS

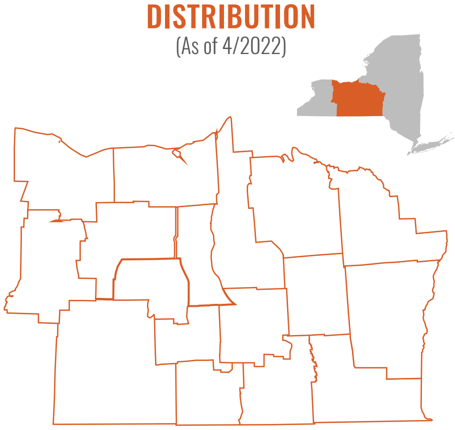
ASIAN LONG-HORNED BEETLE

Anoplophora glabripennis
Origin: Asia

INVASIVE RANKING, NYS
High

MANAGEMENT STRATEGY
Chemical
Physical
Prevention

DISTRIBUTION
(As of 4/2022)



www.fingerlakesinvasives.org

Asian longhorned beetles (ALB) are a forest pest with a wide range of host trees. Adult beetles are 2-4 cm in length, with jet black bodies and mottled white spots on the back. Their black-and-white-banded antennae are 1.5-2.5 times longer than the body. Beetle larvae are cream-colored, cylindrical, and up to 6 cm in length. They produce frass that looks like wood-shavings, and leave a circular exit hole about 1 cm in diameter and over 2.5 cm deep.

HABITAT

These beetles live in a wide range of native hardwoods, but prefer maple trees. Larvae first burrow between the inner bark and the wood of the tree, forming a feeding gallery; as they mature, they move deeper, to the dense inner wood of the tree trunk.

THREAT

Asian longhorned beetles can severely damage the physical and vascular structure of trees, interfering with uptake of vital nutrients. Continued infestation leads to tree death in six to eight years. In the US, $669 billion worth of urban trees are at risk to this pest, and the potential damage to forest ecosystems is currently incalculable.

MANAGEMENT

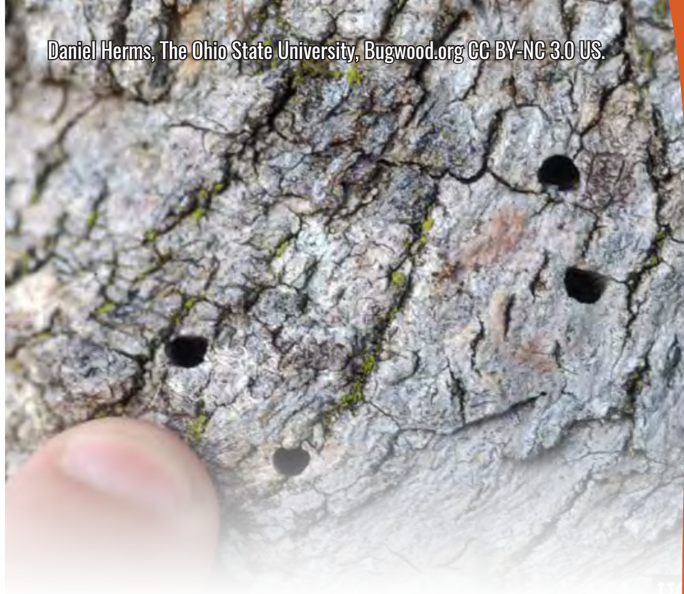
Quarantines and tree removal are the current methods of prevention and eradication. The Don't Move Firewood campaign helps prevent its spread to new locations. Annual pool surveys help monitor for new infestations. In some areas, an insecticide may be used as a preventative measure as well as a treatment, although it can be costly. Biological control methods are being researched, but are not yet available for use. Development of genetically resistant trees may be part of the long-term solution to ALB if eradication from the US is not successful.

REFERENCE - Meng, P. S., K. Hoover, M. A. Keena. "Asian Longhorned Beetle (Coleoptera: Ceram- bycidae), an Introduced Pest of Maple and Other Hardwood Trees in North America and Europe." J. Integ. Pest Mngmt. (2015) 6(1): 4;DOI: 10.1093/jipm/pmv003

US Forest Service. "Forest Health Protection." www.na.fs.fed.us. https://www.na.fs.fed.us/fhp/alb/ident_reporting/identifying.shtm. (accessed May 25, 2017).

HOBART AND WILLIAM SMITH COLLEGES
FINGER LAKES INSTITUTE
FINGER LAKES PRISM
Partnership for Regional Invasive Species Management

INSECTS



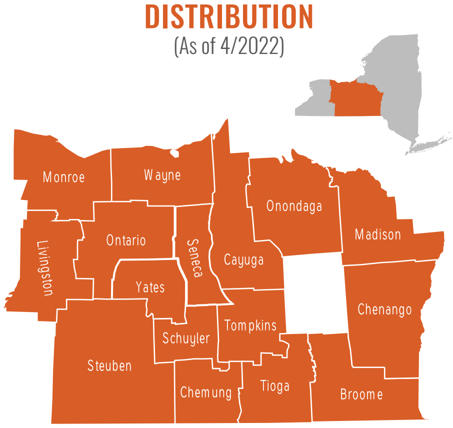
EMERALD ASH BORER

Agrilus planipennis
Origin: Northern China, Korea

INVASIVE RANKING, NYS
Very High

MANAGEMENT STRATEGY
Chemical
Prevention

DISTRIBUTION
(As of 4/2022)



www.fingerlakesinvasives.org

Emerald ash borer (EAB) is a wood boring beetle that feeds on and eventually kills all species of ash. Adults are about 1 cm long, with an elongated metallic green body and narrow brass colored head. Larvae are creamy white with a brown head and are flattened on top and bottom. The larvae have eight abdominal segments, with the last segment sporting two pincer-like spines. Adults emerging from trees in the spring leave a D-shaped exit hole in the bark.

HABITAT

Emerald ash borers can be found in, on, or around ash trees (*Fraxinus* spp.) in hardwood forests.

THREAT

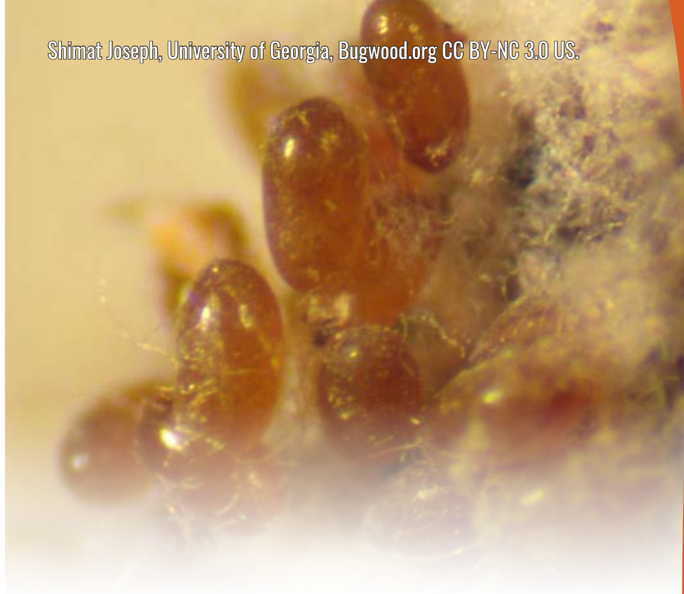
Adult beetles feed on ash foliage, causing aesthetic damage. The larvae damage ash trees by feeding on the inner bark, which disrupts the transportation of water and nutrients, resulting in mortality. Destruction caused by the emerald ash borer is projected to cost $10.7 billion by 2020 through urban tree removal, loss of ecosystem services and property value, and wholesale loss of ash plantations.

MANAGEMENT

Ash trees can be treated with an insecticide to prevent infestation; treatments last for three years. Planning for removal of untreated trees in urban areas will prevent costly emergency removals. It is also important to prevent the spread of established populations. When recreating and camping, only local firewood should be used. Biocontrol with the use of parasitic wasps is currently being deployed in a few states. This is a long-term management method rather than immediate control.

REFERENCE - McCullough, Debra. 2015. Pest Alert: Emerald Ash Borer. United States Department of Agriculture. USDA. June 17, 2017. https://www.na.fs.fed.us/spfo/pubs/pest_al/eab/eab.pdf

HOBART AND WILLIAM SMITH COLLEGES
FINGER LAKES INSTITUTE
FINGER LAKES PRISM
Partnership for Regional Invasive Species Management



HEMLOCK WOOLLY ADELGID

Adelges tsugae
Origin: Asia, Southern Japan

The hemlock woolly adelgid is a small, aphid-like insect that attacks hemlock trees. They are most easily recognized by the white “woolly” masses of wax they use to protect themselves and their eggs from desiccation and predation. These ovisacs can be readily observed on the undersides of branches, at the base of the needles, from late fall to early summer. Infested trees may have gray-tinted foliage or exhibit needle loss and branch dieback.

INVASIVE RANKING, NYS

High

MANAGEMENT STRATEGY

Chemical
Biocontrol
Prevention

HABITAT

The hemlock woolly adelgids feed on native eastern hemlock (*Tsuga canadensis*), and on any ornamental species of hemlock. They are found on twigs at the base of needles.

THREAT

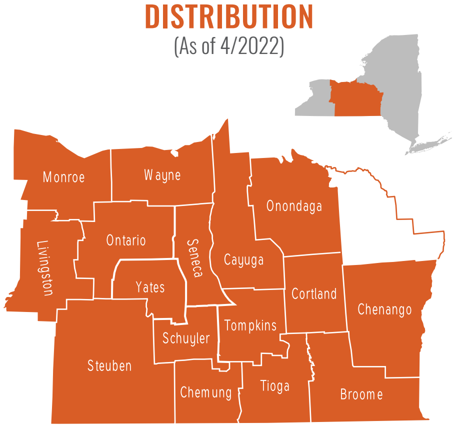
Hemlock woolly adelgids use their long, sucking mouthparts to tap into the food storage of plant cells, which causes the tree to wall off the wound with scar tissue. After an intense infestation, the tree is unable to get sap to the end of its branches to produce new growth; once existing needles die, the tree cannot produce food. Dieback can occur in as little as two years, and mortality in 4-20 years depending on site characteristics and climate. Hemlock woolly adelgids reproduce asexually in the eastern US, so one insect can start a new infestation.

MANAGEMENT

Treatment with systemic insecticides is effective and relatively inexpensive, with treatments remaining effective for up to seven years. Limiting the movement of infested nursery stock will slow its spread. Biological controls are under development and are the best long term management option.

DISTRIBUTION

(As of 4/2022)



REFERENCE - Childs, Robert. Hemlock Woolly Adelgid Frequently Asked Questions. https://ag.umass.edu/landscape/fact-sheets/hemlock-woolly-adelgid-frequently-asked-questions.
DEC. Hemlock Woolly Adelgid http://www.dec.ny.gov/animals/7250.html. May 31, 2017.
US Forest Service. Pest Alert - Hemlock Woolly Adelgid https://www.na.fs.fed.us/spfo/pubs/pest_al/hemlock/hwa05.htm. May 25, 2017.
Hemlock Woolly Adelgid, Adelges tsugae Factsheet. 2016. New York State Department of Environmental Conservation. https://www.dec.ny.gov/docs/lands_forests_pdf/hwafactsheet.pdf.

www.fingerlakesinvasives.org

HOBART AND WILLIAM SMITH COLLEGES
FINGER LAKES INSTITUTE
FINGER LAKES PRISM
Partnership for Regional Invasive Species Management

Richard ardner, Bugwood.org CC BY-NC 3.0 US
SLF Adults and Egg Mass

Richard Gardner, Bugwood.org CC BY-NC 3.0 US.
SLF Nymphs

Lawrence Barringer, Pennsylvania Department of Agriculture, Bugwood.org

SPOTTED LANTERNFLY

Lycorma delicatula

Origin: Asia

INVASIVE RANKING, NYS

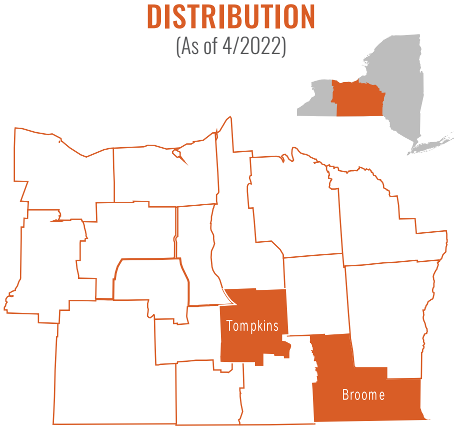
Not Ranked

MANAGEMENT STRATEGY

Prevention
Physical
Chemical

DISTRIBUTION

(As of 4/2022)



www.fingerlakesinvasives.org

The spotted lanternfly (SLF) is an invasive insect with a wide range of host species. Adults are one inch long and about 0.5 in wide. They have pinkish-gray forewings, which are dotted with black spots and have a hashed block pattern near the tips. The upper portion of the hindwings are black with a white band, while the lower part of the hindwings are bright red with black spots. Nymphal development proceeds through four instar stages. The first three instars are black with white spots, while the fourth instar features red patches.

HABITAT

The SLF prefers to feed on tree-of-heaven (*Ailanthus altissima*), which it may need to complete its lifecycle. SLF also feeds on a variety of plants, trees, and agricultural crops, such as grapes, hops, apples, and maples. Females lay gray egg masses on host plants and just about any flat surface, including stone and metal.

THREAT

As SLF feeds, it excretes a sticky sap, called honeydew rain. This honeydew rain attracts black sooty molds, which can impact the health of the host plants and damage their fruits. Resulting fermentation and odor may also attract other insects. This greatly threatens NYS grape and tree-fruit industries, as well as the forestry, nursery, and landscaping industries. The NYS grape industry alone generates an estimated $4.8 million in economic activity annually.

MANAGEMENT

The SLF travels easily as a hitchiker, so gear, vehicles, and equipment should be checked for egg masses before leaving areas with SLF populations (currently in DE, NJ, PA, MD, & VA). Egg masses can be scraped off surfaces and destroyed by crushing and submersion in rubbing alcohol or hand sanitizer. Removal of tree-of-heaven may be a proactive approach to help stop the spread of SLF. To ensure effective removal, consult an expert for guidance. The insecticide, dinotefuran, can be used as a bark spray or injection to kill SLF.

REFERENCE - Dara, S.K., L. Barringer, and S.P. Arthurs. “Lycorma delicatula (Hemiptera: Fulgoridae): a new invasive pest in the United States.” J. Integ. Pest Mngmt. (2015) 6(1). DOI: 10.1093/jipm/pmv021.
PennState Extension. “Spotted Lanternfly.” www.extension.psu.edu/. https://extension.psu.edu/spotted-lanternfly. (accessed March 26, 2020).

HOBART AND WILLIAM SMITH COLLEGES
FINGER LAKES INSTITUTE
FINGER LAKES PRISM
Partnership for Regional Invasive Species Management

Tree and Forest Health

Cornell University Cooperative Extension and
New York State Department of Environmental Conservation
www.ForestConnect.info

Trees are tough - they can handle 40 mile per hour winds, insects feeding on their leaves, and even loosing a limb or two. So, how do we know when we need to step in and give our trees a helping hand? Well, it depends on the situation and your objectives.

For instance, ornamental trees or individual trees that are important to a landscape often require much more attention than forest trees. Whether for aesthetics or shade, having trees in your yard can add value to your property, and having even one unhealthy tree can be a risk to your investment.

Trees generally require much less attention when it comes to forest health. If you lose one or two, there are many more. And, a few trees will die every year as part of the natural forest cycle. In order for all the remaining trees in a forest to grow an average of one inch larger in diameter, one in five of the existing trees must die. When looking at the health of forests, monitor for problems on a "stand" level. One defoliated tree is not a problem, but 10 trees could be.

Our primary forest health issues are the result of insects, diseases, and abiotic (non-living) factors. Most of these "pests" will not be able to kill a tree on their own, but the damage they cause adds stress to the tree. When a tree is stressed, it taps into the food (carbohydrates) stored in its roots or trunk to continue to survive. Stressed trees need to recharge just like humans do. If the stress is mild, the tree usually recovers. If the tree is hit with an additional stressor, it may not be able to recover as well and will begin to decline. Decline is when the growth rate slows down - leaves are small and discolored, annual twig growth is short, and little diameter growth is added to the trunk. Once a tree has started to go into decline, and if stress continues, it likely will die in three to five years. We can group the serious stressors into three categories - predisposing factors, primary invaders, and secondary invaders.

Predisposing factors are usually abiotic (caused by non- living organisms). Abiotic factors are often things we have no control over, and therefore can do little to prevent. If serious enough these predisposing factors, such as drought, flood, ice damage, hail, and soil compaction, can kill trees on their own. One predisposing factor we can control is competition among trees for light. By thinning the forest, we can provide adequate light for the trees that remain.

Primary invaders are insects and diseases that will attack healthy trees. These include insects that feed on foliage, root-feeding insects, fungal rusts and foliar leaf spots. Minor amounts of damage caused by primary invaders can be tolerated by trees or easily controlled for, but serious damage can cause tree mortality.

Secondary invaders are insects and diseases that attack trees that are already stressed (from predisposing factors or primary invaders). Most woodboring insects, bark beetles, and some trunk and butt rots are attracted to stressed trees. These pests often stay with the tree after it dies and help in the decomposition process. There is generally little that can be done to stop secondary invaders.

Predisposing factors such as ice damage can weaken trees, making them more susceptible to insects and disease.[a]

Support provided by USDA Renewable Resources Extension Act and USDA Forest Service - NA State and Private Forestry.

Decline Scenario Example

2001 - Winter; forest hit with severe ice storm- many broken tops (open wounds).
2003 - Spring; Forest Tent caterpillar outbreak- hundreds of trees defoliated
2004 - Spring; Forest Tent caterpillar outbreak continues, weakened trees start to die.
2005 - Spring; Forest Tent caterpillar outbreak continues;
Summer; drought and Lecanium scale outbreak, many trees start to die.

In this situation the first stressor is abiotic (ice storm), followed by three years of defoliation by an insect, compounded by drought (abiotic) and the stress of an additional insect.

How do you know when to start worrying about your trees? Review the following basic list of signs[1] and symptoms[2] of problems, severity of the damage and actions you can take. Ornamental trees generally warrant more pest management due to their high visibility, but some forest pests are worth controlling. Cultural controls (altering the environment) are usually the best approach in more forested situations, but some pesticides can be used in certain circumstances. Evaluate all costs and benefits before using a pesticide. Some pesticides only can be applied by a licensed pesticide applicator. Contact your local Cooperative Extension office for guidance.

Signs and Symptoms of Tree Stress

Insect Damage

Leaf Chewing

Agents - Forest and Eastern Tent Caterpillar, Gypsy Moth, Viburnum Leaf Beetle, Japanese Beetle, Sawflies

Symptoms - Chewed foliage, removes chunks or entire leaves, sometimes leaves the veins.

Control - If only a few leaves are eaten or there is only a little damage, then no control is warranted. If most leaves are affected and are completely eaten, consider treating landscape trees, and promoting predators in forested situations. Healthy deciduous trees can only handle being defoliated three to four years in row; conifers even fewer. In epidemic situations consider spraying.

Prognosis - Minor feeding- prognosis is good; repeated defoliation - expect tree death.

[1] Sign- the actual stressor- egg masses, pupal cases, fungal spots on leaves, mushroom conks.

[2] Symptom- the outward expression of the presence of a stressor- slow growth rate, early leaf drop, cankers

Leaf and Twig Sap - Feeding

Agents - Scales, Aphids, Adelgids. Only a few species of concern- Hemlock Woolly Adelgid, Balsam Twig Aphid, Beech Scale, European Fruit Lecanium.

Symptoms - Leaf distortion and decline, insects suck fluid from leaves and twigs, .

Control - Encourage predators, prune heavily infected areas, sprays available- time appropriately.

Prognosis - Depends on specific insect- range from good to eventual death.

Twig Mining

Agents - White Pine Weevil, Pine Tip Moths, Pine Shoot Beetle

Symptoms - "Wilting" of tips in many conifer species, distorts growth.

Control - Damage can spread quickly through a stand. If only one or two trees affected, identify the pest, prune out damage, and use available sprays. If a whole stand is affected, consider sanitation cut (removal of infected individuals).

Prognosis - Good if controlled early on.

Bark Beetles/Cambium Feeders

Agents - Bronze Birch Borer, Engraver Beetle, Elm Bark Beetle, Black Turpentine Beetle. These agents are generally attracted to stressed/ declining trees but some species in this group will attack healthy trees. Some introduce diseases.

Signs - Small holes in the bark or raised ridges resembling tunnels under the bark. Larvae tunnel through and feed on the vascular tissue between the bark and the wood, girdling the tree.

Control - Remove infested trees if concerned about spread to other declining trees.

Prognosis - Poor, eventual death of most trees.

Borers

Agents - Locust Borer, Pine Sawyer, Wood Wasp, Asian Long-horned Beetle, Sugar Maple Borer, Emerald Ash Borer. Many species will attack healthy trees.

Symptoms - Holes/tunnels into wood- can girdle or make tree susceptible to breaking and decay.

Control - Reduce other stresses. Generally there is little that can be done. Trees can be removed when invasives such as the Asian Long-horned or the Emerald Ash Borers are involved. Some pesticides may be available.

Prognosis - Poor, decline or eventual tree death.

Diseases

Leaf Spots

Agents - Maple Tar Spot, Cedar-Apple Rust, Anthracnose, Rhizosphaera, Dothistroma, Powdery Mildew. Generally not a concern for forest trees.

Signs - Surface spots or dead areas on leaves.

Control - Sanitation- rake up fallen leaves in autumn. Late season spots on deciduous trees are little concern. Sprays are available.

Prognosis - Some leaf spot fungus can cause death, some have little effect; most contribute to decline.

Stem and Branch Cankers

Agents - Cytospora, Stem Rusts, Black Knot

Symptoms - Swellings or sunken areas on twig, branches and trunk, often discolored, cracked open with age.

Control - Prune out affected area 6 inches below canker during winter. Remove cankers from the vicinity.

Prognosis - Eventual death, often slow.

Vascular Wilts

Agents - Dutch Elm Disease, Verticillium Wilt, Ash Yellows

Symptoms - Individual branches turning yellow (flagging), death of major sections of the crown, wilting leaves.

Signs - Bluish streaking on the underside of the bark or surface of the wood; peel back bark on a ½" diameter branch to find coloring.

Control - In a landscaping situation, prune out the affected limb if possible, or remove the whole tree. Some fungicides are available for Dutch Elm Disease. In a forest you should remove the affected trees when thinning- schedule of thinning is important.

Prognosis - Usually tree mortality.

Forest tent caterpillar larvae feed on foliage, leaving only the major veins and leaf petioles behind.[b]

Trunk Rots

Agents - Large Conks (mushrooms) growing out of the side of the tree.

Symptoms - Fungus has colonized the tree and generally there is a large column of decay associated with the conk. Removing the conk will have no effect on the fungus. Generally only found on trees in decline, wounded trees, and standing dead trees.

Control - If infected tree is in a high traffic area or near something of value, consider removing. In forested areas, let stand or remove when thinning. These trees can be hazardous but they can also have high value to wildlife.

Prognosis - Generally tree mortality, can be slow.

Disposal of infected trees can be tricky. Many of the insects and diseases that can cause a tree to die often die with the tree, or are natural parts of the environment and no special precautions need to be taken. When dealing with trees killed by a non-native pest such as Dutch Elm Disease or the Asian Long-horned Beetle, trees should be either burned, buried, or chipped before the next cycle of the pest begins. Also, do not transport firewood out of infested areas, even if you don't expect it to be infested- this is a popular way for insect larvae and eggs to spread quickly as was seen with the gypsy moth and is a potential for the Asian long-horned beetle.

Thinning your forest encourages healthy tree crowns.

General tips for keeping your trees healthy:

- ✔ Keep them free of stress
  - Water ornamental trees during drought.
  - Do not plant in flood prone areas.
  - Thin forests to encourage healthy tree crowns.
  - Do not drive or re-grade over the root system. A good network of roads will help keep soil compaction to a minimum in your forest.
- ✔ Monitor for pests – most pests are adapted to certain trees, so learn about potential pests ahead of time.
  - Every few weeks spend some time in your forest or landscape and look for signs of problems.
  - Carefully and specifically identify the pest before taking action.
  - Get current cultural and chemical recommendations from your local Cornell Cooperative Extension Office.
  - Act quickly- if you feel you might have a real problem on your hands, catch it early.
- ✔ Plant the right tree in the right spot.
  - Select the proper trees for your soils, climate, and weather.
  - Look for insect and disease resistant varieties.
  - Plant trees correctly.
- ✔ Consider your whole "landscape" and know what you're dealing with.
  - Is your pest actually a pest?
  - Is this an isolated incident, or can it spread?
  - Is it a natural pest? Or introduced?
  - How many trees have been effected?

Black knot leads to cankers on tree branches, like this black cherry, and can eventually lead to death of the infected tree.[c]

Additional References:

Houston, David R., Douglas C. Allen, and Denis Lachance. 1990.Sugarbush Management: a Guide to Maintaining Tree Health. Gen. Tech. Rep. NE-129. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 55 pp.

Johnson, Warren T. and Howard H. Lyon. 1994. Insects that Feed on Trees and Shrubs. Ithaca, NY. Comstock Pub. Associates/Cornell University Press. 560 pp.

Sinclair, Wayne A., Howard H. Lyon, and Warren T. Johnson. 2005. Diseases of Trees and Shrubs. Ithaca, N.Y. : Comstock Pub. Associates/Cornell University Press. 660 pp.

Web Pages of Interest:

Cornell Entomology Insect Diagnostics fact sheets http://www.entomology.cornell.edu/Extension/DiagnosticLab/IDLFS

USDA Forest Service Forest Health Protection web site http://www.fs.fed.us/foresthealth/

USDA Forest Service- Northeastern Area Forest Health Protection web site http://www.na.fs.fed.us/fhp/index.shtm

---

Prepared by Bob Beyfuss, Rebecca Hargrave, and Steve Vandermark with support of Cornell Cooperative Extension of Greene, Chenango, and St. Lawrence counties. Edited and compiled by Kristi L. Sullivan, Peter J. Smallidge and Gary R. Goff, Department of Natural Resources, Ithaca, NY. 2006.

Photos from: www.forestryimages.org - [a]Minnesota Department of Natural Resources Archives, Minnesota Department of Natural Resources, [b]Steven Katovich, USDA Forest Service, [c]Tim Tigner, Virginia Department of Forestry.

OAK WILT

A Disease of Oak Trees

What is oak wilt?

Oak wilt is a disease that affects oak trees. It is caused by *Bretziella fagacearum*, a fungus that develops in the xylem, the water-carrying cells of trees. All oaks are susceptible to the fungus, but the red group oaks (with pointed leaf tips) often die much faster than white group oaks (rounded leaf tips).

Oak tree killed by oak wilt
Steven Katovich, USFS, Bugwood.org

Why is oak wilt a problem?

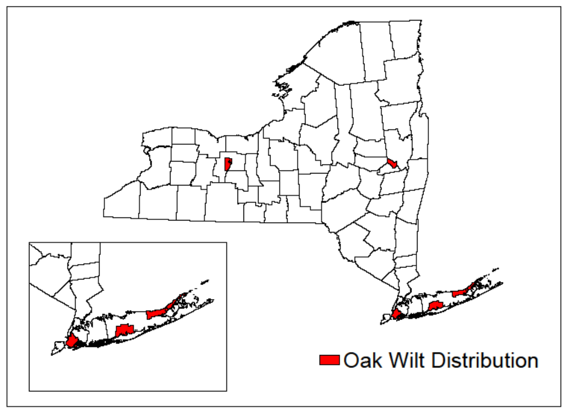
The oak wilt fungus blocks the flow of water and nutrients from the roots to the crown, causing the leaves to wilt and fall off, usually killing the tree. Red group oaks (scarlet oak, pin oak, black oak, etc.) can die within a few weeks to six months, and the disease spreads quickly from tree to tree. White group oaks (bur oak, swamp white oak, etc.), however, often take years to die and the disease rarely spreads to additional trees.

Where does it come from?

Oak wilt was first discovered in Wisconsin in 1944, but where it originated is still unknown. It has spread throughout the Midwest and Texas, killing tens of thousands of trees.

Where has it been found in New York State?

In 2008, a small infection was discovered in Glenville, NY. Despite a quick response to remove and destroy the infected trees, the disease resurfaced in the same location five years later and additional infection sites have been found within a few miles of the original location. Oak wilt has also been discovered in Islip, Riverhead, and Southold in Suffolk County; Brooklyn in Kings County; and Canandaigua and South Bristol in Ontario County.



How does it spread?

There are two main ways oak wilt is spread: 1) above ground by beetles, and 2) below ground through tree roots.

Fungal spore mats form just under the bark of infected red group oaks after they have died from the disease. During the warmer months, these spore mats emit a sweet odor that attracts sap-feeding beetles and bark beetles, which can pick up fungal spores as they crawl around. The beetles are also highly attracted to fresh tree wounds—such as those caused by pruning. In this way, they spread the fungus from infected trees to healthy trees sometimes miles away. Infected firewood and other wood materials also pose a threat because they can harbor the fungus and/or beetles that can spread the disease.

Root graft
Ronald F. Billings, Texas A&M Forest Service, Bugwood.org

Spread underground occurs when roots of nearby red group oaks graft to each other (fuse together), creating a connection through which nutrients and the disease can move. In the Midwest, large blocks of red oak forests have died from the disease in a single season due to their vast network of interconnected roots. In contrast, *white* group oaks are much less likely to create root grafts, and spore mats rarely form under their bark, significantly reducing the chance of spread from these trees.

What are the symptoms?

Symptoms of oak wilt infection are often very noticeable in red group oaks, but aren't easily seen in white oaks.

- Brown coloration develops on leaves starting at the outer edge and progressing inward toward the mid-vein of the leaf.
- Branch dieback may be visible starting at the top of the tree's canopy and progressing downward.

Diseased red oak leaves

Fungal spore mat under bark

- Leaves suddenly wilt in the spring and summer and may fall while there is still some green on them.
- Fungal spore mats may develop under the bark of infected trees.

What is being done?

- During the growing season, DEC will take samples from oak trees around the infection sites to look for additional signs of the disease.
  - These areas will continue to be monitored using aerial and ground surveys for at least five years after the last oak wilt detection.
- Established quarantine districts will prohibit the movement of potentially diseased oak wood including firewood.
- DEC is attempting to eradicate the disease in Glenville, Canandaigua, South Bristol and Brooklyn using the following methods:
  - Oak-free zones will be established where infected and surrounding oak trees will be removed.
  - Where possible, trenching will be used to break root connections to lower the chance of spread.
- In Suffolk County, DEC will only attempt to contain the disease due to the number of infection sites and distribution across Long Island. Only infected trees will be removed.

Trenching to break grafted roots

What can I do?

- Learn to recognize the symptoms of oak wilt including leaf discoloration, rapid leaf loss, and fungal spore mats. If you think your tree is infected with oak wilt, contact DEC (see below).
- Avoid pruning or wounding oak trees in the spring and summer, when spore mats are present and beetles are the most active. If an oak wound occurs during spring or summer, it should be sealed immediately with wound covering. This will slow wound recovery, but also deter beetles from landing on those areas – which will lower the spread of oak wilt.
- Adhere to the NYS firewood regulation which limits untreated firewood movement to no more than 50 miles and obey the rules of the quarantine districts which prevent firewood or oak wood from leaving those areas.
- Visit www.dec.ny.gov/lands/46919.html for more information.

CONTACT INFORMATION

Bureau of Invasive Species and Ecosystem Health
Division of Lands and Forests

New York State Department of Environmental Conservation
625 Broadway 5th Floor, Albany, NY 12233-4253
P: (518) 402-9425 | foresthealth@dec.ny.gov
www.dec.ny.gov

Updated June 14, 2019

NEW YORK STATE | Department of Environmental Conservation