Chapter 3:

How Trees and Woodlands Grow

Melvin J. Baughman, Extension Forester, University of Minnesota

To manage your woodland, it is helpful to know how individual trees grow and what factors influence the growth of the whole woodland.

Your woodland is more than a collection of trees. It is part of an ecosystem with trees, shrubs, herbaceous plants, insects, and animals that interact with each other and with the soil, water, and climate. Trying to change one part of this ecosystem will affect the other parts. Your woodland is ever changing due to many influences.

How Trees Grow

To survive and grow, trees need adequate amounts of carbon dioxide, water, sunlight, and nutrients. Factors that influence the availability or use of these elements include tree characteristics, site characteristics, and climate.

Parts of a Tree

Trees are composed mainly of carbon, but to ensure healthy growth, trees also need oxygen, hydrogen, nitrogen, potassium, calcium, magnesium, phosphorus, sulfur, and trace amounts of several other elements. In general, carbon dioxide and sunlight are absorbed by the leaves, water is absorbed by the roots, and nutrients are absorbed mostly by the roots but also by the leaves. Leaves are the food factories in a tree. They contain a green substance called chlorophyll that enables the sun's energy to convert carbon dioxide and water into sugar. Trees use sugar as a basic ingredient in all plant parts.

Tree growth occurs from buds on the ends of branches, from the tips of tiny roots, and in the cambium—a thin layer of cells beneath the bark that covers the whole tree. (Figure 3-1)

Cambium cells produce both inner bark and sapwood. Inner bark or phloem is spongy tissue that transports food from the leaves to other parts of the tree. Phloem cells live for a relatively short time, then die and become part of the outer bark, which insulates the tree from weather extremes and serves as a barrier against insects and disease. Sapwood or xylem is the pipeline that transports water from the roots up to the leaves. A new layer (ring) of sapwood grows each year. Light-colored bands of sapwood are called springwood—thin-walled cells that grow early in the year. Dark-colored bands of sapwood are summerwood—thick-walled cells produced in the summer when tree growth has slowed. Sapwood cells live for several years, then lose their vitality, die, turn a darker color, and become known as heartwood. Heartwood provides substantial physical support for the tree.

Effects of Tree Characteristics

A tree's genetics, crown size, and ability to tolerate shade and competition from other plants influence how well it will grow in different environments.

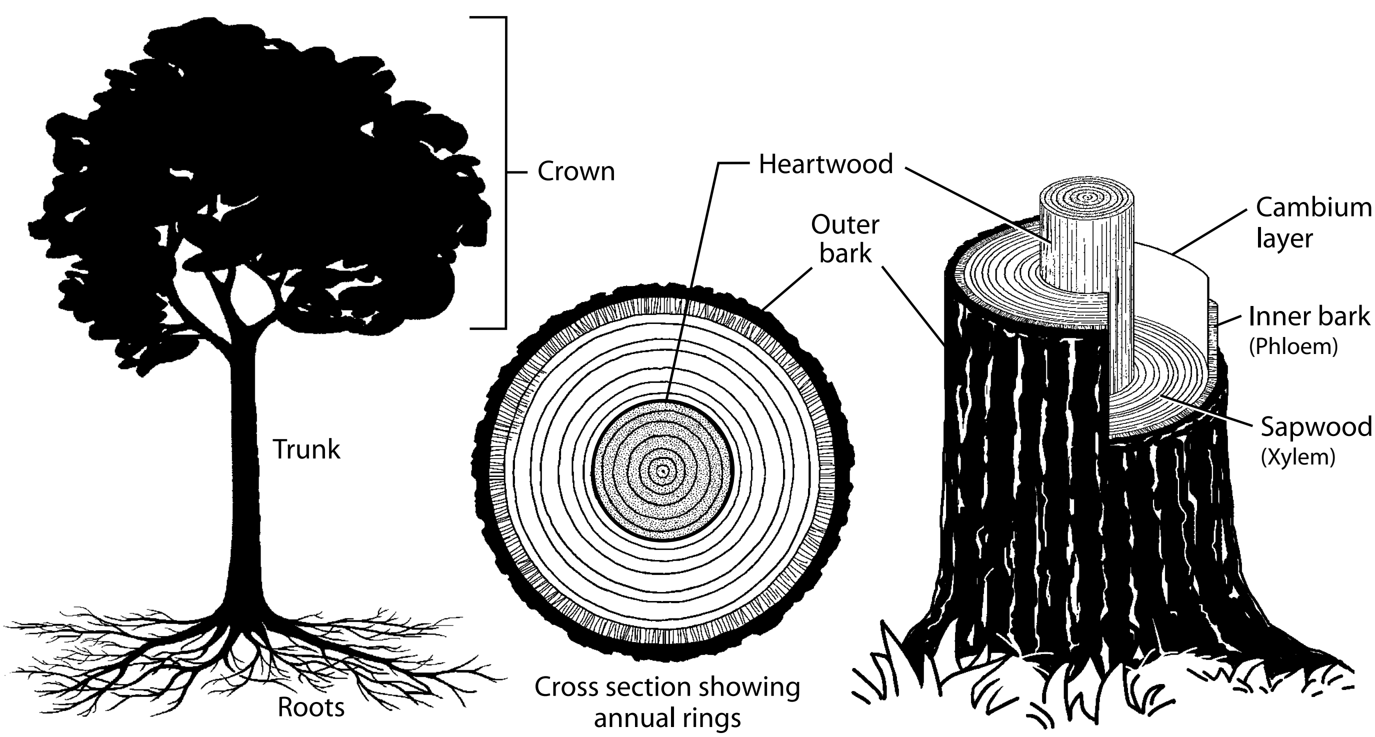

Figure 3-1. Parts of a tree.

Genetics affects many aspects of tree form and growth, including the rate of height and diameter growth, stem form, crown form, any tendency to self-prune, the angle of branch attachment, and tolerance to insects and diseases. You must decide which of these traits is important in helping you achieve your objectives for your woodland. For example, when relying on natural reproduction, kill or harvest undesirable trees during intermediate and final harvests. Permit only desirable trees to produce seed, stump sprouts, or root suckers. When growing trees for timber, poor-quality trees may be an acceptable seed source if their rough appearance is a result of stand conditions or damage not related to genetic characteristics. When planting seeds, seedlings, or cuttings, use planting materials from a reputable tree nursery that collects seed or cuttings from high quality trees growing as close to your planting site as possible. Depending on your needs, the seed source also may exhibit one or more of the form and growth characteristics listed above.

Trees with large crowns have more leaves and, therefore, normally grow faster in height and stem diameter than trees with small crowns. The live-crown ratio of a tree is the percentage of total tree height that has live branches on it (Figure 3-2).

For timber production purposes a live-crown ratio of approximately one-third often is optimum, but the optimum percentage varies by species. If the crown is too small, the tree will grow slowly. If a crown is too large, there will be too much wood in the limbs and too little in the more usable main stem.

Tree species differ in their tolerance for shade and competition (Table 3-1, pg. 28). Trees often are classified as very tolerant, tolerant, intermediate, intolerant, and very intolerant to shade. Some species tolerate more shade as seedlings than as larger trees. Species that are very tolerant will reproduce and grow in deep shade beneath a dense canopy. Species that are very intolerant will survive only if their seeds sprout in wide openings that receive direct sunlight. The size of canopy openings, ranging from the loss of a single tree to removal of many acres, greatly influences which tree species will reproduce and survive. You must know the shade tolerance of a species to determine the light conditions necessary for reproducing it. Tree species that regenerate in openings may be different from species forming the original canopy, thus changing the species composition over time according to the size of canopy openings created.

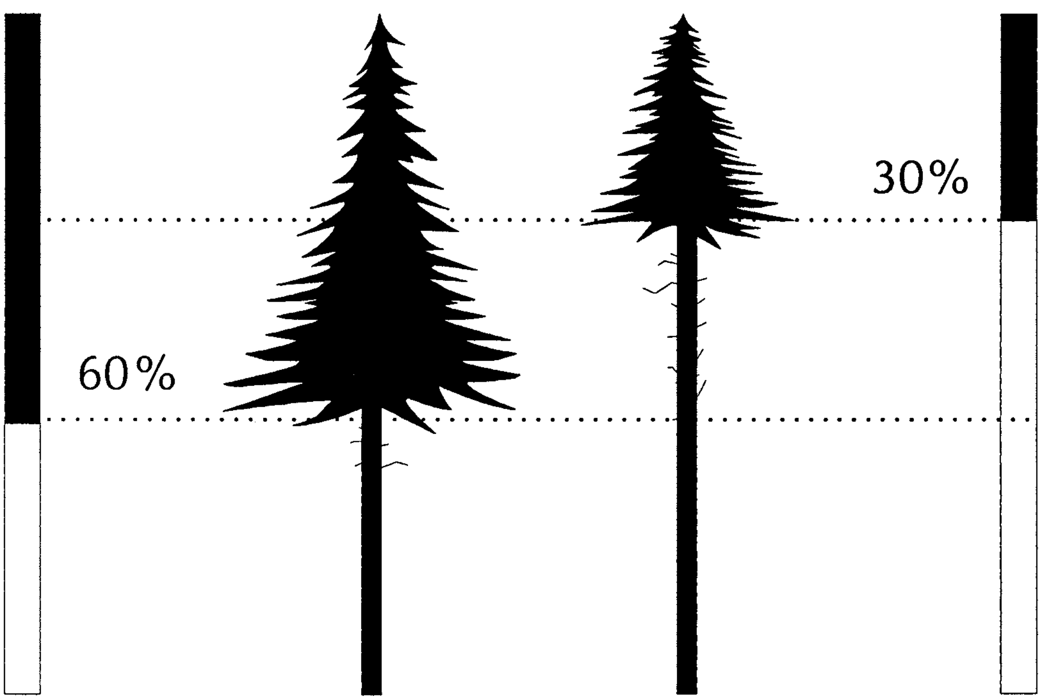

Figure 3-2. Live-crown ratio of a tree.

Table 3-1. Tree species by shade tolerance classification.[1]

Very Intolerant	Intolerant	Intermediate	Tolerant	Very Tolerant
Black Spruce	Black Cherry	Balsam Poplar	Balsam Fir	Beech
Black Willow	Black Walnut	Bitternut Hickory	Basswood	Eastern Hemlock
Eastern Cottonwood	Paper Birch	Black Ash	Bigtooth Aspen	Sugar Maple
Jack Pine	Red Maple	Bur Oak	Black Ash	
Quaking Aspen	Red Pine	Green Ash	Green Ash	
Tamarack	Silver Maple	Hackberry	Hackberry	
		Red Maple	Northern White-Cedar	
		Red Oak	White Ash	
		Shagbark Hickory	White Spruce	
		White Ash		
		White Oak		
		White Pine		
		Yellow Birch		

[1] Note: Some species occur in two columns because of their wide tolerance range.
Source: U.S. Department of Agriculture, Forest Service. 1990. *Silvics of North America, Volume 1* and [2] (Agricultural Handbook No. 654). U.S. Government Printing Office, Washington, DC 20402. http://www.na.fs.fed.us/Spfo/pubs/silvics_manual/table_of_contents.htm

Effects of Site Characteristics

Site characteristics that affect tree growth include soil depth, texture, moisture, fertility, pH, and topography.

Soil Depth, Texture, Moisture, Fertility, and pH

On the whole, deep soils are better for tree growth than shallow soils because they potentially have a greater nutrient supply and water-holding capacity. Rooting depth may be restricted by bedrock, coarse gravel, a hardpan layer, or excess soil moisture. Tree roots that absorb the most nutrients and water usually are found in the top two feet of the soil profile.

Soil particles are classified by size as sand (<0.002mm diameter), silt (0.002mm to 0.05mm), and clay (0.05mm to 2.0mm).

Soil texture refers to the relative proportions of sand, silt, and clay in a mass of soil. Soils with a high percentage of sand have large pore spaces between soil particles. Since they absorb and drain water quickly, they are droughty unless there is a shallow water table. Clay soils have a large water-holding capacity, but they absorb water slowly and water adheres so tightly to the soil particles that much of it is unavailable for plant use. Soils with a high percentage of silt have the most favorable texture for moisture absorption and drainage.

Soil fertility is based largely on the type of parent material from which the soil originated. Some of the most fertile soils originated from limestone, shale, and windblown deposits, whereas some of the least fertile soils originated from sandstone and granite. On the whole, fine-textured (clay) and medium-textured (silt) soils have a greater nutrient supply than coarse-textured (sandy) soils.

Most tree species grow well when the soil remains moist much of the year, but only a few species tolerate very dry or very wet conditions for long periods. Soil may be too dry for good tree growth where the soil is sandy, rocky, or shallow. Soil may be too wet where the soil is clay and the area has high rainfall or groundwater close to the surface. Soil pH is a measure of its acidity or alkalinity. Soil pH affects absorption of minerals by plant roots. A pH of 7 is neutral, neither acid nor alkaline. A pH below 7 is acidic; above 7 is alkaline. Most tree species grow best in a slightly acid soil, but the preferred pH varies by species.

Definitions of Basic Soil Texture Classes

Sand is loose and single-grained. Individual grains can readily be seen or felt. If you squeeze a handful of dry sand, it will fall apart when you release the pressure. If you squeeze a moist handful, it will form a clump that will crumble when touched.

Sandy loam contains a great deal of sand, but also has enough silt and clay to make it stick together when wet. Individual sand grains can readily be seen and felt. Squeezing a dry handful of sandy loam will form a clump that readily falls apart. If you squeeze a moist handful, a clump will form that will bear careful handling without breaking.

Loam has a relatively even mixture of different grades of sand, silt, and clay. It has a somewhat gritty feel, yet is fairly smooth and slightly plastic. If you squeeze a dry handful, it will form a clump that will bear careful handling. A clump formed by squeezing moist soil can be handled quite freely without breaking it.

Silt loam has a moderate amount of fine grades of sand and only a small amount of clay. More than half of the particles are silt. When dry, silt loam may appear lumpy, but the lumps can be readily broken, and when pulverized it feels soft and floury. When wet, the soil readily runs together and puddles. Whether dry or moist it will form clumps that can be freely handled without breaking, but when moistened and squeezed between thumb and finger to form a ribbon, it will break apart.

Clay loam is a fine-textured soil that usually breaks into hard lumps when dry. When moist clay loam is pinched between a thumb and finger, it will form a thin ribbon that will break readily, barely sustaining its own weight. Moist clay loam soil is plastic and will form a clump that will bear much handling. When kneaded in the hand, it does not crumble readily, but works into a compact mass.

Clay is a fine-textured soil that usually forms very hard lumps when dry and is quite plastic and usually sticky when wet.

Topography

Topography affects tree growth largely because of its influence on soil depth, moisture availability, and sunlight exposure.

Because gravity pulls soil particles and water downhill, soil depth, nutrient supply, and water supply usually are greater on lowlands, hillside benches, and coves than on steep hills. For similar reasons concave slopes are better for tree growth than convex slopes.

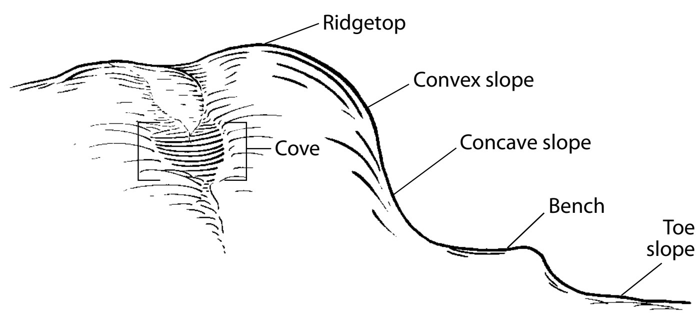

Figure 3-3. Landscape position

Aspect is the compass direction a slope faces when you are standing on it looking downhill. Aspect influences the intensity of sunlight reaching the ground, which in turn affects the moisture evaporation rate. Slopes that face north and east tend to be cooler and moister than slopes facing south and west. In the northern hemisphere the sun's rays shine more directly on south slopes, warming and evaporating moisture from them. West slopes are drier than east slopes because the sun shines on west slopes during the hottest part of the day, increasing water use by trees and evaporation from the soil. These effects become exaggerated as the slope becomes steeper or the hills become higher.

Effects of Climate

Trees are genetically programmed to grow within certain climatic conditions. The length of the frost-free growing season, temperature extremes, precipitation amounts, and the duration of droughts are a few elements of climate that influence tree growth. A single tree species also varies in its climatic requirements across its natural range. For example, quaking aspen naturally occurs from northern Alaska to northern Illinois, but a quaking aspen transplanted from Illinois will not flourish in Alaska.

Native trees have evolved and adapted to a specific climate. When tree seeds or seedlings in the Northern Hemisphere are moved a short distance northward for planting, they may grow faster than local trees because they are genetically programmed to begin growth earlier in the spring and to extend their growth longer in the fall. But when trees are moved too far north, they often cannot survive the winters, are damaged by late spring or early fall frosts, or find the growing season too short to consistently produce viable seed. Trees growing on the northern limits of their natural range usually should not be moved more than 50 miles north.

When planting stock is moved southward in the Northern Hemisphere, it often grows more slowly than native trees because such introduced trees are genetically programmed to begin growth later in the spring and end growth sooner in the fall. They also may not tolerate the higher temperatures and greater water demands of a warmer climate.

Plant hardiness zone maps have been created to show where tree species typically can be grown in North America based on the average annual minimum temperature. Search online to find a plant hardiness zone map. Zone boundaries have changed in recent years because of climate changes. Trees and tree seeds usually should not be moved from one zone to another. Plant hardiness zones should not be your only criteria for tree selection since they do not take into account other climatic factors affecting tree survival, such as summer temperatures, precipitation, number of frost-free growing days, humidity, and snow cover.

In the Lake States much of our winter snowfall runs off in the spring, summer rainfall is not evenly distributed over the growing season, and prolonged summer droughts occur periodically. Our native trees have adapted to this precipitation pattern. Where the prairie meets the forest, evaporation may exceed precipitation, greatly reducing tree survival. Some tree species will grow in droughty prairie regions, but may need supplemental watering, mulching, or weed control, especially when young.

Trees also influence the climate on a global scale. Since individual trees are composed mainly of carbon, woodlands are great reservoirs of carbon, a greenhouse gas. Carbon storage is becoming a recognized value for woodlands to help offset the impact of burning coal, oil, natural gas, which releases carbon into the atmosphere, leading to global warming. Trees remove carbon from the atmosphere and store it in their woody tissues.

How Woodlands Grow

A tree seed germinates, a seedling emerges, it is browsed by a deer, it grows to a sapling, a bird nests in its branches. When it is a pole-sized tree, wind breaks a branch. When mature, it is felled by a logger. In the vacant space left behind, a seed germinates, but it's of a different tree species than the felled tree, and the forest changes.

This process of change, in which a collection of tree species is slowly replaced by a different collection of tree species is called succession. Forestry is the art and science of manipulating a woodland to achieve your personal goals. Forestry can speed up or slow down natural succession. Your management may affect the characteristics of your woodland for a century or much longer, so it is wise to consider the long-term impacts of your decisions. Doing nothing may not yield the outcome you want to see. Future owners and others who depend on your resources will live with the consequences of your management practices.

The basic unit of management is a stand. It is common practice for a forester to develop a set of management practices for each stand based on the owner's objectives. Woodland owners often have different objectives for different stands because their growth potential may be different.

The growth potential of a stand is partly affected by the mix of tree species growing on it, but in the long term, growth potential is governed by the underlying site characteristics: soil, moisture, topography, and climate. Each stand in a woodland has an ecological trajectory, a natural pathway for change, that is heavily influenced by site characteristics. This pathway can be altered and the species composition of a stand changed via natural disaster (such as a fire or windstorm) or human activities (such as harvesting, thinning, or introducing invasive exotic species). To simplify management and reduce costs, you ordinarily should encourage growth of tree species that are naturally adapted to the site characteristics.

To further understand the concept of an ecological trajectory, let's assume you are walking through a 40-acre stand of quaking aspen and paper birch that is about 20 years old. The forester with you notices that part of this stand is on an upland with loamy-sand soil. He points to understory plants that indicate a moderately dry growing site. Besides the tall aspen, there are quite a few shorter red and white oaks, red maple, sugar maple, white ash and basswood. If nature takes its course and no natural disaster or human interference occurs while the hardwoods are maturing, this aspen stand will eventually succeed to a northern hardwood stand in which aspen is a minor component. But if a fire sweeps through the stand or it is clearcut when the aspen are mature, then hardwoods will be suppressed and aspen will continue to dominate the stand.

Another portion of the aspen stand you are exploring is on a lowland with silty clay-loam soil with a high percentage of humus (decaying organic matter). The forester points to shrubs and understory plants that indicate the site is moist to wet during much of the growing season. Beneath the canopy of aspen, balsam fir and white spruce are growing in abundance. In the absence of a natural disaster or clearcut, the ecological trajectory for this stand is toward a spruce-fir stand with a minor component of aspen. If a fire swept through this stand or it were clearcut when the aspen were mature, then aspen would quickly regenerate and the balsam fir and white spruce would again be suppressed.

Do not assume that the tree species currently growing on a site are those best adapted for long-term production. Ask a forester to evaluate the whole plant community (trees, shrubs, and understory plants) as well as soil, moisture, topography, and climate, then recommend which tree species will grow best on the site. Change stand boundaries as needed to encompass sites with relatively uniform growing conditions.

From the above discussion, you probably also realize that if no human management intervenes in a woodland, natural forces still cause change. Each tree species has a natural life span that may be shortened on a poor site or lengthened on a good site. Competition for nutrients, moisture, and sunlight leads to the death of individual trees. Fire, wind, insects, and disease can weaken and eventually kill trees.