LUC 7 Envirothon

Forestry

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G3277

WISCONSIN WOODLANDS: How Forest Trees Grow

Theodore T Kozlowski

Knowing how forest trees grow can help woodland owners predict yields. It can help them understand how different trees might be affected by environmental stresses, and how thinning and pruning affect wood production. Understanding the growing cycles of different trees will help the owner decide when and how to plant, thin and prune trees to increase wood production.

Forest trees grow in both height and diameter. Trees grow taller—and branches longer—because of the division of cells at the tips of branches. Roots also grow at their tips. By contrast, the diameter of trees' woody parts increases as a result of cell division in a layer located between the bark and wood. This layer is called the cambium (see Fig. 1).

Trees vary widely in their growth patterns. They vary in crown form; ultimate size; longevity and branching habits; and in the growth rates of roots, stems and leaves. Growth patterns differ between temperate-zone trees and tropical trees, evergreen and deciduous trees, and in different parts of the same tree. In many temperate-zone trees, roots begin to grow earlier in the year before shoots elongate, and diameter growth begins even later (Fig. 2).

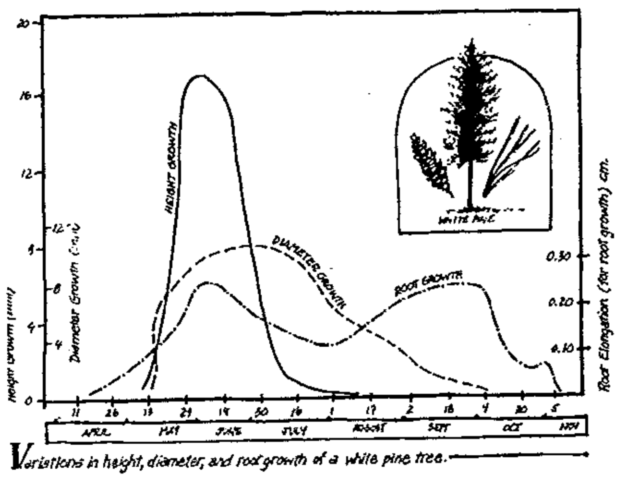


Figure 2. Seasonal differences in height growth, diameter growth and root elongation of an eastern white pine tree.

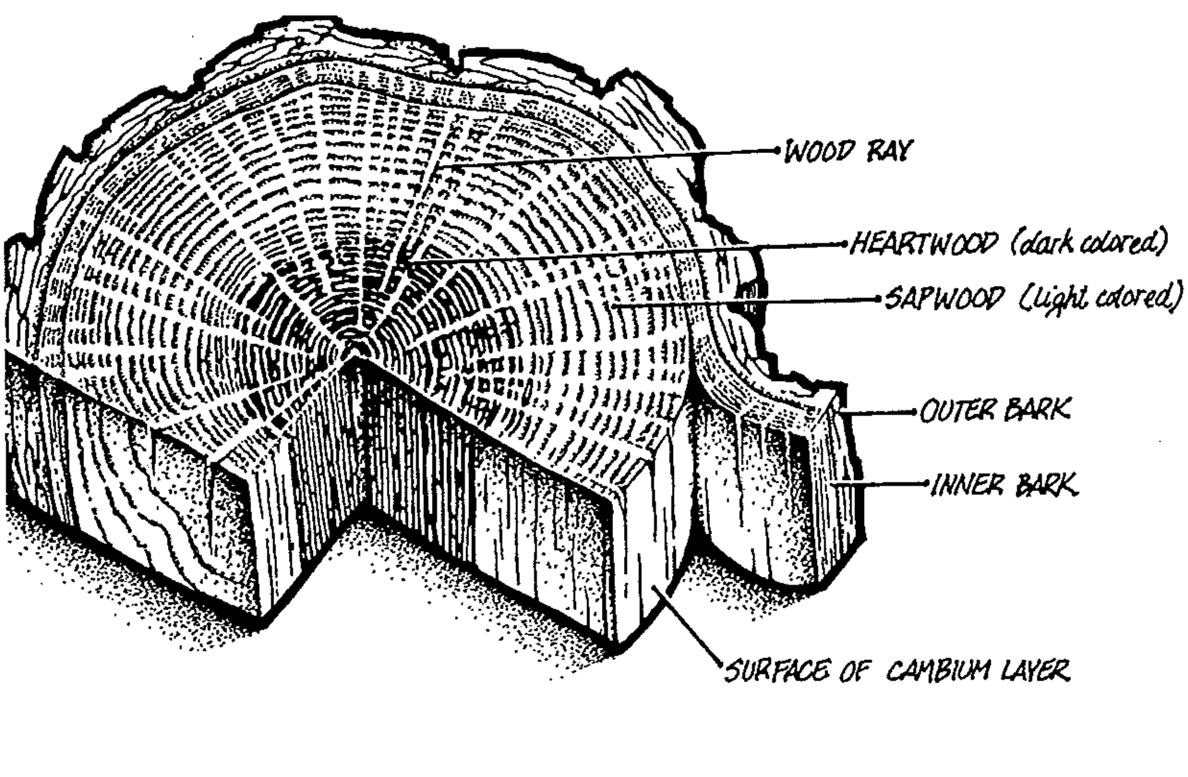


Figure 1. Annual layers of wood in a tree's stem and branches.

HEIGHT GROWTH AND ELONGATION OF BRANCHES

Species vary in the duration of their seasonal height growth. Some complete their growth in height within 2-6 weeks during the early part of the growing season. Others may increase in height for several months. Duration of height growth and branch elongation are controlled genetically.

Species with Fixed Growth

In some species, such as red pine, white pine and beech, the winter bud contains an unexpanded shoot (a branch tip with its leaves and appendages). The shoots form late in the growing season of one year and then expand during the following year. Height growth and branch elongation occur relatively rapidly in species with fixed growth. Wisconsin red pines, for example, complete their height growth by the end of June, although the needles continue to elongate until much later in the summer. Thus, a drought in August will not affect their height that year, but may affect growth in the following year.

Species with Free Growth

In other species, such as poplars and birches, some of the winter buds contain some shoots that are only partially formed (others are fully formed). In such species, leaves preformed in the bud one year expand the next year, but new leaves also form and expand as a stem or branch elongates. Height growth and elongation of branches usually take much longer in species with free growth than in species with fixed growth. Species with free growth will respond to stresses such as drought differently than species with fixed growth. A drought in August would be likely to decrease that year's growth.

Species with Recurrently Flushing Growth

In still other species, annual height and branch growth involve elongation of more than one terminal bud per shoot. This is the case for some temperate zone pines (such as loblolly and slash pines of the southern states), most tropical pines and many broad-leaved tropical trees. There are no trees with recurrently flushing growth which grow in Wisconsin. Pines with this kind of growth, for example, increase in height by extending a succession of buds formed at the tip of the stem. After a period of bud extension, height growth stops briefly while a new terminal bud cluster forms. Shortly thereafter this recently formed bud expands to "increase the height of the tree further. At the same time, a whorl of lateral branches grows from lateral buds at the base of the main bud. Typically, there are two to four such periods of elongation growth every year. The annual increase in height represents the cumulative growth of several growth flushes. Trees with recurrently flushing growth can be very productive because they continue to grow over many months. They are more affected by late season environmental stresses than are fixed growth species.

Abnormal Late-Summer Shoots

Some species with fixed growth have a tendency to produce abnormal late-summer shoots from buds that normally do not open until the following year. Hickory from some seed sources, pines, spruce, and oak are especially well-known for such shoots. Abnormal late-summer shoots are subject to winter injury because they may not harden adequately.

Tree Form

Shoots on a tree do not all grow to the same length. Differences in the elongation of shoots in different parts of a tree help determine the tree's shape. In many trees, upper shoots interfere with the elongation of lower shoots. In most conifers, for example, the terminal leader (main stem) elongates more each year than the branches below it. Furthermore, whorls of lateral branches elongate more at the top of the tree than at the bottom, and branches growing from the main stem elongate more than branches growing from other branches. This orderly pattern of growth produces a tree with a conical shape.

Many Christmas tree growers routinely "shear" trees to shape them. Removing the tips of lateral shoots stimulates expansion of subordinate shoots and the formation and expansion of new buds into additional shoots. The result is a well-shaped, bushy Christmas tree.

Shoot growth does not vary in such an orderly manner in many broad-leaved trees. Rather, many shoots elongate at about the same rate, and the trees branch and rebranch until sometimes the main stem becomes difficult to identify. Such trees often have characteristic crown shapes. Beech and oak, for example, tend to have oval or elongated crowns, whereas American elm has a vase- or umbrella-shaped crown.

Height Growth and Tree Age

A tree's annual increase in height varies with its age. Height growth of a young seedling increases a little each year, usually until the tree reaches the pole stage. The annual growth in height then remains relatively constant for a number of years and then declines fairly rapidly. Of course, the amount of height growth differs appreciably from year to year as environmental conditions, particularly water supply, vary.

Maximum Height

Trees also vary greatly in the ultimate heights they reach. A tree's maximum height is more related to its longevity than to its annual growth rate when young or to the type of shoots it produces. Trembling aspen grows fast when young, but never becomes very tall because it ages rapidly and is relatively short-lived. By contrast, the long-lived white oak, a slow grower when young, often becomes a tall tree. Tables 2 and 3 show variations in size, growth rate and longevity. Note: Both tables list species in addition to those which grow in Wisconsin.

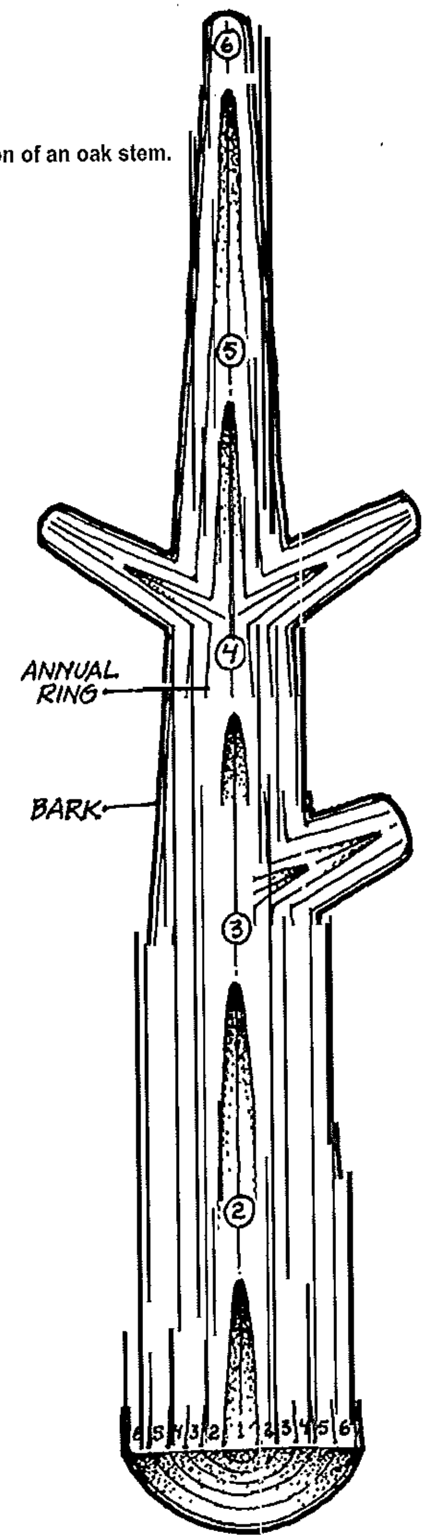
GROWTH IN DIAMETER

The diameter of a tree determines how it can be used, and its value. In general, and particularly with hardwood species, the larger the diameter the greater the value (and age) of the tree. Trees grow in diameter because each year new layers of wood and inner bark are inserted between the previous year's layer of wood and bark. The new layers are produced by the division of cells in the cambium, a thin layer just under the bark (see Fig. 1). These cells divide to produce wood (xylem) cells toward the inside of the tree and living bark cells (phloem) toward the outside. The cambium produces more wood than bark. Bark cells eventually collapse and die and some of the old outer bark is shed.

Because of this mode of growth, a tree's stem consists of annual increments of wood, one added on top of another. If you cut the tree in half from top to bottom you would see a series of overlapping cones (see Fig. 3).

Figure 3.

Cross-section of an oak stem.



People often use annual rings as a way to determine the age of a tree. But a tree may appear to be different ages depending on where in the stem the rings are counted. There will be fewer rings higher on the tree than at its base. Trees sometimes grow more on one side than another. The annual rings of wood in a stem cross section result from variations in growth rate and differences in the kind of wood produced early and late in the growing season. Wood formed early, called *springwood* or *earlywood,* has cells of large diameter and is much less dense than wood formed late in the season, which is called *summerwood* or *latewood.* Annual rings are visible in stem cross sections because of the differences in density of the earlywood of one year and the adjacent latewood of the previous year.

Temperate zone trees usually produce one ring of wood each year. However, they may produce more than one in some years. Foresters can recognize "false" or "multiple" rings as well as "missing" ones. There also may be "discontinuous" rings, formed when the cambium is dormant on one side of a tree, as sometimes happens in trees with injured crowns and in very old trees. Frosts that occur after annual growth starts may injure a tree's cambium and cause "frost" rings, which are sometimes mistaken for annual rings. So ring counts do not always indicate a tree's true age.

Seasonal Duration of Diameter Growth

A tree's growth in diameter usually continues later into the summer than its growth in height does. However, the duration of diameter growth varies among species and crown classes and with weather and site. Diameter growth is very responsive to water supply and often slows during a drought and speeds up after a rain. Seasonal diameter growth in one year usually continues for a longer time in conifers than in deciduous trees because conifers retain their needles and continue to produce carbohydrates and growth regulating hormones later in the fall.

Dominant trees, whose crowns extend above the general level of the crown canopy, not only grow faster, but they continue to produce wood much later into the summer than suppressed trees do. Dominant trees may continue to grow in diameter throughout most of the growing season, whereas suppressed trees (whose crowns are completely below the general crown canopy) may increase in diameter during only a small part of the growing season. Dry weather can shorten the duration of diameter growth substantially, especially in suppressed trees.

Vertical Distribution of Diameter Growth

A tree does not grow in diameter at the same rate all along the stem. In fact, the rate of diameter growth varies consistently. The annual sheath of wood laid down by the cambium is quite thin near the top of the tree. It is thicker further down the stem, becoming thickest in deciduous trees at about the stem height where the number of leaves is greatest. In pines, the annual sheath is thickest somewhere between the middle and base of the crown.

How the thickness of the annual sheath varies with stem height depends on the tree's crown class (Fig 4). In dominant trees, the sheath becomes thinner below the crown and thickens again near the stem base. In suppressed trees, maximum sheath thickness occurs at a greater stem height and,

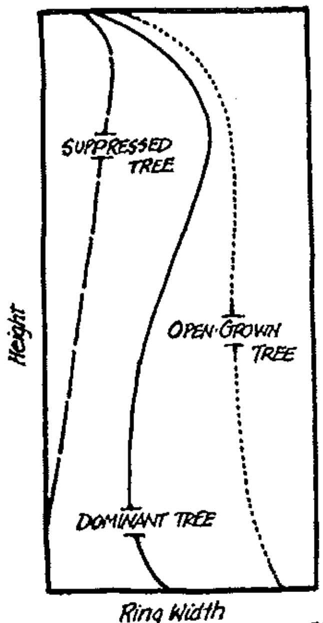


Figure 4. Thickness of the annual layer of wood produced at different stem heights in suppressed, dominant and open-grown trees. Suppressed trees are those with crowns completely below the general level of the crown canopy. They receive no direct sunlight from above or from the side. The crowns of dominant trees extend above the general level of the crown canopy and receive full sunlight from above, some from the side.

Variations in thickness of the annual ring at various stem heights.

below the height of maximum thickness, the sheath becomes thinner and does not thicken near the base of the tree. The annual layer of new wood in suppressed trees is also thinner overall than in dominant trees. Stems of very suppressed trees which often lay down very little wood near the base are much less tapered than those of dominant trees. However, even though there is more diameter growth in the upper stem than in the lower stem of suppressed trees, the trees are still thicker toward the base where there are more annual rings of wood (see Fig. 3). Unlike dominant and suppressed trees, open-grown trees usually show a progressive increase in thickness of the annual sheath from the height of maximum crown width to the base of the stem.

In managed plantations, the annual increment of new wood changes in rather predictable ways. When the trees are young, the annual layer is progressively thicker from the top of the tree downward. As the trees grow older and the crowns grow together or "close," competition for light, water, and minerals intensifies among the trees, and the zone where the layer is thickest moves upward. Below this height, the thickness of the layer decreases toward the stem base. Removing some trees by thinning a stand stimulates cambial growth near the stem base of the remaining trees. As the trees subsequently become more crowded, the position of greatest layer thickness again moves upward. Therefore, to obtain optimum volume growth (and value) it is important to keep forest stands in an uncrowded condition.

Effects of Thinning and Pruning on Diameter Growth and Stem Form

There is much interest in cultural practices which stimulate diameter growth of trees. Although an increase in diameter growth by such practices increases stem taper, normal crown closure tends to keep these effects from becoming serious. Generally, thinning accelerates diameter growth and the greater wood volume combined with an increase in log grade more than compensate for change in stem form.

Thinning a stand of trees increases the growing space for the remaining trees and accelerates physiological activity in their crowns. As a result, the remaining trees grow faster in diameter, and the form of their stems changes. Thinning usually stimulates wood production most near the stem base, resulting in a more tapered stem. How much a tree responds to thinning of a stand depends among other things on its crown class. Dominant trees with large crowns often do not show much response to thinning. More suppressed trees show much greater response.

Pruning branches has just the opposite effect from thinning. Removing lower branches tends to slow diameter growth at the stem base, so more wood is produced in the upper stem after pruning. Pruning, in other words, tends to reduce stem taper. The extent to which tapering is reduced depends on the severity of the pruning and the crown class of the tree. Pruning affects diameter growth of open-grown trees more than stand-grown trees. Both the amount of wood formed and its distribution along the stem of a large-crowned tree vary with the intensity of pruning and the tree's age. Many pruning trials have not changed stem form appreciably because too few branches were removed or the trees were pruned too late.

Extreme taper is normally not a problem in forest-grown trees because they can be bucked into shorter logs, minimizing the impact of volume lost to taper. Nevertheless, using pruning and thinning to manage stem form can pay off in higher stumpage prices.

ROOT GROWTH

The most common types of roots are tap roots (found in oaks and hickories), and fibrous root systems, such as those in pines. However, for many species, rooting characteristics are not fixed because site conditions alter the pattern of root growth. Red maple, for example, has a very plastic root system. It develops many shallow laterals in swamps and a deep taproot in dry upland soils.

The root system of a tree consists of large perennial roots and many small ones that are short-lived. In many tree species, root hairs on the surface of these small roots increase their absorbing surface. Most of these hairs live only days or weeks. As old hairs die, new ones form behind the growing root tips. Many of the small roots normally die, mostly during winter, but also at other times from unfavorable environmental conditions or attacks by pests. Complete defoliation of a tree may induce death of most of these small "feeder" roots.

Roots usually begin to elongate earlier in the spring, and to continue longer, than shoot growth (Fig. 2). The rate of root growth varies during the growing season and in many species occurs in cycles regulated by environmental changes. Root growth rate varies at different soil depths because of differences in water and mineral supply, aeration, temperature and other factors. In woody roots, seasonal cambial growth begins near the soil surface, then the zone of growth moves downward like a wave. Cambial growth in roots is much more irregular than in stems. False and double rings are common in roots, as are roots that are eccentric in cross section.

Closely related species of trees often become joined by root grafts. When growing roots of related trees come into contact, their tissues often fuse in such a way that carbohydrates, growth hormones, water, minerals and disease agents such as fungus spores may pass from one tree to another. Sometimes stumps stay alive for many years because they receive carbohydrates and growth hormones through root grafts with another tree. Herbicides injected into one tree can move through grafted roots and kill other trees by "backlash."

REPRODUCTIVE GROWTH

To produce a large seed crop, a tree must go through several sequential stages. It must form flower buds and then flower. The flowers must be pollinated and female and male reproductive cells must unite (fertilization). The fruits and seeds must grow and ripen, and then the seeds must be shed. Poor seed years often result from a breakdown in one of these essential stages of reproductive growth.

Flowering

Flowers of most forest trees are small and inconspicuous. Some trees, such as birches and alders, have female and male flowers on the same plant. Poplars and willows have female and male flowers on separate plants. Only female trees of these species produce seeds.

Many broad-leaved trees form flower parts between late May and early June in the season preceding the spring in which the flowers open. Weather and site conditions influence the timing.

Flowers of most broad-leaved trees open sometime between March and mid-June, with the order of bloom varying among species. The usual order of flowering is as follows: silver maple, willows, red maple, American elm, birches, sugar maple, oaks, black cherry, and black locust. Unlike these early-flowering species, witch hazel does not flower until autumn. The actual date of flowering of a given species varies from year to year because of differences in weather, especially temperature (Table 1). Over a 48-year period the dates of first flowering of silver maple and black locust trees in southern Wisconsin varied by 43 and 26 days, respectively.

Table 1. Variation in dates of flowering of silver maple and black locust trees in Dane County, Wisconsin.

Year	Silver Maple	Black Locust
1945	March 7	May 31
1950	April 4	June 6
1955	March 15	May 20
1960	April 8	June 1
1965	April 11	May 25
1970	April 5	May 24
1975	April 11	May 24

Growth of Fruits and Cones

The time required for fruits and cones to grow and mature varies a lot. The fruits of elms, poplars, red maple and green ash ripen within 4-6 weeks after pollination. Fruits of most other broad-leaved species develop throughout the entire growing season. Acorns are exceptions and require two years to mature.

On most conifers—including firs, larch and spruce—cones ripen and shed their seeds during one season. Pines, however, require a much longer time to mature seeds. Red pines growing in central Wisconsin, for example, require three growing seasons to produce mature seeds. Cones begin to form in August of one year, but do not become visible until late May or early June of the next year. They grow little during this year, but grow rapidly in the third year, and the seeds ripen by early September.

Periodicity of Seed Production

It is important to know seed production intervals for seed collecting. If you expect to collect and sell seed or use it for your own tree regeneration you will need to know which species are likely to produce heavy seed crops. If you plan to depend on natural seed production for forest regeneration, knowing seed production cycles will help you develop forest management plans.

Forest trees go through a juvenile stage during which they do not produce any seeds. Once they reach adulthood, however, they may produce seeds for as long as they live, providing that environmental conditions are suitable. The length of the juvenile, non-flowering stage varies from 5-10 years for shade-intolerant species to 30-40 years for shade-tolerant species. Jack pine may produce cones by the third year. Slash pine usually takes about 10 years and does not produce many cones until about 20 years of age. The juvenile period may last 20-25 years in Norway spruce and 30-40 years in beech.

As trees age and lose vigor, both the size and quality of their seed crops decrease. Even after reaching adulthood, forest trees do not produce seeds every year because environmental conditions influence flowering. Open-grown trees and those on the edge of a stand usually produce more seeds—and at an earlier age—than do trees growing in a dense stand.

Irregular and unpredictable seed production by many forest trees is one of the most serious problems in forestry. The amount of seed produced by forest trees varies greatly among species and among trees of the same species. It also varies from year to year in the same tree. Some species produce good crops almost every year, while others have good crops irregularly and still others at regular intervals of several years.

Even closely related tree species show considerable variation in seed production. Red maple and silver maple have good seed crops almost every year, whereas sugar maple produces a good seed crop every 2-5 years. Black oak and bur oak tend to have good seed crops every 2-3 years; white oak has irregular heavy seed crops, at roughly 4- to 10-year intervals. Poplars also vary widely in seed production. Black poplar and cottonwood typically have good annual seed crops, but trembling aspen and big-tooth aspen have good crops at 4- to 5-year intervals. Poor seed crops seem to be due to blocking of one or more of the sequential reproductive phases. Each phase is necessary for a good seed crop.

Tree Vigor and Seed Production

Dominance and vigor are important factors in a tree's capacity to produce large seed crops. In the same forest stand, dominant trees of a given species produce much larger seed crops than trees of intermediate or suppressed crown classes do. In very dense stands, suppressed trees may not produce any seeds at all. Within a tree, variations in the vigor of branches also affect seed production. Red pines, for example, typically produce larger cones on the vigorous branches in the upper and middle part of the crown than on the less vigorous lower branches. Furthermore, the large cones contain more and higher-quality seeds than the small cones.

In conifers, pollen cones and seed cones form at different locations and at different times of the year. In pines, pollen cones form at the base of the current year's growth in the lower crown. The seed cones develop in the upper crown, sometimes forming clusters near the end of the current year's growth. In balsam fir, seed cones form mostly in the upper 4-5 feet of the crown, pollen cones much lower. In tamarack, pollen cones develop on 1- or 2-year-old branches; seed cones on older branches (usually 2-4 years old). Pollen cones usually form before seed cones.

Effect of Seed Production on Vegetative Growth

Trees do not grow as much in heavy seed years as they do in other years. Branches of flowering balsam firs elongate only about half as much as those of non-flowering trees. Furthermore, the shoots of flowering balsam firs have poorly developed needles.

Both conifers and broad-leaved trees grow less in diameter in years of abundant seed production. In beech, for example, the width of annual rings that form in good seed years may be only half as wide as those formed in years of low seed production. In fact, ring width may be reduced for two years after a good seed year. Apparently, the reproductive phase in trees monopolizes substances needed for growth. Reproductive growth and vegetative growth seem to compete for carbohydrates, and vegetative growth often loses out.

For More Reading

Physiology of Woody Plants by P. J. Kramer and T.T. Kozlowski. Academic Press, New York, 1979.

Table 2. Variations in Size, Growth Rate, and Longevity of North American Conifers

Common Name	Scientific Name	Maximum height (feet)	Maximum diameter (feet)	Growth Rate	Longevity (years)
Arbovitae (see Whitecedar)					
Douglas fir	*Pseudotsuga menziesii*	270	15	Rapid	—
Balsam fir	*Abies balsamea*	85	3	Rapid	100-150
Fraser fir	*A. fraseri*	65	2.5	Moderate	200-300
Grand fir	*A. grandis*	250	6	Moderate	200-400
White fir	*A. concolor*	200	6	Moderate	100-400
Hemlock (eastern)	*Tsuga canadensis*	160	6	Slow	300-600
Juniper (see Redcedar)					
Larch (see Tamarack)					
Jack pine	*Pinus banksiana*	90	2	Rapid	80-150
Jeffrey pine	*P. jeffreyii*	130	9	Moderate	300-500
Loblolly pine	*P. taeda*	190	5	Rapid	150-250
Lodgepole pine	*P. contorts*	150	3	Slow	120-300
Longleaf pine	*P. palustris*	150	4	Rapid	300-400
Pinon pine	*P. edulis*	50	3	Very slow	150-400
Pitch pine	*P. rigida*	100	3	Rapid	100-200
Ponderosa pine	*P. ponderosa*	235	9	Moderate	300-500
Shortleaf pine	*P. echinata*	150	4	Rapid	200-300
Slash pine	*P. elliottii*	130	3	Rapid	150-250
Sugar pine	*P. lambertiana*	250	10	Rapid	300-600
Virginia pine	*P. virginiana*	100	3	Moderate	100-200
White pine (eastern)	*P. strobus*	220	6	Rapid	300-500
White pine (western)	*P. monticola*	120	8	Rapid	200-500
Redcedar (eastern)	*Juniperus virginiana*	100	4	Slow	150-300
Redwood	*Sequoia sempervirens*	365	20	Rapid	800-1500
Giant Sequoia	*S. gigantea*	350	38	Rapid	2000-3000
Black spruce	*Picea mariana*	100	3	Slow	150-250
Red spruce	*P. rubens*	120	4	Slow	200-300
Sitka spruce	*P. sitchensis*	300	16	Rapid	400-750
White spruce	*P. glauca*	120	4	Slow	150-350
Tamarack	*Larix laricina*	100	3	Moderate	100-200
Whitecedar (northern)	*Thuja occidentals*	125	6	Slow	300-400

Table 3. Variations in Size, Growth Rate, and Longevity of North American Broadleaved Trees

Common Name	Scientific Name	Maximum height (feet)	Maximum diameter (feet)	Growth Rate	Longevity (years)
Black ash	*Fraxinus nigra*	90	5	Slow	—
Green ash	*F. pennsylvanica*	85	2.5	Rapid	—
White ash	*F. americana*	125	6	Rapid	260-300
Bigtooth aspen	*Populus grandidentata*	80	3	Rapid	70-100
Trembling aspen	*P. tremuloides*	120	4.5	Very rapid	70-100
Balsam poplar	*P. balsamifera*	100	5	Rapid	100-150
American basswood	*Tilia americana*	125	5	Rapid	100-140
American beech	*Fagus grandifolia*	120	4	Slow	300-400
Grey birch	*Betula populifolia*	60	1.5	Rapid	50
River birch	*B. nigra*	100	5	Rapid	—
White birch	*B. papyrifera*	120	5	Rapid	80-100
Yellow birch	*B. alleghaniensis*	100	4	Rapid	150-300
Blackgum	*Nyssa sylvatica*	100	4	Rapid	—
Yellow buckeye	*Aesculus octandra*	100	4	Rapid	60-80
Butternut	*Juglans cinerea*	110	3	Rapid	80
Catalpa	*Catalpa speciosa*	120	5	Rapid	100
Black cherry	*Prunus serotina*	100	5	Rapid	100-200
Cottonwood (eastern)	*Populus deltoides*	175	11	Very rapid	60-100
Black cottonwood	*Populus trichocarpa*	225	8	Rapid	150-200
Flowering dogwood	*Cornus florida*	50	1.5	Slow	125
American elm	*Ulmus americana*	120	11	Rapid	150-300
Red elm	*U. rubra*	90	4	Rapid	300
Hackberry	*Celtis occidentals*	130	5	Rapid	75-150
Bitternut hickory	*Carya cordiformis*	85	4	Slow	175
Mockernut hickory	*C. tomentosa*	100	3.5	Slow	200-300
Pecan (hickory)	*C. illinoensis*	180	6	Moderate	300
Pignut hickory	*C. glabra*	120	4	Slow	200-300
Shagbark hickory	*C. ovata*	120	4	Slow	250-300
American holly	*Ilex opaca*	140	4	Slow	100-150
Honeylocust	*Gleditsia triacanthos*	140	6	Rapid	120
Ironwood or Hophornbean	*Ostrya virginiana*	55	1.5	Slow	—
Black locust	*Robinia pseudoacacia*	100	5	Rapid	60-100
Red maple	*Acer rubrum*	120	5	Rapid	80-250
Silver maple	*A. saccharinum*	120	7	Rapid	50-125
Sugar maple	*A. saccharum*	135	5	Slow	200-300
Red mulberry	*Morus rubra*	50	1.5	Moderate	125
Black oak	*Quercus velutina*	55	7	Moderate	150-200
Blackjack oak	*Q. marilandica*	55	2	Slow	100
Bur oak	*Q. macrocarpa*	170	7	Slow	200-400
Northern red oak	*Q. rubra*	150	11	Rapid	200-400
Pin oak	*Q. palustris*	120	5	Rapid	125-150
Post oak	*Q. stellata*	100	4	Slow	250
Scarlet oak	*Q. coccinea*	110	4	Moderate	150
Southern red oak	*Q. falcata*	110	7	Moderate	200-275
Swamp white oak	*Q. bicolor*	100	7	Slow	300
Water oak	*Q. nigra*	125	5	Rapid	175
White oak	*Q. alba*	150	8	Slow	300-600
Persimmon	*Diospyros virginiana*	130	7	Slow	60-80
Sweetgum	*Liquidambar styraciflua*	200	6	Rapid	200-300
Sycamore	*Platanus occidentals*	175	14	Rapid	250-300
Black walnut	*Juglans nigra*	150	7	Rapid	150-250
Black willow	*Populus trichocarpa*	225	8	Rapid	150-200
Yellow popular	*Liriodendron tulipifera*	200	12	Rapid	200-250

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Extension FactSheet

School of Natural Resources, 2021 Coffey Road, Columbus, Ohio 43210

Measuring Standing Trees

Determining Diameter, Merchantable Height, and Volume

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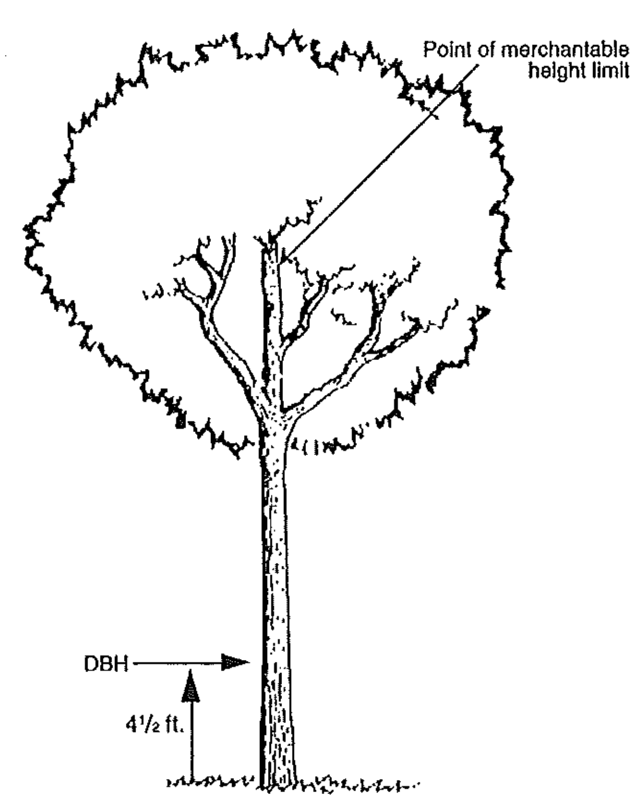
Woodland owners often need to measure the merchantable board-foot content (termed "volume") of certain trees in their woodland. In order to sell timber, for example, an estimate is needed of the quantity to be sold. If trees are to be cut to provide lumber, an estimate of volume is needed to determine what size and how many trees to cut. Using the methods described in this article, a woodland owner can estimate the board-foot volume in one or several trees. If an estimate is needed for several acres, however, it is recommended that the woodland owner engage the services of an Ohio Department of Natural Resources Division of Forestry Service Forester, a consulting forester, or an industry forester. Methods needed to accurately and efficiently inventory timber volume on large areas are beyond the scope of this publication.

Tree Volume Estimation

In the United States, the most common measure of lumber volume is the board foot, defined as a piece of wood containing 144 cubic inches. It can most easily be visualized as a board 12 inches square and one inch thick (12" x 12" x 1" = 144 cubic inches). However, any piece of wood containing 144 cubic inches is a board foot (e.g., 3" x 4" x 12"; 2" x 6" x 12"; etc). The board-foot content of any board may be determined by multiplying the length by the width by the thickness, all expressed in inches, and dividing by 144 cubic inches.

The board foot is also the most common volume measure for trees and logs to be used for lumber and veneer. The board-foot volume of a tree or log is an expression of the number of board feet of lumber that can be cut from that tree or log. The lumber volume that can be cut from a tree or a log depends on a great many variables, including how the tree is cut into logs, the dimensions of the lumber, how much of the log is lost in sawdust and waste, and the efficiency of the sawmill and workers. Because of these variables, the board-foot volume of a tree or log cannot be measured exactly but is estimated.

Numerous methods (called "rules") have been developed to estimate board-foot tree volume. Two board-foot volume rules are commonly used in Ohio, the Doyle and the International 1/4-Inch rules (Tables 1 and 2). Both of these rules provide an estimate of the board-foot content of a tree based on tree-trunk diameter breast high and merchantable tree height (discussed later). The Doyle rule is the most common rule in Ohio. It is used



Common reference points used to measure standing trees.

by the timber industry and many professional foresters. The International 1/4-Inch rule is used by state agencies and the U.S. Forest Service.

A comparison of these two volume tables will show that they are not identical. The International 1/4-Inch rule is generally considered to be the best estimate of the amount of lumber that can actually be sawn from a tree or a log under optimum conditions. The Doyle rule substantially underestimates the volume of trees in the smaller diameter classes. The International 1/4-Inch rule should, therefore, be used when the most accurate estimate of yield is important, as when determining how many trees to cut to obtain a specified amount of lumber. When marketing timber stumpage, however, the choice of volume rule is less critical. Confusion on quantity should not arise as long as both buyer and seller know which rule was used to estimate volumes. Timber stumpage prices are commonly adjusted based on which rule is used.

Measuring Tree Diameter

Tree-trunk diameters are measured at breast height (termed diameter at breast height or DBH), defined as the diameter of the tree 4-1/2 feet above ground on the uphill side of the tree. If a tree forks below breast height, each trunk is treated as a separate tree. DBH can be measured with a tree caliper, a Biltmore stick, a tree diameter tape, or a flexible measuring tape (e.g., cloth or steel). Tree calipers, Biltmore sticks, and tree-diameter tapes can be purchased through forestry equipment supply companies. The flexible measuring tape can be used to measure tree trunk circumference and circumference divided by 3.14 to determine diameter.

Measuring Merchantable Height

Merchantable height is the height of the tree (or the length of its trunk) up to which a particuar product may be obtained, usually minus a one-foot stump height. Merchantable tree heights for sawlogs and veneer are generally estimated to the height where the trunk diameter tapers to 10 inches, or until heavy branching or defects are encountered. The merchantable height of very valuable trees, such as veneer black walnut, may be measured to the nearest foot or two feet. The merchantable height of most other trees is measured in units of 16-foot logs and 8-foot half-logs. Merchantable height measurements are rounded to the nearest half-log. Thus, a tree with a merchantable height of 42 feet would be measured as having 2-1/2 logs of merchantable height.

Merchantable heights may be measured with a number of special instruments designed specifically for tree-height measurements such as clinometers, altimeters, relascopes, or hypsometers. These instruments are available through forestry equipment supply companies. Merchantable heights can also be measured with a long pole if only a few trees are being measured and they have relatively short merchantable heights. With some practice, merchantable heights in log and half-log units can be estimated quite accurately, particularly for trees with short merchantable heights.

Using the Tables to Estimate Merchantable Tree Volume

Once the diameter at breast height and the merchantable height of a tree have been measured, Table 1 or 2 may be used to estimate its volume in board feet. For example, a 20-inch DBH oak tree with a merchantable height of 2-1/2 logs contains 260 board feet Doyle rule or 350 board feet International 1/4-Inch rule.

When using these tables, it is important to remember that only that portion of the trunk that will produce a useable product should be measured. Portions of the trunk or entire trunks that are hollow, excessively crooked, rotten, etc., should not be measured. You may hear foresters or buyers talking about gross and net volume. Gross volume is the estimated tree volume without deduction for defects (i.e., the DBH and merchantable heights of all of the trees were measured ignoring defects, volumes were determined, and the volumes were added up). Net volume is the estimated tree volume with proper deductions made for defects.

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Table 1. Standing Tree Board Foot Volumes — Doyle Rule

Dbh (inches)	Number of 16-Foot Logs							
	1/2	1	1-1/2	2	2-1/2	3	3-1/2	4
	Board Feet							
12	20	30	40	50	60			
14	30	50	70	80	90	100		
16	40	70	100	120	40	160	180	190
18	60	100	130	160	200	220	40	160
20	80	130	180	220	260	300	320	360
22	100	170	230	280	340	380	420	460
24	130	220	290	360	430	490	540	600
26	160	260	360	440	520	590	660	740
28	190	320	430	520	620	710	800	880
30	230	380	510	630	740	840	940	1,040
32	270	440	590	730	860	990	1,120	1,220
34	300	510	680	850	1,000	1,140	1,300	1,440
36	350	580	780	970	1,140	1,310	1,480	1,640
38	390	660	880	1,100	1,290	1,480	1,680	1,860
40	430	740	990	1,230	1,450	1,660	1,880	2,080
42	470	830	1,100	1,370	1,620	1,860	2,100	2,320

From: Ashley, Burl S. 1980. *Reference handbook for foresters.* USDA NA-FR-15. 35 pp.

Table 2. Standing Tree Board Foot Volumes — International 1/4-Inch Rule

Dbh (inches)	Number of 16-Foot Logs							
	1/2	1	1-1/2	2	2-1/2	3	3-1/2	4
	Board Feet							
12	30	60	80	100	120			
14	40	80	110	140	160	180		
16	60	100	150	180	210	250	280	310
18	70	140	190	240	280	320	360	400
20	90	170	240	300	350	400	450	500
22	110	210	290	360	430	490	560	610
24	130	250	350	430	510	590	660	740
26	160	300	410	510	600	700	790	880
28	190	350	480	600	700	810	920	1,020
30	220	410	550	690	810	930	1,060	1,180
32	260	470	640	790	940	1,080	1,220	1,360
34	290	530	730	900	1,060	1,220	1,380	1,540
36	330	600	820	1,010	1,200	1,380	1,560	1,740
38	370	670	910	1,130	1,340	1,540	1,740	1,940
40	420	740	1,010	1,250	1,480	1,700	1,920	2,160
42	460	820	1,100	1,360	1,610	1,870	2,120	2,360

From: Ashley, Burl S. 1980. *Reference handbook for foresters.* USDA NA-FR-15. 35 pp.

FORESTRY FACTS

UW Extension

COLLEGE OF AGRICULTURAL & LIFE SCIENCES
UNIVERSITY OF WISCONSIN-MADISON

Department of Forest Ecology and Management • School of Natural Resources

No. 44 August, 1989

What Is A Cord?

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A cord is a unit of measure applied to stacked roundwood, usually pulpwood or firewood. With firewood, the pieces may be split before the cordwood stack is formed. Since a cord is a measure of a loose stack of wood, it contains air space as well as solid wood and bark, and is therefore more of an indication of space occupied than actual wood measure. A standard cord contains 128 cubic feet of wood, bark, and air space, often measuring 4 feet high, 4 feet wide, with pieces 8 feet in length, or 4 feet high, 8 feet wide, with pieces 4 feet in length. Although the dimensions can vary, depending on the length of the pieces, the cubic-foot content is constant for a standard cord.

To estimate the number of standard cords in a stack (or truckload) of roundwood, use the following formula:

$$\text{Cords} = \frac{\text{height x width x length}}{128}$$

Where: height, width, and length of the stack are in feet.

A stack with irregular height is best measured by a series of height measurements. These should be taken at even intervals at right angles to the ground or truck bed. The average height is then determined from the series of measurements.

Sometimes we are interested in the solid wood contents of a cord, excluding the bark and air space. Or, we may want to know the amount of wood and bark only. In the Lake States, the average values (based on many measurements for a variety of species and conditions) are shown in the table on page 2.

CONTENTS OF A STANDARD CORD:	
Wood, bark and air space	128 cu. ft.
Wood and bark	92 cu. ft.
Solid wood	79 cu. ft.

Therefore, an average standard cord contains 62 percent solid wood, 28 percent air space, and 10 percent bark. Since these are average values, you should remember that some variability will be found, due to differences between species, diameter of the pieces, care in piling, and straightness of the pieces.

Sometimes the pieces are cut to very short lengths, as with firewood, and the face cord (or short cord) is used as the unit of measure. A face cord is 4 feet high, 8 feet wide, with pieces less than 4 feet in length. Firewood lengths are commonly 16 inches.

In the Lake States, pulpwood pieces or "sticks" are commonly cut to 100 inches in length. Therefore a pulpwood cord is 4 feet high, 4 feet wide, with pieces 100 inches long. The pulpwood cord actually contains 133 cubic feet of wood, bark, and air space.

Often we are interested in estimating the number of cords that we will obtain when standing trees are harvested. To do this we normally estimate the number of 8-foot sticks and the DBH (diameter at breast height) for each tree. These values are then used with a cordwood volume table to estimate the cords available. Numerous tables have been developed for this purpose. A table commonly used in the Lake States can be found in UW-Extension Bulletin G3332.

Sometimes we want to convert cordwood volumes to board feet and vice versa. This is often not very reliable because small trees suitable for pulpwood and firewood are not large enough to produce lumber. Therefore such a conversion should be viewed as an approximation only and used accordingly. It is probably safer to convert board feet of sawlog-sized wood to cords rather than converting cords to board feet, to avoid the problem with converting undersized wood. In the Lake States we often assume that 1000 board feet of sawtimber equals about 2.4 standard cords for softwoods (pines, spruce, fir, etc.), and 2.2 standard cords for hardwoods (oaks, maples, etc.)

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No. 45

August, 1989

What Is A Chain?

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A chain is a unit of measure commonly used by foresters to determine horizontal distances. However, the chain is seldom used by others, being replaced by feet and other units. This is unfortunate because the chain, for many purposes, is a more convenient unit.

The chain has a history of use in early surveys. In fact the original tool for measuring distances in the woods of the United States and Canada was commonly the Gunter's Chain. This chain was 66 feet long and composed of 100 links of stout wire, each 7.92 inches long. Today's "chain," also 66 feet long, is actually a steel tape that is either coiled or retracted on a reel for carrying.

Why a unit of measure having such an odd length of 66 feet? This can best be explained by looking at some of the conversions that are possible with the chain. First, let's look at distance:

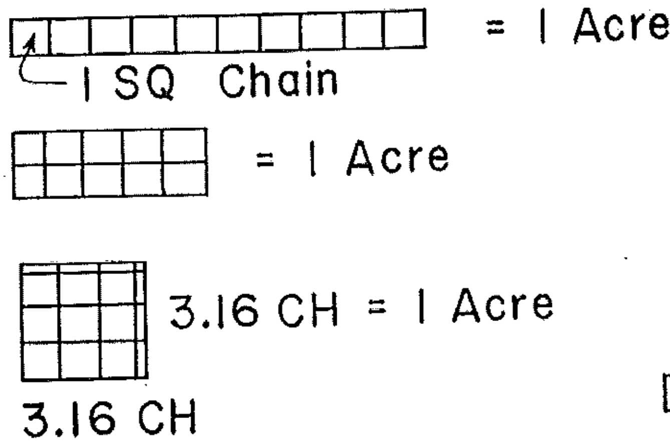
Since a rod equals 16 ½ feet, a chain contains exactly 4 rods; 66/16.5 = 4.0

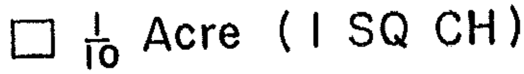
A mile is 5,280 feet long, therefore a mile contains exactly 80 chains; 5,280/66=80.

What really makes the chain a handy unit of measure is when it is used to measure areas:

One square chain (a square having sides that are each 1 chain, or 66 feet in length) contains 4,356 square feet; 66' x 66' = 4,356.

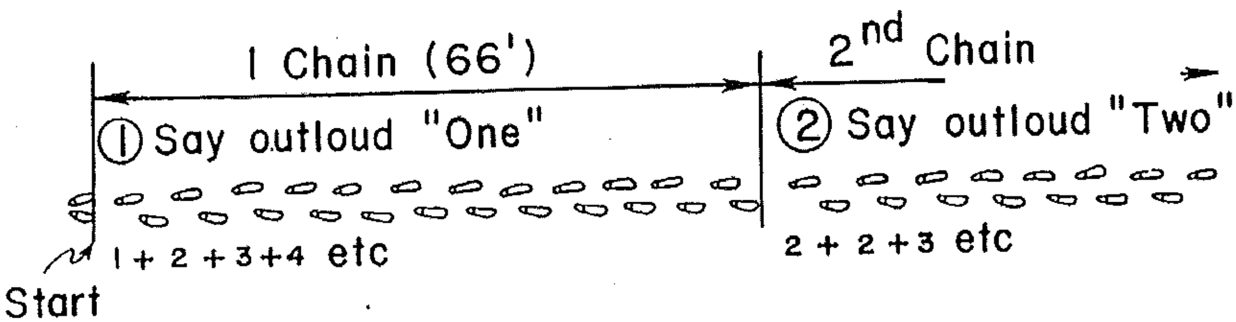
Since one acre contains 43,560 square feet, it also contains exactly 10 square chains; 43,560/4,356=10 (see diagram on page 2).





Therefore, with such useful conversions as 80 chains per mile and 10 square chains per acre, it's no wonder that this unit has survived over the years.

You can borrow or purchase a steel tape graduated in chains for use in determining distances and areas in your woodlot, or you can learn to pace the distances. The latter is less accurate, but may suffice for many purposes other than legal surveys. To learn pacing lay off a 66-foot distance in your woods and mark the ends with stakes. Then walk between the stakes, counting your paces (one pace equals two steps) as you go. You may want to repeat the process a few times and average the results. A word of caution, determine your pacing for a comfortable stride, not one that you normally don't use or can't maintain.



If your land is hilly, you'll want to practice this on steeper ground as well. In this case you must be sure to lay off the 66-foot distance horizontally and not along the slope. This may require measuring the 66 feet in several shorter horizontal segments - called "breaking chain" by surveyors.

Once you've determined the number of paces it takes for you to walk one chain, you're ready to measure distances and areas in the woodlot.

For example, suppose you're curious about the number of acres actually harvested during your last timber sale. If the area is roughly rectangular in shape you can pace the length and width and multiply the two to get the area. If in this example, the width is 12 chains and the length is 15 chains, you would multiply 12 x 15 and obtain 180 square chains in the harvested area. This can easily be converted to acres by dividing 180 by 10, resulting in 18 acres. The acreage of irregular shaped areas can be estimated by partitioning the area into smaller rectangles. Then, estimate the acres in each (as above) and add the results to get a total.

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What Is Basal Area?

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A tree's basal area is the cross-sectional area of the stem at 4 1/2 feet above ground - breast height (see drawing, page 2). Foresters report basal area as either square feet per tree or square feet per acre (see table, page 2).

If you are interested in the mathematics, you can estimate a tree's basal area (in square feet) with the following formula:

$$\textbf{Basal Area} = \frac{3.1416 \times DBH^2}{4 \times 144}$$

This formula simplifies to:

$$\textbf{Basal Area} = 0.005454 \times DBH^2$$

Where: DBH equals the diameter of a tree's stem, in inches, at 4 ½ feet above the ground.

Basal area per acre, the sum of each tree's basal area in your woodlot divided by the acres involved, is used to gauge whether your forestland is overstocked (too many trees), understocked (too few trees), or just right. For more on estimating and interpreting stocking information, the reader is referred to UW-Extension Bulletin No. G3362.

You could determine the basal area for your entire woodlot by actually summing the basal areas of each tree - after considerable effort was spent in obtaining the individual DBH measurements. Fortunately there are several ways of estimating basal area per acre without measuring every tree.

To determine basal area per acre, foresters use a special kind of prism or an angle gauge to obtain precise estimates. However, if you are interested only in a rough estimate to help decide if you need to thin your stand or call in a forester, there are other tools. For a gauge, glue a 1-inch wide target to the end of a 33-inch stick, or use a penny held 25 inches from the eye - about arm's length. If you use the stick/gauge combination, place the zero end under your eye and look toward the 1-inch target 33 inches away.

While standing over a single point, hold the gauge and look at each nearby tree as you rotate in a full circle. Don't miss any trees as you turn. Focus on each tree at breast height - 4 1/2 feet above ground. If the stem of any tree is wider than your target - sticks out past the sides of the penny, for example -- count the tree (see drawing). You don't have to measure anything, just count trees. When you've completed a 360-degree circle about the point, multiply the count by 10. The result is one estimate of basal area per acre. You should repeat this several times throughout your woodlot and average the results.

Table 1. Basal Area Per Tree

DBH	SQ. FT.	DBH	SQ. FT.	DBH	SQ. FT.
5	0.14	**12**	0.79	**19**	1.97
6	0.20	**13**	0.92	**20**	2.18
7	0.27	**14**	1.07	**21**	2.41
8	0.35	**15**	1.23	**22**	2.64
9	0.44	**16**	1.40	**23**	2.89
10	0.55	**17**	1.58	**24**	3.14
11	0.66	**18**	1.77	**25**	3.41

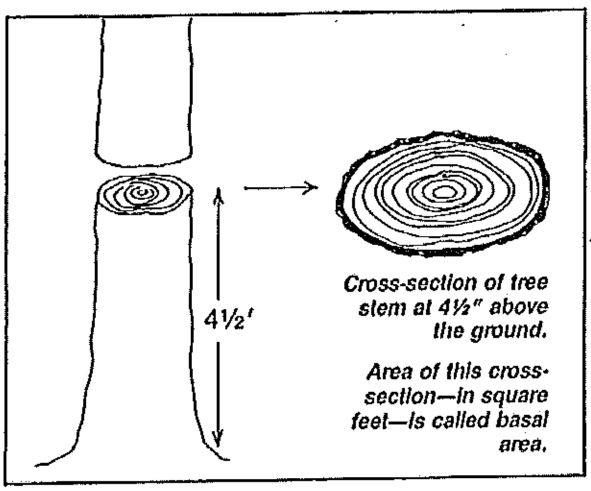

Figure 1....Basal Area Of An Individual Tree

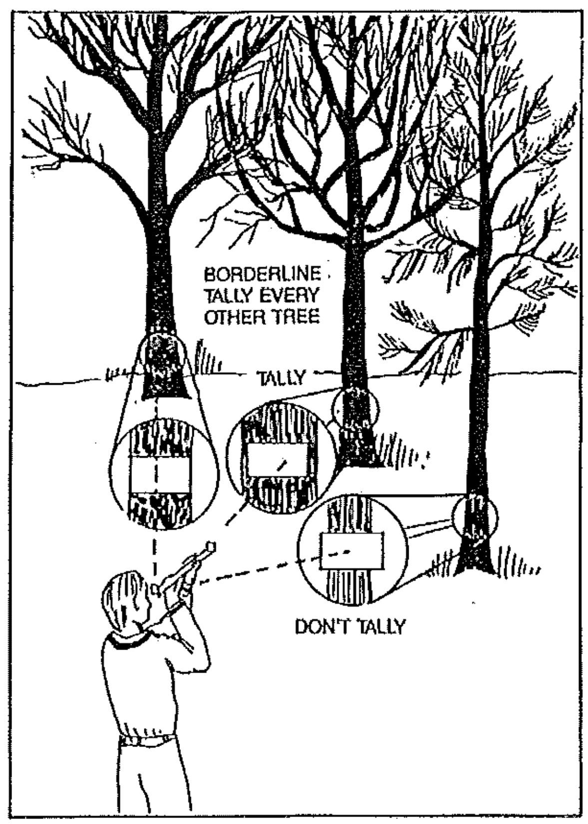

Figure 2....Point Sampling With An Angle Gauge

Master Naturalist
EAST CENTRAL ILLINOIS

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CHAPTER 11

Forest Ecology and Management

Chapter Goals

Goals of the chapter are to describe

- ❒ The major forested regions and types of forests in Illinois
- ❒ The major factors influencing forest composition and structure in Illinois
- ❒ Patterns of succession in Illinois forested ecosystems
- ❒ Forest cycles: nutrients, water, carbon, oxygen
- ❒ Benefits of forests
- ❒ The differences and meanings of preservation and conservation in forest ecology and management
- ❒ Major threats to the health of Illinois forests
- ❒ Ecological goals of forest management
- ❒ The benefits of urban forests and their management

Introduction

Forest ecology is the study of the components and functions of forest ecosystems: communities of organisms interacting with each other and with their physical environment. Forest ecosystems consist of many components including bacteria, fungi, insects and other arthropods, plants, birds, mammals, reptiles, amphibians, climate, soil, water and air. Forest ecosystems differ from others in that they are dominated by trees. Each biological and physical component plays a role in the function and health of a forest.

Forest ecology is not rocket science. In fact, it is much more complicated. Consider the fact that a volume of forest soil about the size of a sugar cube may contain from 6,000 to 10,000 different types of bacteria. Most of these bacteria are virtually unknown to science, detected only by the structure of their DNA extracted from soil and analyzed using techniques of molecular biology. This large number of bacterial types does not include other soil microbes such as fungi, protozoa, algae, and viruses. On top of this, organisms found in the soil component of the forest ecosystem alone include nematodes, earthworms, millipedes, mites, moles, salamanders, and many others. We certainly do not understand all of the interactions among forest organisms and their environments for even a single forest stand, let alone a forest type. But many ecological patterns of forests have been established by science. It is part of human nature to seek patterns, after all, and those patterns of forest structure, function and change that have been determined serve as the basis for protecting and managing forests.

Forest Classification and Regions

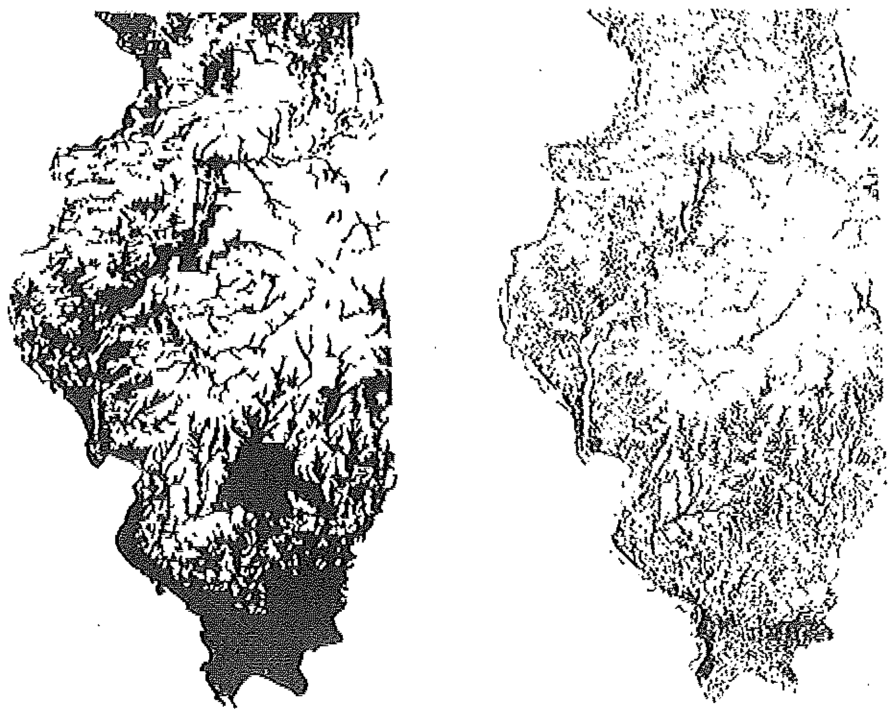
The broadest regional classification recognized by plant geographers and other scientists is a **biome**. A forest biome is a zone where predictable tree, plant and animal communities exist resulting from the effects of climate, soil, the presence or lack of moisture and other physical variables.

In North America, biomes include tundra, boreal forest, **broad-leaved temperate deciduous forest**, desert, prairie, mixed evergreen and deciduous forest, tropical, montane, temperate and tropical rain forest and Mediterranean scrub. The temperate deciduous forest biome of North America occupies most of the eastern part of the United States and a small strip of southern Ontario and Quebec. Temperate deciduous forests comprise 14% of the world's forests and are dominated by broad-leaved deciduous trees.

The retreat of the last major glacial front from central and northern Illinois began 20,000 years before present. The ancestors of our current Illinois broad-leaved deciduous tree species migrated northward from **refugia**, or refuges, in which they sheltered from the harsh, ice age climate. Fossil records suggest that these refuges were in the southern and southeastern part of North America in the lower reaches of river valleys flowing into the Atlantic Ocean and Gulf of Mexico, as well as in coves of the bluffs of the southern reaches of the Mississippi River. Fossils of an extinct species of spruce have been found in the lower Mississippi valley from this time, probably because the river cooled its floodplain area with torrents of glacial melt water in the summers. This likely created a cool, misty environment for the spruces, relegating broadleaved deciduous species of the lower Mississippi River drainage to warmer, sheltered upland areas.

The broad-leaved temperate deciduous trees migrated northward and expanded beyond their refuges as the climate warmed, joining with and separating from a variety of tree associates during their continental migrations. To the north a narrow zone of tundra occurred near the retreating glaciers, and pine and spruce forests covering large areas retreated northward with the warming climate. The migrations were spurred by the warming of the current interglacial period and have culminated today in the widespread, eastern, temperate deciduous forest biome. Precipitation in the temperate deciduous forest biome ranges from 28 inches per year in the northwestern section of the biome to 60 inches in the southeastern part. In most areas the precipitation is evenly distributed throughout the year. Frost occurs throughout this biome and summer and winter are distinct seasons.

Illinois is within both prairie and temperate deciduous forest biomes. At the time of European settlement temperate deciduous forest covered 40% of what is now Illinois, mainly in the south, in areas of rough terrain that glaciers did not impact, and along river systems (Figure 1). Tall grass prairie ecosystems of the prairie biome dominated the rest of the area.



1820 1980

Figure 1. Forests in Illinois, 1820 and 1980

Source: *The Changing Illinois Environment: Critical Trends. Volume 3: Ecological Resources.* Illinois Natural History Survey, 1994.

Because the temperate deciduous forest biome covers such a large geographic area, differences in climate, soils, topography and other factors have led to the recognition of eight major forest regions within the biome. This diversity is often reflected in more detailed classifications at smaller scales called **ecoregions**. Ecoregions are defined by similarities in plant and animal species, climate, soils, and the general topography of the landscape. Ecoregions exist at three levels of definition: domains, divisions, and provinces, from largest to smallest, respectively. A method for naming these forest ecoregions is to list the dominant tree species that characterize these distinct elements of the temperate deciduous forest biome. In Illinois the most widespread major region within the eastern temperate deciduous forest biome is the oak-hickory forest region. Illinois also contains elements of the maple-basswood forest region and the beech-maple forest region.

These regions are not totally uniform in forest composition. Within these regions are smaller areas with unique types of forests, sometimes with affinities to neighboring regions, such as oak-pine forest stands in the Illinois Ozarks, cypress-tupelo swamps of the Cache River bottoms, larch bogs in northeastern Illinois, and white pine-northern hardwood stands of northern and northwestern Illinois. Other important types of forest in Illinois include those of extensive floodplains and wetlands that vary in composition from north to south and with topographic features within the floodplains and wetlands themselves. **Forest associations**, even at the smallest scale, are often named for their dominant tree species.

Another ecological classification system is the **Natural Divisions of Illinois** (Schwegman 1973) which includes 14 bioregions plus Lake Michigan (Figure 2). These fifteen natural divisions of Illinois are defined by both biological and geological characteristics. This classification scheme is based upon geographic regions having similar topography, soils, bedrock, plants, and animals. Natural Divisions are an important classification system for recognizing biological variation across Illinois. Illinois Department of Natural Resources (IDNR) staff members and other professionals have organized regional needs, objectives and strategies in the IDNR Comprehensive Wildlife Conservation Plan, organized around the Natural Divisions of Illinois http://dnr.state.il.us/orc/Wildliferesources/theplan/final/.

Summarized in the next section are distinctive features of Illinois Natural Divisions (Schwegman 1973), including their forest types derived from the IDNR Comprehensive Wildlife Conservation Plan. The physical part of the forest descriptions often includes topographic terms such as upland, floodplain, beach, dune, terrace, flat or slope, often mixed with water regime descriptors, such as **xeric** (dry) upland forest, **mesic** (moist) slope forest, or **hydric** (wet) swamp forest. The forest descriptions also refer to soil features such as acidity (pH below 7.0), texture (i.e. gravel, sand, clay, loam) or temperature (i.e. algific soils that are cold during the summer because they are underlain by ice in rock formations such as fissures). Biotic components of the forest descriptions can include compositional information such as dominant tree species (i.e. cypress-tupelo) and forest structure (i.e. barrens, savanna, open woodland). The same topographic term for a forest might be used in different locales, but in each locale different dominant tree species with different ranges, soil requirements, and climatic tolerances could occur. For example, minor upland forest associations in northern Illinois might include uniquely northern species such as paper birch and eastern white pine, while minor associations occurring in similar topographic and soil situations in southern Illinois upland forests might include black oak and shortleaf pine. Note how different combinations of topographic, moisture, soil, forest structure and dominant tree information are used to describe the forests of each Natural Division.

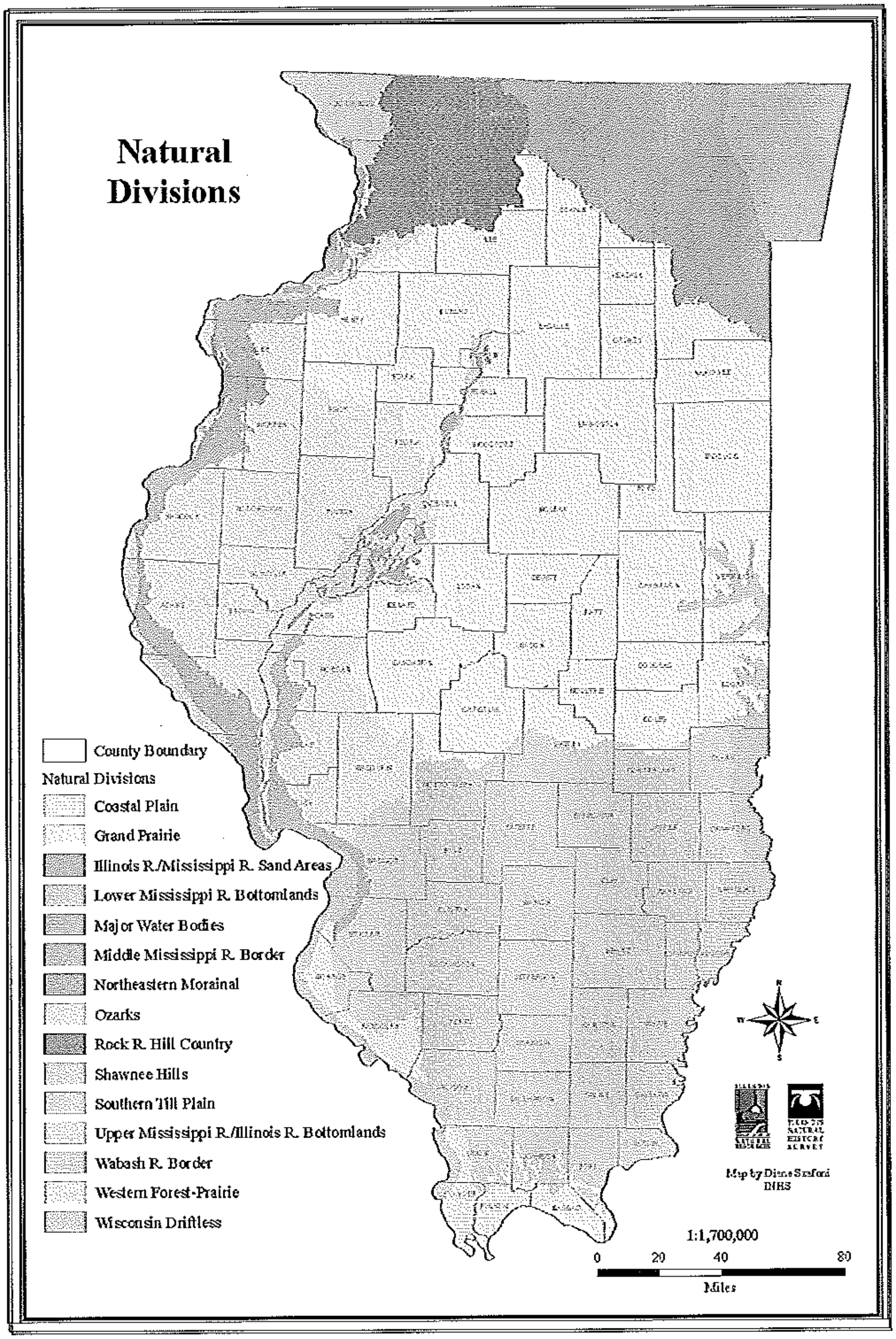

Natural Divisions
County Boundary
Natural Divisions
Coastal Plain
Grand Prairie
Illinois R./Mississippi R. Sand Areas
Lower Mississippi R. Bottomlands
Major Water Bodies
Middle Mississippi R. Border
Northeastern Morainal
Ozarks
Rock R. Hill Country
Shawnee Hills
Southern Till Plain
Upper Mississippi R./Illinois R. Bottomlands
Wabash R. Border
Western Forest-Prairie
Wisconsin Driftless
1:1,700,000
0 20 40 80
Miles

Figure 2

Frequently Used Forestry and Natural Resource Terms for Landowners of Oklahoma

OSU EXTENSION FACTS

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One challenge faced by landowners when trying to make a management decision concerning forest land use is understanding the terminology used in forestry. Without a good working vocabulary, a landowner cannot make well-informed decisions.

Confusion over meanings is often a problem for the forestry professional as well. Misunderstandings often arise concerning what a specific management procedure entails, what is involved in setting up a sale, how timber is measured, or terminology used in prescribed burning, etc. Many of these misunderstandings could be avoided if the landowner and the professional forester used the same terminology.

On the following pages are definitions for terms frequently used in forestry and other natural resource management disciplines (words *italicized* within a definition are defined elsewhere in this glossary). These definitions should help the landowner communicate with public, private, and industrial foresters and other natural resources professionals, with the end result being more informed decision making.

acre: An area of land, 43,560 square feet in any shape; also, the equivalent of a square 209 feet on a side, a circle with a radius of 117.75 feet, approximately 1.5 football fields, 10 square *chains*, 160 square *rods*, or 4,480 square yards.

ad valorem: In property taxation, the tax that is assessed as a percent of the appraised value of the property. It is classified as a management cost when calculating expected returns on a forestry investments.

age class: An interval, commonly 10 or 20 years, into which the age range of trees is divided for classification purposes; for example, trees ranging in age from 21-40 years fall into a 30-year age class.

allowable cut: The maximum volume of wood that can be harvested during a given period, without exceeding the forest's net growth during that period.

area-sensitive species: A species of animal that requires a large area of continuous, non-fragmented habitat of a similar successional stage.

aspect: The direction towards which a *slope* faces. Aspect is important in hilly or mountainous terrain and affects site quality and species composition. The southerly and westerly facing aspects are generally drier and less productive than the northern and eastern facing aspects.

backfire: Any *prescribed burn* against the wind for the purpose of reducing fuels, creating a blackline buffer, etc. See OSU Extension Circular E-927, *Using Prescribed Fire in Oklahoma.*

basal area: Cross sectional area of a tree, in square feet, measured at breast height, 4.5 feet above the ground. Used as a method of measuring the volume of timber in a given stand, or the relative density of a stand.

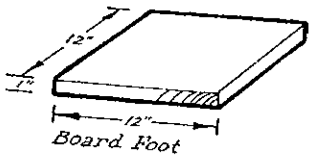
bedding: A raised mound on which *seedlings* are planted. A site preparation method used in the southeastern United States where surface drainage is poor. Bedding can be controversial when used in *wetlands* where section 404 of the Clean Water Act might be violated.

best management practices (BMPs): Techniques recommended in the management of timber harvesting and road construction that result in minimal impact on streams, soils, water quality, and wildlife. Examples are leaving *streamside management zones,* and installing *waterbars, broad-based dips,* etc. See OSU Forestry Extension Report #5, *Best Management Practices for Forest Road Construction and Harvesting Operations in Oklahoma.*

biodiversity: The variety of living organisms. Biodiversity is generally recognized as occurring on 3 levels: species, community, and landscape diversity. The term should not be confused with total number of species.

blue-stain: Discoloration in the sapwood of pine. Causes discoloration in the production of paper. At one time this was thought to be a serious defect in lumber; now it is used as high-quality interior finish.

board foot: A unit for measuring wood volumes equaling 144 cubic inches, commonly used to measure and express the amount of wood in a tree, sawlog, or individual piece of lumber. For example, a piece of wood 1 foot by 1 foot by 1 inch or a piece measuring 1 foot by 2 inches by six inches both contain 1 board foot of wood.



bole: The main trunk of a tree.

bolt: A short piece of *pulpwood*, usually from 2 to 8 feet long.

broad-based dip: A surface drainage structure specifically designed to drain water from a road while vehicles maintain normal travel speed. See OSU Forestry Extension Report #5, *Best Management Practices for Forest Road Construction and Harvesting Operations in Oklahoma.*

browse: Buds, shoots, twigs, and leaves of woody growth that are fed upon by livestock and wild animals.

buck: To cut a *log* into specified lengths.

butt: The base of a tree or *log*.

cant: A *log* that is squared on two or more sides.

capital gains: Profit on the sale of an asset such as timber, land, or other property held for 1 year or longer. Capital gains taxation rate (capped at 28 percent) is advantageous over taxation at ordinary income rates, which can be as high as 39.6 (as of the date of this publication.)

catface: A wound on a tree or *log,* usually caused by sideswiping by equipment or by wildfire.

chain: A unit for measuring distance. A chain is 66 feet in length. An *acre* contains an area equal to 10 square chains. A section of land is 80 by 80 chains square or 640 acres.

chaining: A method of removing brush from a site by dragging a chain between two tractors.

chip-n-saw: 1) A process that makes small *logs* into *cants,* converting part of the outside of the log into chips. Cants are then sawed into lumber; 2) small pine logs 7 to 10 inches in *d.b.h.* to a 5-inch top.

clearcutting: A harvest and regeneration technique which removes all the trees (typically down to 4 inches in *d.b.h.*) on an area in one operation. Clearcutting is commonly used with *shade-intolerant* species like loblolly and shortleaf pine, which require full sunlight to reproduce and grow well. Clearcutting produces an *even-aged* stand. See OSU Extension Facts #5028, *Even- and Uneven-Aged Forest Management.*

clinometer: A hand instrument used in measuring the heights of trees and percent *slope.*

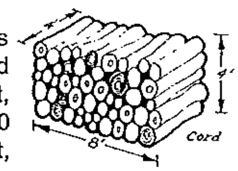
codominant: Describes trees with medium-sized crowns forming the general level of the canopy cover. Tree canopies receive full light from above but are crowded on the sides and thus receive comparatively little light from the sides.

competition: The struggle among adjacent trees for growth requirements such as sunlight, nutrients, water, and growing space. Competition goes on among both the roots and crowns of trees in the same stand.

controlled burning: See *prescribed burning.*

coppice: A regeneration method in which the forest stand regenerates primarily from stump and root sprouts after *clearcutting.*

cord: A stack of wood that has a gross volume of 128 cubic feet. A standard cord measures 4 feet by 4 feet by 8 feet, and should contain approximately 80 cubic feet of solid wood. Also, by weight, a cord of pine is 5200-5350 pounds; a cord of hardwoods is 5600-5800 pounds.



corridors: Travel routes that allow animals to migrate between areas of similar successional stage, for example, a *streamside management zone.* Corridors provide cover during movement, thus minimizing predation, and ensuring gene exchange between populations.

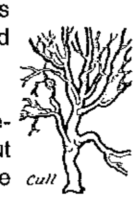
cost share: A subsidization, by different governmental agencies and some private industries, of *site preparation,* reforestation, *timber stand improvement,* wildlife and fisheries management, and water quality expenses. Some federal programs are the Forestry Incentives Program (FIP), the Conservation Reserve Program (CRP), and the Stewardship Incentive Program (SIP).

crook: An abrupt bend in a tree or *log*; a defect.

crop tree: A tree identified to be grown to maturity for the final harvest cut. Usually selected on the basis of its species, its location relative to other trees, and its quality.

cruise: An inventory of forestland that includes the location, volume, species, size, age and quality of timber.

cull: A tree or log that is unmerchantable because of defects; a tree or log that is picked out for rejection or relegated to another use because it does not meet certain specifications.



cutover: Land that has previously been logged.

cutting unit: An area of timber designated for harvest.

deck: A location where *logs, pulpwood,* or chips are loaded for transport from the woods.

defect: *Crook,* conk, decay, split, *sweep,* or other injury that decreases the amount of usable wood that can be obtained from a *log* or tree.

den tree: A tree that provides shelter and protection for wildlife. These trees often have cavities adequate for concealment or nesting.

diameter breast height (d.b.h.): The diameter of a tree at 4.5 feet above ground level on the high side of the tree.

diameter limit cut: A harvest where all *merchantable* trees above a specified *d.b.h.* or stump diameter are removed. This type of harvest often results in *high grading* where only poorly formed and *cull* trees are left in the stand.

diameter tape (D-tape): A tape measure specially graduated so the diameter may be read when the tape is placed around a tree stem or *log*. One inch on a diameter tape equals 3.14 inches on a standard tape.

dibble; planting bar: A long-handled, tapered spade used to make a narrow, relatively deep slit, suitable for planting seedlings.

direct seeding: Spreading seeds over the forest seedbed, usually from the air, to supplement or replace natural seed fall.

discount rate: The minimum annual *rate of return* that is acceptable for investment.

dominant trees: The tallest, most vigorous trees in a forest stand; larger-than-average trees with well developed crowns, which receive sun exposure on all sides.

Doyle log rule: A *log rule* used in the Eastern and Southern United States. It underestimates the volume of small *logs* and overestimates large *logs*.

ecology: The study of plants and animals in relation to their physical and biological surroundings.

ecosystem management: An approach to *forest management* that seeks to include economic, ecologic, and social components.

edge: The boundary where two or more different types of vegetation or successional stages meet. Edges attract many different wildlife species because a variety of food, cover, and other habitat requirements are arranged close together. Edge can be detrimental to some *area-sensitive species*.

even-aged stand: A stand of trees in which there are only small differences in age, usually within 20 percent of *rotation* age. See OSU Extension Facts #5028, *Even- and Uneven-Aged Forest Management.*

feller-buncher: A timber harvesting machine that severs the tree, holds it upright in a collector arm, then lays it down in a pile with other felled trees for transport.

financial maturity: The point in time in which the growth or increase in value of a financial asset (such as a tree) falls below the *discount rate*.

financial rotation: The *rotation* length of tree crops determined solely by financial considerations in order to obtain the highest monetary return over time.

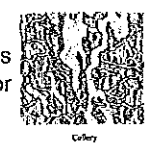
fire-adapted: A plant species or plant community that is adapted to and maintained by periodic fires. For example, shortleaf pine saplings will sprout from the root collar if injured by fire, whereas loblolly pine saplings are killed.

firebreak: Any natural or constructed barrier utilized to segregate, stop, and control the spread of fire or provide a control line from which to work.

forest fragmentation: "Islands" of forest habitat that are disconnected from other forests by agricultural lands, transmission lines, roads, developments, etc. This phenomenon is thought to be particularly detrimental to *area-sensitive species* of animals that need large expanses of uninterrupted forests for foraging, breeding, nesting, etc.

forest management: The practical application of scientific, economic, and social principles to the administration and management of a forest to accomplish specified objectives.

forest type: A class of forest defined by the vegetation growing on the site; also defined as the actual or potential capabilities of forest or forestland. Examples in Oklahoma include the oak-hickory type, cross-timbers (post oak and blackjack oak) type, and shortleaf pine type.



gallery: A passage or burrow that bark beetles have excavated in the cambium of a tree for feeding or egg-laying purposes.

girdle: To encircle a tree with an ax or saw cut to sever the bark and cambium layer and kill the tree.

grading: Evaluating and sorting trees, *logs*, or lumber according to quality and intended use.

group selection: A method of regenerating *uneven-aged* stands in which trees are removed and new *age classes* are established in small groups. The maximum width of an opening in a group selection cut can vary depending on *shade tolerance* of the species but is approximately twice the height of mature trees in the stand. See OSU Extension Facts #5028, *Even- and Uneven-Aged Forest Management.*

growing stock: All live trees in a forest or stand, including *sawtimber, pulpwood, saplings,* and *seedlings,* that continue to put on growth.

head fire: A fire spreading, or set to spread, with the wind. See OSU Extension Circular E-927, *Using Prescribed Fire in Oklahoma.*

heavy fuels: Fuels of large diameter, such as logging slash, downed logs, and large branchwood, that ignite and burn more slowly than flash (fine) fuels. See OSU Extension Circular E-927, *Using Prescribed Fire in Oklahoma.*

herbicide: Any chemical preparation used to kill or inhibit the growth of certain plants.

high grading: The practice of harvesting only the biggest and best trees from a stand and leaving only the poorest to dominate the site.

horizon: Any layer of soil that can be distinguished from adjacent layers by physical, chemical, or biological characteristics, for example, color or soil structure.

hunting lease: A legally binding agreement in which a landowner leases specific hunting rights to an individual or a group. The rights should be stated in contract form and usually give the individual(s) access to the land area during a specified time period to harvest designated game species within legal bag limits. See OSU Extension Facts #5032, *Lease Hunting Opportunities for Oklahoma Landowners.*

increment borer: A hollow, auger-like instrument used to bore into the tree trunk (at *d.b.h.*) to remove a cylindrical cross section (core sample) of wood. It is used to determine growth rates and age.

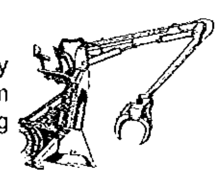
injection: The single stem killing of unwanted trees by application of specific registered *herbicides* under the bark. The removal of undesirable trees improves the site by reducing competition for light, moisture, and nutrients.

intensive forest management: Utilization of a wide variety of silvicultural practices, such as planting, *thinning*, fertilization, release, harvesting, and genetic improvement, to increase the capability of the forest to produce fiber.

intermediate trees: A class of trees in a stand with small, crowded crowns below (but extending into) the general canopy level. These trees receive a little sunlight from above and none from the sides and are often slow-growing.

International log rule: A method of estimating tree volume through a *log rule* that assumes taper and which is generally considered the most accurate log rule in the southeast.

J-Root: An improperly planted seedling that takes a J-shaped configuration in the planting hole. Such seedlings often die prematurely, grow poorly, or are susceptible to windthrow.



knuckleboom loader: A hydraulically operated machine with a loading boom that has a mechanical action imitating the human arm.

logging costs: The total costs of felling, *bucking, skidding*, loading, and hauling associated with harvesting forest products.

log rule: A table intended to show the amounts of lumber that can be sawed from *logs* of different sizes under various assumed conditions. See OSU Extension Facts #5021, *Measuring Woodland Timber.*

longwood: Stemwood delivered to the mill in lengths of 10 feet or longer.

lump-sum sale: The sale of specified timber on a specified area for a sum of money that is usually agreed upon and payable in advance. See OSU Extension Facts #5035, *Selling Your Timber.*

log: A merchantable stem of wood, usually cut to a length of 8, 10, 12, 14, or 16 feet with a minimum small-end diameter inside bark (d.i.b.) of 8 inches for hardwood, 6 inches for pine. See OSU Extension Facts #5021, *Measuring Woodland Timber.*

lop: To chop or saw branches, tops, or small trees after felling. These pieces, or debris, are usually left on the ground to decompose.

mast: (hard) The fruit of trees such as oak, beech, hickory, and also the seeds of pines which are considered as food for different kinds of wildlife such as squirrels, turkey, and deer; (soft) the berries of such plants as serviceberry, dogwood, plums, farkleberry, blackberry, raspberry, etc., also considered as wildlife foods.

mature timber (maturity): The stage at which a tree or other plant has attained full development, particularly height, and is in full seed production; the stage at which a tree crop or stand best fulfills the main purpose for which it was maintained, e.g. produces the best possible supply of specified products or will no longer earn a specified rate of return in the future.

MBF (thousand board feet): A unit of measure for tree volume or sawed lumber; log rules (*Doyle, Scribner, International 1/4*) should always be specified.

merchantable: The part of a tree that can be manufactured into a saleable product.

multiple use: Land management for more than one purpose, such as wood production, water conservation, wildlife conservation, recreation, forage production, aesthetics, or clean air.

nonindustrial private forest land (NIPF): Forestland owned by a private individual, group, or corporation not involved in wood processing.

natural regeneration: The renewal of a forest or stand either by natural seeding or vegetative reproduction (stump or root sprouts) by trees on the site.

net present value: A comparison of cost and revenues that have been discounted back to the present time, thus rendering revenue directly comparable in time to costs. All discounted costs are summed and subtracted from discounted revenues.

opportunity cost: The value of the best alternative (usually expressed as an interest rate) forgone by devoting resources to a particular project.

over mature: The stage of the life cycle of a tree or stand characterized by a decline in vigor, health, or growth rate.

peeler log: A log considered suitable in size and quality for producing *veneer* for plywood.

plantation: A forest established by planting. It is usually made up of a single species.

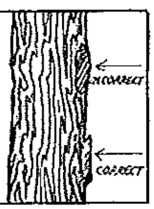
poles/pylon: Any considerable length of round timber of saw-log size with the straightness and taper suitable for supporting transmission lines or for supporting piers.

poletimber stand: A stand of trees whose diameters range from approximately 5 to 9 inches.

precommercial thinning: The elimination of trees in a submerchantable-size stand (trees too small to be sold for forest products) to increase the growth rate of residual trees.

prescribed burning: The controlled use of fire to achieve *forest management* objectives. Prescribed fire can be used to prepare seed beds for natural pine regeneration, reduce hazardous fuel levels, control unwanted vegetation, improve visibility, and improve wildlife habitat. See OSU Extension Circular E-927, *Using Prescribed Fire in Oklahoma.*

pruning: Removing live or dead branches from standing trees to improve wood quality.



pulpwood: Wood to be converted into pulp for the manufacture of paper, fiberboard, or other wood-fiber products. Pulpwood-size trees are usually 4 to 9 inches in *d.b.h.* or are too poorly formed to make lumber.

regeneration cutting: A harvesting technique that provides for tree/forest reproduction, such as *clearcutting, seed-tree, shelterwood, and selection cutting* methods.

rate of return (ROR): The compound rate that invested funds increase in value.

residual stand: The part of a stand of growing stock retained after an intermediate cutting, such as *thinning*, or a partial cutting.

rod: A linear measure of 5.5 yards or 16.5 feet.

rotation: The planned number of years between the regeneration of a stand and its final cutting at a specified stage of maturity. The length of a rotation varies by species, environmental conditions, and market forces. See OSU Extension Facts #5028, *Even- and Uneven-Aged Forest Management.*

sanitation/salvage cut: A cultural procedure where dead, damaged, or susceptible trees are removed to prevent the spread of pests or pathogens and to promote forest health.

sapling: A small tree, usually 0.6 - 3.5 inches in *d.b.h.*

sawtimber: Those trees fit to yield saw logs, which are of suitable size and quality for producing lumber cut by a saw to any dimension; usually 10 inches in *d.b.h.* or larger for pine, 12 inches for hardwood. See OSU Extension Facts #5021, *Measuring Woodland Timber.*

scarify: To disturb the forest floor and topsoil in preparation for *natural regeneration, direct seeding,* or planting.

Scribner log rule: A method of estimating tree volume that makes liberal allowances for slabs and disregards taper.

seed-tree harvest: Removing nearly all trees from the harvest area at one time, but leaving a few scattered trees to provide seed for a new forest stand. Usually, 6 to 12 trees per acre that are 14 inches or greater in *d.b.h.* are retained. These are removed later, after sufficient regeneration is established. See OSU Extension Facts #5028, *Even- and Uneven-Aged Forest Management.*

shade intolerant: A tree relatively incapable of developing and growing normally in the shade of, and in competition with, other trees.

shade tolerant: A tree's capacity to develop and grow in the shade of, and in competition with, other trees. Examples of highly shade tolerant species are flowering dogwood and American beech.

shelterbelt: A strip of living trees and/or shrubs maintained mainly to provide shelter from wind, sun, and snow.

shelterwood cut: *Regeneration cutting* method carried out over 2 or more operations, designed to establish a new crop of seedlings under the protection of the old trees (generally, 30 to 50 mature, seed-bearing trees per acre are left after the first cut). Harvests are usually 5 to 10 years apart, resulting in an *even-aged* stand. See OSU Extension Facts #5028, *Even- and Uneven-Aged Forest Management.*

silviculture: The art, science, and practice of establishing, tending, and reproducing forest stands with desired characteristics, based on knowledge of species characteristics and environmental requirements.

single-tree selection: An *uneven-aged* reproduction cutting method in which the trees are selected from all *d.b.h.* classes for harvest or retention based on individual tree merits. See OSU Extension Facts #5028, *Even- and Uneven-Aged Forest Management.*

site index: A relative measure of productivity of a given site to grow a particular species. Site Index is based on the height of the dominant trees of a particular species at either 25 or 50 years of age.

site preparation: Any process that reduces competing vegetation or logging debris to make it easier to plant or to improve conditions favorable for seedling growth and survival. The major kinds of site preparations include: mechanical, chemical (*herbicides*), and burning to kill competing vegetation.

skidding: The transportation of trees or parts of trees by trailing or dragging from stump to landing by log skidder or horses.

slope: A measure of steepness, or the degree of deviation of a surface from the horizontal, measured as a numerical ratio, percent, or in degrees.

snag: Any dead, dying, or *den tree* suitable as a nest or roost site for a cavity nesting animal. Most birds prefer snags that are at least 10 inches in *d.b.h.*, and the larger, the better.

soil series: The basic unit of soil classification, consisting of soils that are alike in all major profile characteristics except texture of the surface layer.

species evenness: An index of the number of individuals of a species in a given area.

species richness: An index of the total number of species in an area.

stocking: A subjective estimation of the number of trees occupying the site as compared to the desired number (i.e., overstocked or understocked).

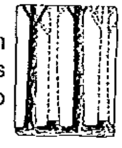
streamside management zone (SMZ): A strip of land of varying size and shape maintained for protecting a sensitive area such as a stream. See OSU Extension Facts #5034, *Riparian Forest Buffers.*

stumpage: The monetary value of a tree or group of trees as they stand in the woods uncut (on the stump). Often, this value is paid by a mill to a landowner or logger as a delivered log price less logging and transportation costs. See OSU Extension Facts #5035, *Selling Your Timber.*

succession: The change in species composition and structural arrangement over time. For example, an abandoned farm in a temperate climate, if left undisturbed by fire, man, or catastrophic weather events, would gradually go through different stages of vegetative cover and become a mature forest over time.

suppressed trees: One of the 4 major crown classes; specifically, trees with crowns entirely below the general level of the crown cover receiving no direct light either from above or from the sides; also known as overtopped.

sweep: Curve in a stem or *log* as distinct from an abrupt bend as defined by a *crook*. It is generally a response to environmental conditions (strong winds) rather than genetics.



thinning: Generally, a partial harvest in an immature stand to reduce the number of trees per *acre* and encourage the remaining trees to grow faster and produce higher quality wood.

timber marking: The selection and identification, usually with paint, of those trees to be harvested or retained.

timber stand improvement (TSI): Applying cultural practices, such as *precommercial thinning* or *prescribed fire*, that improve the quality of a forest stand and achieve the desired stocking and species composition.

tree length: The entire tree, excluding the unmerchantable top and limbs. Highly mechanized logging crews often *skid*, load, and transport to mill in tree length form.

uneven-aged stand: A stand composed of 3 or more age classes. See OSU Extension Facts #5028, *Even- and Uneven-Aged Forest Management.*

veneer log: A *log* of high quality and desirable species suitable for conversion to veneer. Logs must be large, straight, of minimum taper, and free from defects.

volume table: A table showing, for one or more species, the volume contents of trees or logs based on *d.b.h.* and *merchantable height.*

water bar: A diversion ditch or hump in a trail or road for the purpose of diverting surface water runoff into roadside vegetation, duff, ditch, or dispersion area to minimize soil movement and erosion. See OSU Forestry Extension Report #5, *Best Management Practices for Forest Road Construction and Harvesting Operations in Oklahoma.*

watershed: The total land area draining into a given stream river, lake, or reservoir; also known as a catchment area.

wetlands: Areas that are flooded or saturated by surface or ground water at a frequency and duration sufficient to support vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas. See OSU Extension Facts #5034, *Riparian Forest Buffers.*

wildlife habitat: An area where animals live, naturally or otherwise, with relation to all the environmental influences affecting it. There are five major components: food, water, cover, space, and arrangements.

windbreak: A small-scale *shelterbelt* or other barrier, natural or artificial, maintained to deflect the wind.

windfall: A tree or trees blown down by the wind; also known as windthrow.

wolf tree: A tree of poor growth form (often a single tree growing in the middle of a field). It may have wildlife and aesthetic value.

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Department of Forest Ecology and Management • School of Natural Resources

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Forest Succession

Jeff Martin and Tom Gower

Succession is the natural replacement of plant or animal species, or species associations, in an area over time. When we discuss forest succession, we are usually talking about replacement of tree species or tree associations.

Each stage of succession creates the conditions for the next stage. Temporary plant communities are replaced by more stable communities until a sort of equilibrium is reached between the plants and the environment. The following sequence is usually observed if sufficient time passes and no disturbance occurs:

Plant Community	Description
Grass-forb:	Forbs, grasses and shrubs dominate the site. Seedlings may be present.
Shrub-seedling:	Trees tend to share and then begin to dominate the site. The intolerant species (see Forestry Fact No. 79, Tolerance of Tree Species) grow rapidly and dominate over tolerant species.
Sapling-pole:	Trees eventually overtop and out-compete the forbs and shrubs. The intolerant trees continue rapid height growth while the tolerant trees occupy their respective niche.
Young:	Growth is still rapid. Tree-to-tree competition may be severe resulting in competition caused mortality. Any intolerant individuals that drop behind may die and their growing space may be occupied by tolerant trees.
Mature:	Competition caused mortality continues. Both intolerant and tolerant trees may share the main canopy. In mixed conifer stands there may be a distinct layering of intolerants and tolerants.
Climax:	A relatively stable plant community which has a dominant plant population suited to the environment. Tolerant species dominate the site and the climax species will reproduce successfully under their own shade. These species will maintain the community under the current climatic conditions. Intolerant trees cannot reproduce.

Disturbance

The rate of natural succession is affected whenever a disturbance such as fire, a windstorm, pests or management activities occurs on the site. The more severe the disturbance, or the more often disturbances occur, the slower will be the natural process of succession.

Following a major disturbance, **pioneer species**, such as aspen or jack pine, will become established in open areas under full sunlight. Eventually, in the absence of further disturbance, these pioneer species will be replaced by **seral species** that will occupy the site through a series of successional stages, leading ultimately to a plant community comprised of **climax** species.

Forest successional stages are closely tied to the tolerance of various tree species (see Forestry Fact No. 79, Tolerance of Tree Species, for more information). For example, very tolerant species such as sugar maple, beech and hemlock are climax species on many sites in Wisconsin where they are capable of normal growth. However, sugar maple does not typically grow on dry, sandy soils

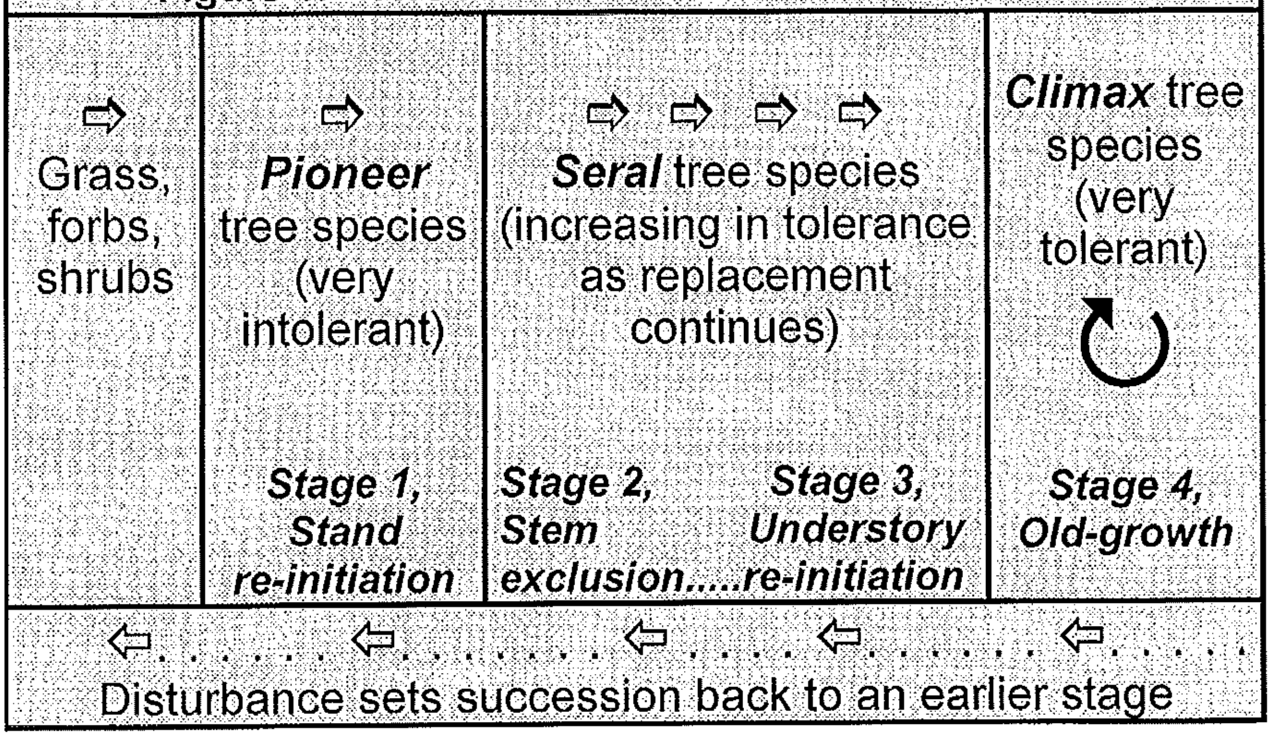


Figure 1. *The Process of Forest Succession*

and therefore cannot replace jack or red pine on such sites.

Other Stand Changes

In addition to the well-studied changes in species composition during succession, there are other changes, in the structure and function of the stand, that are also taking place. Although the changes are subtle and continuous, ecologists have developed relatively simple stand development classification systems to classify forests according to their stage of succession. Figure 1 illustrates the four basic stages of stand development recognized for even-aged forests, and shows how they relate to the typical forest plant communities.

Stand re-initiation denotes the beginning of succession. Woody and foliage biomass steadily increase during this stage. Another important characteristic of this stage is that resources that influence tree growth (e.g. light, water and nutrients) are abundant relative to the other stages of stand development.

The second stage, **stem exclusion**, marks the onset of intense inter- and intraspecies competition for limiting resources, resulting in mortality or self-thinning. Foliage mass reaches a maximum near the onset of this second stage - this is noteworthy because foliage is the tissue that carries on photosynthesis and is the primary tissue regulating the growth of the forests. Foliage mass remains relatively stable or decreases by 10-30% in the older stages of stand development and this decline may be responsible for decreased forest growth in older forests (see the next section).

The third stage, **understory re-initiation**, is characterized by renewed growth of the understory in response to gaps in the canopy caused by tree mortality.

The fourth stage is referred to as **old-growth**; managed forests seldom reach this stage because the growth of these forests is often 10-70% less than young forests in the stand re-initiation or stem exclusion stages.

Succession and Nutrition

Foresters and ecologists have long-known that the growth of forests decreases as they age; however, the causes for the age-related decline have remained a mystery until recently. What is emerging is an interesting story that suggests the decline in forest growth, and other age-related functional changes, are because of the changes in stand structure.

Most notable is the dramatic changes in the nutrient cycles of forests during succession because of the changes in litter quality. Except for forests growing in heavily polluted areas, forests derive the bulk of their annual requirement of nutrients from minerals released from decomposing leaves, branches, stems and roots.

During the early stages of succession a high proportion of the litter is comprised of leaf tissue which, compared to branches and stems, is more easily decomposed by decomposers because of its greater nutrient concentration. In the later stages of succession however, the annual production of tissue falling to the forest floor is comprised of more woody tissue (e.g. branches and stems resulting from the self-thinning stage). Woody tissue decomposes slower than foliage by a factor of 10 to 100, resulting in nutrients being sequestered (locked up) for decades in the branches, twigs and stems.

Numerous studies have shown that nitrogen may limit growth in mature conifer forests while several recent studies suggest that calcium and potassium may limit growth of mature northern hardwood forests. The steady decline in nutrient availability during succession adversely affects leaf photosynthetic rates and causes trees to grow more fine roots and less foliage and stem wood.

A second possible cause for the decline in tree growth during succession is related to greater constraints of transporting water to the top of the tree and end of the long branches in mature trees. Just as it is more difficult to suck water through a long versus short straw, trees have a more difficult time providing water to the very tops of the canopy of mature trees. To compensate for the inefficient plumbing, large trees have a more conservative water balance. If water transport up the stem cannot keep pace with water loss from the canopy (this process is called transpiration) the tree suffers irreparable water stress. Therefore, to avoid permanent damage mature trees restrict the opening of the pores on leaves (stomata) where carbon dioxide is absorbed into the leaf for photosynthesis, and water is lost from the leaf to the atmosphere.

In summary, it seems likely that nutrient and water transport constraints may be responsible for the decline in tree growth during succession and both of the constraints are directly or indirectly related to changes in the structure of the forest during succession.

Impact on Forest Management

Understanding forest succession is very important when we make forest management prescriptions. On some sites it is often easier to work with the natural progression and maintain one of the late successional stages than it is to maintain an early stage.

When harvests are prescribed, heavier cuts cause, in general, greater disturbance to the natural succession process than do light selection cuts. Therefore, if you are hoping to regenerate certain species naturally following a harvest, it is important to know what successional stage these species typically occupy; and, what type of harvest will generate the desired conditions for stand establishment.

What can woodland owners do to minimize the decline in forest growth in aging stands? The most obvious solution is to reduce the rotation length of the forest. Another option might be to fertilize the forest to prevent a nutrient limitation; however, this approach is not inexpensive and in many cases would not be cost-effective. Finally, landowners can minimize the reduction in growth by managing forests such as northern hardwoods (sugar maple, yellow birch, basswood and hemlock) on an uneven-aged basis. Uneven-aged management, while not appropriate for all species, does maintain a balance of healthy, vigorous trees and a smaller number of mature trees.

NUMBER 4

Forest Stewardship

Terminology

Stewardship draws on various disciplines—including ecology, forestry, wildlife biology, and even recreation. Some of the terms used in discussions of forest stewardship may be unfamiliar to you. The following descriptions will help you better understand forest stewardship practices and aid in communications between you and natural resource managers. As you work with resource professionals in managing your land, you will gain a deeper understanding and appreciation of the forest resource and its complexity.

Aesthetics—forest value, rooted in beauty and visual appreciation, affording inspiration, contributing to the arts, and providing a special quality of life.

Afforestation—the establishment of forest trees by planting or seeding an area not previously forested.

Agroforestry—a cultivation system combining agriculture and forestry where trees and crops are interplanted; not common to Pennsylvania.

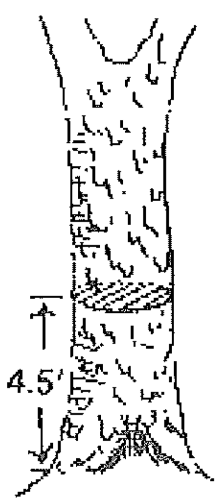
Allegheny hardwood type—a portion of the northern hardwood forest in Pennsylvania, of which black cherry, white ash, and tulip poplar are major components.

Area sensitive species—plants or animals with very specific habitat requirements that are susceptible to population decline when their habitat is altered.

Aspect—the orientation of a slope with respect to the compass; the direction toward which a slope faces; north facing slopes are generally cooler than south facing slopes.

Basal area—a measurement of the cross-sectional area of a tree trunk in square feet at breast height. Basal area (BA) of a forest stand is the sum of the basal areas of the individual trees, and is reported as BA per acre.

Basal area



Biological diversity—the variety of plants and animals, the communities they form, and the ecological functions they perform at the genetic, stand, landscape, and regional levels.

Biological maturity—the point in the life cycle of a tree at which there is no net biomass accumulation; the stage before decline when annual growth is offset by breakage and decay.

Biological simplification—the reduction of biological diversity that results from altering the environment in ways that favor, either directly (i.e., through management) or indirectly (i.e., through pollution), certain species over many others.

Biomass—the total weight of all organisms in a particular population, sample, or area; biomass production may be used as an expression of site quality.

Biome—the largest ecological unit, distinguished by an extensive complex of terrestrial communities, corresponding to a particular climatic zone or region, and associated with an environmental region such as the northern coniferous forest, the Great Plains, the tundra, or as in Pennsylvania, the eastern temperate hardwood biome.

Board foot—a unit of wood 1 inch thick, 12 inches long, and 12 inches wide. One board foot contains 144 cubic inches of wood.

Bole— the main trunk of a tree.

Browse—portions of woody plants including twigs, shoots, and leaves used as food by such animals as deer.

Buffer strips—forestland left relatively undisturbed to lessen visual or environmental impacts of timber harvesting, usually along a road or waterway.

Canopy—the upper level of a forest, consisting of branches and leaves of taller trees. A canopy is complete (or has 100 percent cover) if the ground is completely hidden when viewed from above the trees.

Carrying capacity—the maximum amount of animal or plant life that a particular forest environment can support indefinitely without ecosystem degradation, given the limitations of food, shelter, competition, predation, and other available resources; usually expressed in terms of an individual species.

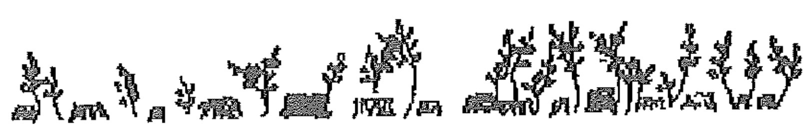
Clearcutting—a harvesting and regeneration technique that removes all the trees, regardless of size, on an area in one operation. Clearcutting is most often used with species like aspen or black cherry, which require full sunlight to reproduce and grow well, or to create specific habitat for certain wildlife species. Clearcutting produces an even-aged forest stand.

Commercial forestland—see *timberland.*

Community—a collection of living organisms in a defined area that function together in an organized system through which energy, nutrients, and water cycle.

Conservation—the wise use and management of natural resources.

Consumptive activities—forest uses which involve the removal of something from the site (hunting, fishing, timber harvesting). Non-consumptive activities include hiking, bird watching, and nature study.



Clearcutting

Corridor—a strip of wildlife habitat, unique from the landscape on either side of it, that links one isolated ecosystem "island" (e.g., forest fragment) to another. Corridors allow certain species access to isolated habitat areas, which consequently contributes to the genetic health of the populations involved.

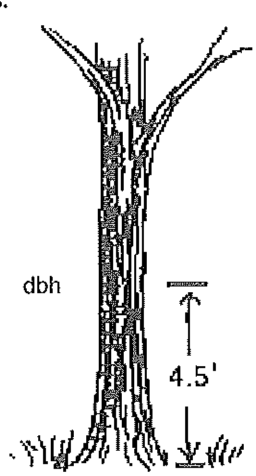
Covert—a geographic unit of cover for wildlife (usually game); for example, a thicket or underbrush sheltering grouse or deer.

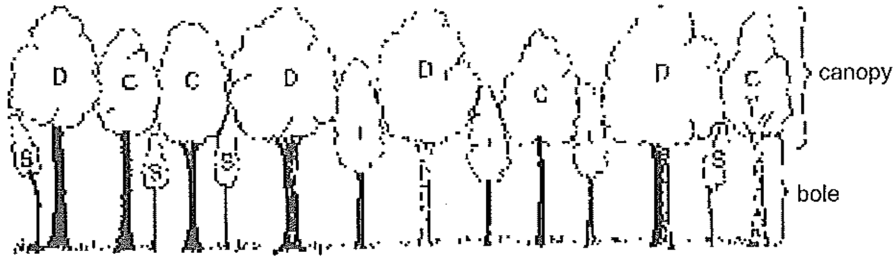
Crop tree—a term traditionally reserved to describe a tree of a commercially desirable species, with the potential to grow straight, tall, and vigorously. However, a crop tree can be one selected for nontimber purposes (varying with landowner objectives), such as mast production or den tree potential.

Crown class—an evaluation of an individual tree's crown in relation to its position in the canopy and the amount of full sunlight it receives. The four recognized categories are: dominant (D), codominant (C), intermediate (I), and overtopped or suppressed (S). (See figure above.)

Cull—a tree of such poor quality that it has no merchantable value in terms of the product being cut. However, a timber cull tree may have value for wildlife or aesthetics.

dbh—diameter at breast height, or 4.5 feet above ground level. The abbreviation generally is written without capital letters and without periods.





Crown classes

Deforestation—the unintentional or intentional conversion of land use from forest to nonforest. Associated with nonrenewable timber harvesting practices in ecologically sensitive areas, such as tropical rainforests.

Den tree—a tree with cavities in which birds, mammals, or insects such as bees may nest (also known as cavity tree).

Diameter-limit cut—a timber harvesting treatment in which all trees over a specified diameter may be cut. Diameter-limit cuts often result in high-grading.

Disturbance—a natural or human-induced environmental change that alters one or more of the floral, faunal, and microbial communities within an ecosystem. Timber harvesting is the most common human disturbance. Windstorms and fire are examples of natural disturbance.

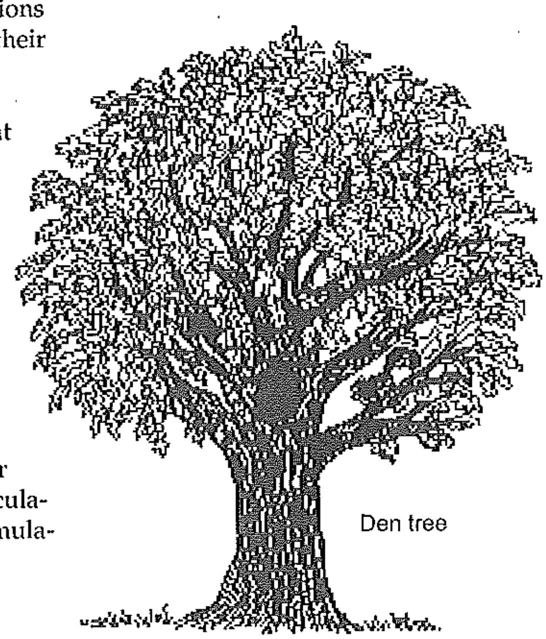
Ecology—the study of interactions between living organisms and their environment.

Economic maturity—the point in the life cycle of a tree or stand when harvesting can be be most profitable, i.e., when the rate of value increase of an individual tree or stand falls below a desired alternative rate of return.

Ecosystem—a natural unit comprised of living organisms and their interactions with their environment, including the circulation, transformation, and accumulation of energy and matter.

Ecotype—a genetic subdivision of a species resulting from the selective action of a particular environment and showing adaptation to that environment. Ecotypes may be geographic, climatic, elevational, or soil related. Red maples and northern red oaks are both adapted to moist soils, but can also be found on drier sites where the genetic difference is their enhanced ability to retain water.

Edge—the boundary between open land and woodland or between any two distinct ecological communities. This transition area between environments provides valuable wildlife habitat for some species, but can be problematic for sensitive species, due to increased predation and parasitism.



Den tree

Even-aged stand

Emergent wetlands—a class of wetland dominated by grasses, sedges, rushes, forbs, and other rooted, water-loving (possibly broad-leaved) herbaceous plants that emerge from the water or soil surface; marshes are an example.

Endangered species—species in danger of extinction throughout all or a significant part of their range. Protection mandated by the United States Endangered Species Act, 1973.

Even-aged stand—a group of trees that do not differ in age by more than 10 to 20 years or by 20 percent of the rotation age.

Extirpation—the eradication of a species from a portion of its natural range.

Forest—a biological community dominated by trees and other woody plants.

Forest interior dependent species—animal species that depend upon extensive areas of continuous, unbroken forest habitat to live and reproduce, and are susceptible to higher rates of predation and population decline when interior forest habitat is fragmented or disturbed.

Forest recovery—the complex natural process by which floral, faunal, and microbial communities respond to disturbance in the forest ecosystem. More resilient ecosystems respond rapidly to disturbance, returning to the pre-disturbance ecological state within a relatively short time period (perhaps decades as opposed to centuries).

Forest types—associations of tree species that commonly occur because of similar ecological requirements. Pennsylvania's three major forest types are oak-hickory, northern hardwoods, and Allegheny hardwoods.

Forested wetland—an area characterized by woody vegetation over 20 feet tall where soil is at least periodically saturated with or covered by water.

Fragmentation—the segmentation of a large tract or contiguous tracts of forest to smaller patches, often isolated from each other by nonforest habitat. Results from the collective impact of residential and commercial development, highway and utility construction, and other piecemeal land use changes.

Genotype—growth or development characteristics dependent on genetic information. The genetic constitution of an organism or a species in contrast to its observable characteristics.

Girdling—a method of killing unwanted trees by cutting through the living tissues around the bole. Can be used instead of cutting to prevent felling damage to nearby trees. Girdled trees can provide cavities and dead wood for wildlife and insects.

Girdling

Guild—species similar in their habitat needs as well as their response to habitat changes (e.g., ovenbird and woodthrush). One species in a guild is often used to represent the others when developing a stewardship management plan.

Habitat—the geographically defined area where environmental conditions (e.g., climate, topography, etc.) meet the life needs (e.g., food, shelter, etc.) of an organism, population, or community.

High-grading—a type of timber harvesting in which larger trees of commercially valuable species are removed with little regard for the quality, quantity, or distribution of trees and regeneration left on the site; often results when a diameter-limit harvest is imposed.

Horizontal structure—the spatial arrangement of plant communities; a complex horizontal structure is characterized by diverse plant communities within a given geographic unit.

Improvement cut—any cutting treatment used to alter species composition and tree spacing to realize ownership objectives. Thinning is a type of improvement cut.

Indicator species—species with such specialized ecological needs that they can be used for assessing the quality, condition, or extent of an ecosystem on the basis of their presence and density, or the accumulation and effect of materials in their tissues.

Land ethic—the principles and values guiding our use and treatment of the land. Forest stewardship is a land ethic. (See *stewardship.*)

Management plan—a document prepared by natural resource professionals to guide and direct the use and management of a forest property. It consists of inventory data and prescribed activities designed to meet ownership objectives.

Mast—all fruits of trees and shrubs used as food for wildlife. Hard mast includes nutlike fruits such as acorns, beechnuts, and chestnuts. Soft mast includes the fleshy fruits of black cherry, dogwood, and serviceberry.

Maturity—see *economic maturity* and *biological maturity*.

Multiple use and value—a conceptual basis for managing a forest area to yield more than one use or value simultaneously. Common uses and values include aesthetics, water, wildlife, recreation, and timber.

Neo-tropical birds—birds that breed in the northern hemisphere during summer months, and winter in tropical regions (e.g., woodthrush or barn swallows). One-third of Pennsylvania's breeding birds are neo-tropical migrants.

Niche—the physical and functional location of an organism within an ecosystem; where a living thing is found and what it does there.

Non-industrial private forestland (NIPF)—forestland owned by a private individual, group, or corporation not involved in wood processing.

Old-growth—forests that approximate the structure, composition, and functions of native forests prior to European settlement. They vary by forest type, but generally include more large trees, canopy layers, standing snags, native species, and dead organic matter than do young or intensively managed forests.

Patch—a small area of a particular ecological community surrounded by distinctly different ecological communities, such as a forest stand surrounded by agricultural lands or a small opening surrounded by forestland.

Patch dynamics—the process of recolonization by plant and wildlife species following the creation of a patch. Small patches and ones close to a source of plant and animal species will be recolonized faster than larger, more isolated patches.

Phenotype—outward appearance or physical attributes of an organism resulting from both the effects of the environment and genetic makeup.

Pole stand—a stand of trees with dbh ranging from 5 to 9 inches.

Population—a group of individuals of one plant or animal taxon (species, subspecies, or variety).

Preservation—a management philosophy or goal which seeks to protect indigenous ecosystem structure, function, and integrity from human impacts. Management activities are generally excluded from "preserved" forests.

Rare species—species which exist only in one or a few restricted geographic areas or habitats or occur in low numbers over a relatively broad area.

Reforestation—the re-establishment of forest cover by natural or artificial means on areas recently supporting forest cover.

Regeneration—the replacement of one forest stand by another as a result of natural seeding, sprouting, planting, or other methods; also young trees which will develop into the future forest.

Regeneration cut—a timber harvest designed to promote and enhance natural establishment of trees. Even-aged stands are perpetuated by three types of regeneration cuts: seed tree, shelterwood, and clearcutting. Uneven-aged stands are perpetuated by selecting individual or small groups of trees for removal (e.g., the selection system).

Release—removal of overtopping trees to allow understory or overtopped trees to grow in response to increased light.

Residual stand—trees remaining following any cutting operation.

Riparian zone—an area adjoining a body of water, normally having soils and vegetation characteristic of floodplains or areas transitional to upland zones. These areas help protect the water by removing or buffering the effects of excessive nutrients, sediments, organic matter, pesticides, or pollutants.

Rotation—the planned time interval between regeneration cuts in a forest.

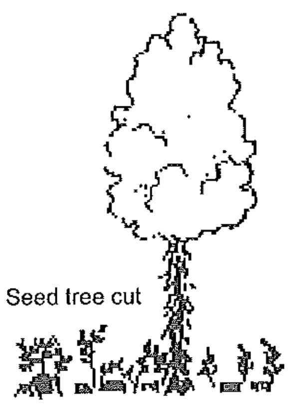
Salvage cut—the removal of dead, damaged, or diseased trees with the intent of recovering value prior to deterioration.

Sapling—a small tree, usually defined as being between 2 and 4 inches dbh.

Sawlog—a log large enough to yield lumber. Usually the small end of a sawlog must be at least 6 to 8 inches in diameter for softwoods and 10 to 12 inches for hardwoods.

Second growth—the forests re-established following the removal of virgin (i.e., previously unharvested) or old-growth stands. Most of Pennsylvania's forests are either second or third growth.

Seed tree cut—a regeneration cut where mature trees are left standing in a harvested area to provide seed for regeneration of the cut-over site.

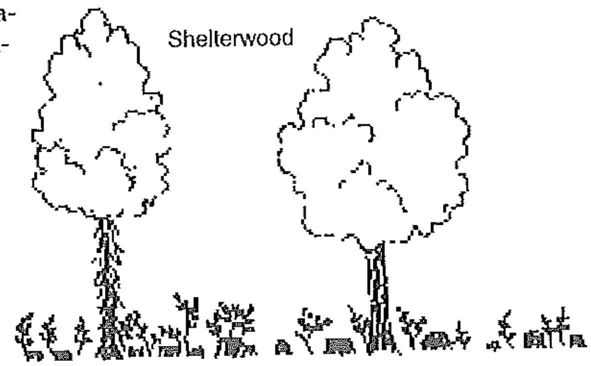


Seed tree cut

Seedling—a young tree originating from seed that is less than 4 feet tall and smaller than 2 inches in diameter at ground level.

Selection cut—a regeneration cut designed to create and perpetuate an uneven-aged forest. Trees may be removed singly or in small groups. A well-designed selection cut removes trees of lesser quality and trees in all diameter classes along with merchantable and mature high-quality sawlog trees. Should be differentiated from "select" or "selective" cuts, which often equate to high-grading.

Shelterwood—a regeneration cut designed to stimulate reproduction by removing all overstory trees. This is achieved by a series of cuts over several years. Gradual reduction of stand density protects understory trees and provides a seed source for stand regeneration.



Silviculture—the art, science, and practice of establishing, tending, and reproducing forest stands.

Site—the combination of biotic, climatic, topographic, and soil conditions of an area; the environment at a location.

Site quality—the inherent productive capacity of a specific location (site) in the forest affected by available growth factors (light, heat, water, nutrients, anchorage); often expressed as tree height at a given age.

Slash—branches, tops, and cull trees left on the ground following a harvest. Although some of this material can be used for firewood, slash may be arranged in brush piles to provide wildlife cover. Left scattered, slash can protect seedlings and sprouts from deer browsing and reduce soil erosion.

Snag—a standing dead tree with few branches, or the standing portion of a broken-off tree. Snags may provide feeding and/or nesting sites for wildlife.

Species—a subordinate classification to a genus; reproductively isolated organisms that have common characteristics, such as eastern white pine or white-tailed deer.

Species richness—the number of species present in a community or a defined area.

Spring seep—a class of wetland created by groundwater emerging on lower slopes in small pools surrounded by vegetation. These create snow-free zones critical for wildlife feeding during winter.

Stand—a grouping of vegetation sufficiently uniform in species composition, age, and condition to be distinguished from surrounding vegetation types and managed as a single unit. (See figure.)

Stewardship—the wise management and use of forest resources to ensure their health and productivity for the future with regard for generations to come.

Stream management zones—areas adjacent to waterbodies where unique management strategies are applied to protect water quality and maintain stream temperature through shading. Zone width is normally 50 feet, but varies according to site.

Stumpage—the commercial value of standing trees.

Succession—the natural series of replacements of one plant community (and the associated fauna) by another over time and in the absence of disturbance.

Sustained yield—historically, a timber management concept in which the volume of wood removed is equal to growth within the total forest. The concept is applicable to nontimber forest values as well.

Thinning—removal of trees to encourage growth of other selected individual trees. May be commercial or pre-commercial.

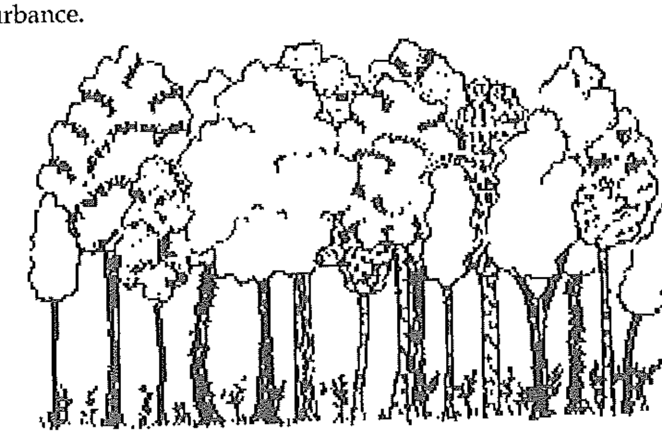
Threatened species—a species likely to become endangered in the foreseeable future, throughout all or a significant portion of its range, unless protected.

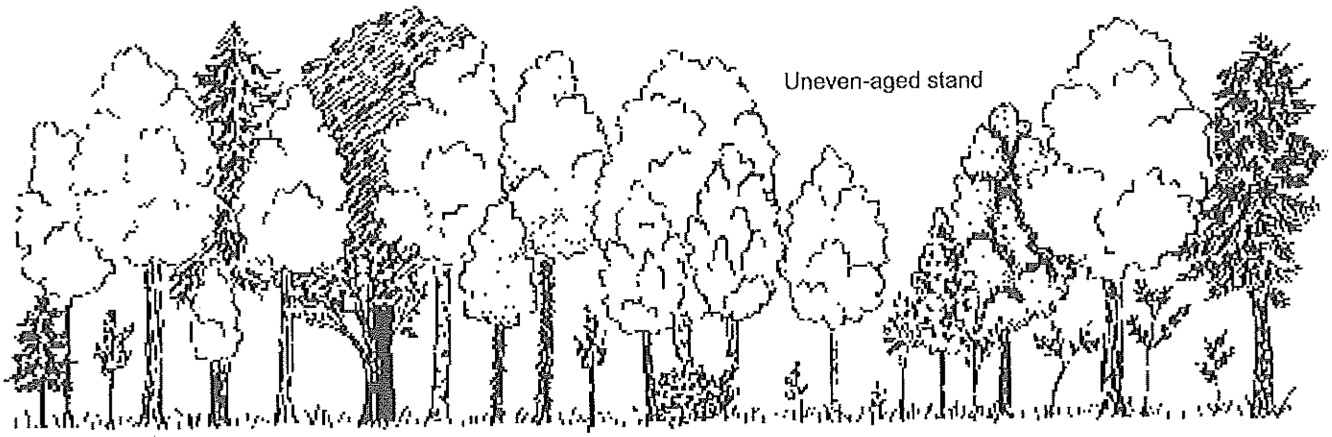
Timber cruising—the process of estimating the quality, quantity, and characteristics of trees in a forest.

Timberland—forestland producing or capable of producing crops of industrial wood (more than 20 cubic feet per acre per year), and not withdrawn from timber utilization. Formerly known as commercial forestland.

Timber stand improvement (TSI)—a combination of intermediate treatments designed to improve growth and composition of the forest; often spoken of as TSI.

Tolerance—a characteristic of trees that describes the relative ability to thrive with respect to the growth factors (light, heat, water, nutrients, anchorage). For instance, a "shade tolerant" species may thrive at low light levels.





Understory—the smaller vegetation (shrubs, seedlings, saplings, small trees) within a forest stand, occupying the vertical zone between the overstory and the herbaceous plants of the forest floor.

Uneven-aged stand—a group of trees of various ages and sizes growing together on a site. (See figure.)

Urban forestry—the professional management of natural resources in and around urban areas, including trees and associated vegetation, wildlife, and open space.

Vernal or autumnal ponds—a class of wetland characterized by small, shallow, temporary pools of fresh water present in spring and fall, which typically do not support fish but are very important breeding grounds for many species of amphibians. Some species are totally dependent upon such ponds; examples are spring peepers and mole salamanders.

Vertical structure—the arrangement of plants in a given community from the ground (herbaceous and woody shrubs) into the main forest canopy; a complex vertical structure is characterized by lush undergrowth and successive layers of woody vegetation extending into the crowns of dominant and codominant trees. (See *crown class.*)

Virgin forest—a forest that has never been harvested or altered by humans.

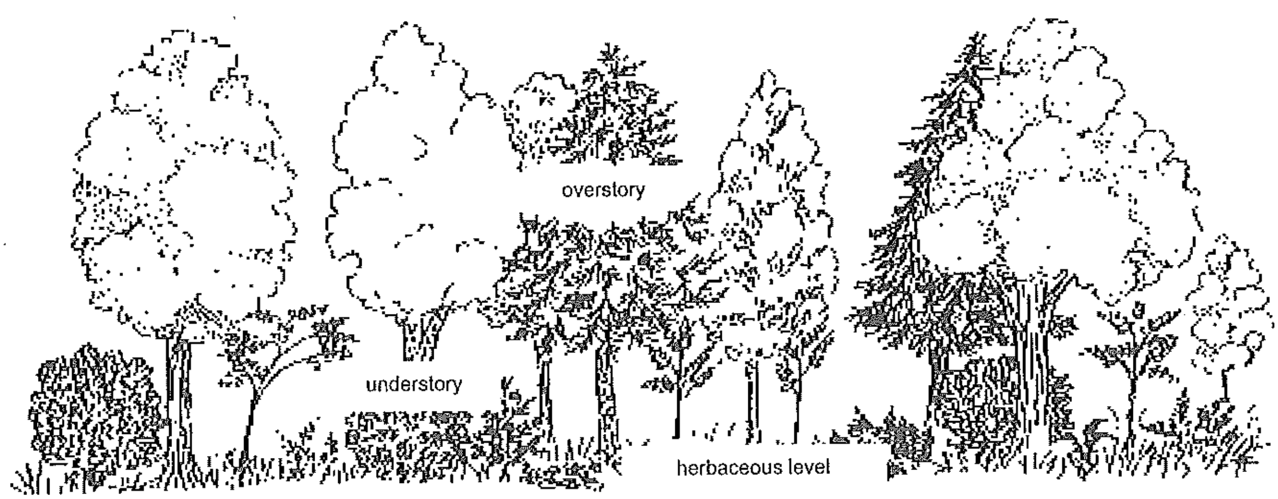
Watershed—a region or area defined by patterns of stream drainage. A watershed includes all the land from which a particular stream or river is supplied.

Wetlands—areas which are either transitional between land and water (where the water table is at or near the land surface) or areas of land which are covered by shallow water (such as marshes, swamps, bogs, and fens). Although only 2 percent of Pennsylvania remains as wetlands today, these areas fulfill an essential role in our landscapes by maintaining water quality, stabilizing shores and stream banks, controlling floods and erosion, and providing critical habitat to many plant and animal species.

Wolf tree—a large, excessively branchy tree which occupies more space in the forest than surrounding trees. Wolf trees have high wildlife and aesthetic value, but little if any timber value.

Woodland—see *forest*.

Vertical structure



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This publication is available in alternative media on request.

Pennsylvania Forest Stewardship Program

Forests for Life

The Forest Stewardship Program is administered nationally by the USDA Forest Service and is directed in Pennsylvania by the DER Bureau of Forestry with assistance from a statewide steering committee. The Forest Stewardship Program assists forest landowners in better managing their forestlands by providing information, education, and technical assistance. For more information about program services and publications contact: The Pennsylvania Forest Stewardship Program, DER Bureau of Forestry, P.O. Box 8552, Harrisburg, PA 17105-8552. Phone: (800) 235-WISE, or (717) 787-2105.

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emerald ash borer
Agrilus planipennis Fairmaire

This borer, native to Asia, was first identified in North America in 2002 feeding on ash trees in Michigan. Larvae feed in the phloem and outer sapwood, producing galleries that eventually girdle and kill branches and entire trees. It appears to feed only on ash and in Michigan has killed green, white, and black ash. Dieback of the tree canopy may be the first symptom of borer attack. Vertical splits occur in the bark due to callus formation. Within two to three years of infestation, the tree is often killed. Trees of various sizes (from small sapling to sawtimber-sizes) and conditions are killed including trees that are stressed or apparently healthy.

Adult beetles are slender, elongate, and about 7.5 to 13.5 mm long. The body is brassy or golden green overall, with darker, metallic, emerald green wing covers. Larvae reach a length of 26 to 32 mm, are cream-colored and flattened. The 10-segmented abdomen has a pair of brown, pincer-like appendages on the last segment.

Adults emerge in May and June and females soon begin depositing eggs on bark of trunk or branches. Eggs hatch in 7 to 10 days and larvae chew through the bark into the cambium. They feed on phloem and outer sapwood for several weeks producing S-shaped galleries packed with fine frass. Full-grown larvae overwinter in a shallow chamber in the sapwood, pupate in the spring, and adults emerge through D-shaped exit holes that are 3 to 4 mm in diameter. The borer appears to have a one year life cycle.

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red oak borer

Enaphalodes rufulus **(Haldeman)**

This is a major pest of red oaks, accounting for millions of dollars in losses from defects and degrade in lumber. Valuable shade trees in parks and cities are sometimes attacked, but are rarely killed.

Adult borers are longhorned beetles. Their antennae are very long, almost doubling their 1 -inch (25 mm) body length. Their rust brown color blends well with the bark surface, and they are rarely seen. The pale, robust larvae have very small legs on the thorax.

The first signs of attack resemble the fine frass produced by ambrosia beetles. As the larvae bore into the tree, sap begins to extrude from the attack points (see photo on front side). Within the tree, tunnel diameters gradually increase from pinhole size to about 1/2 inch (12 mm) in diameter as larvae grow. Tunnels are 6 to 10 inches (15 to 25 cm) long and are often accompanied by discolored and decaying wood. They are usually within 6 inches (15 cm) of the pith.

The red oak borer has a 2year life cycle. Eggs are laid in midsummer in roughened areas or near wounds, and larvae tunnel under the bark for the first year. In the second year, the more damaging wood tunneling commences. Prior to pupation, the larvae chew round exit holes through which they later emerge as adults.

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USDA United States Department of Agriculture

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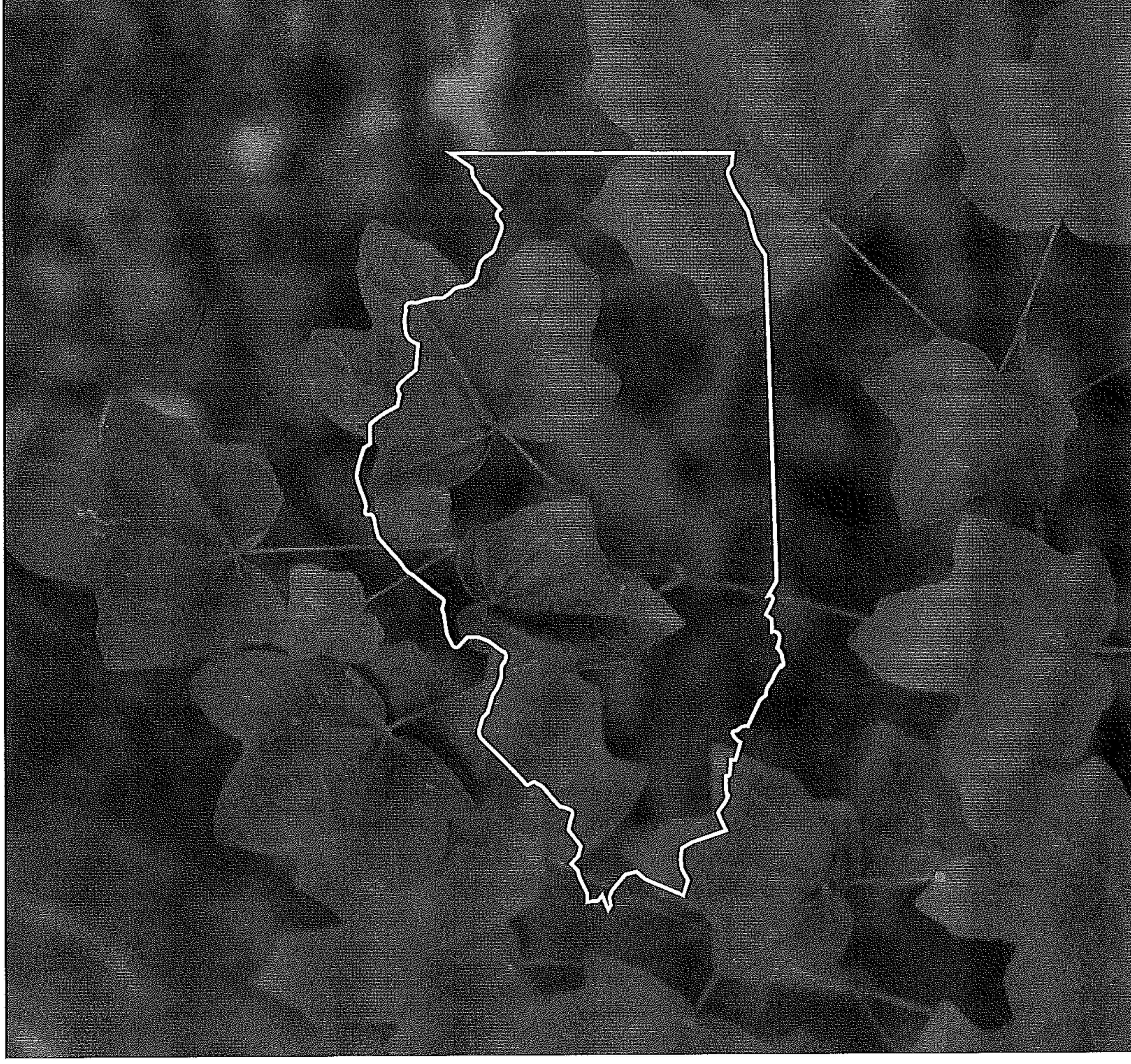
Illinois' Forest Resources, 2005

Susan J. Crocker, Gary J. Brand, and Dick C. Little



Abstract

Results of the completed 2005 Illinois annual inventory show an estimated 4.5 million acres of forest land that supports 7.6 billion cubic feet (ft^3) of total net live-tree volume. Since 1948, timberland area has steadily increased and now represents 96 percent of total forest land. Growing-stock volume on timberland has risen to an estimated 6.8 billion ft^3. Ten percent of live-tree volume on timberland is in cull trees. Live-tree aboveground biomass is 210.5 million dry tons. Net growth of growing stock increased by an average of 327 million ft^3/yr. Growing-stock was removed at an average of 60.6 million ft^3/yr. Average annual mortality of growing stock was 86.6 million ft^3/yr. Oak wilt, gypsy moth, emerald ash borer, Dutch elm disease, Asian longhorned beetle, and drought were among Illinois' forest health concerns.

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Illinois' Forest Resources, 2005

INTRODUCTION

Historically, the Northern Research Station's Forest Inventory and Analysis (NRS-FIA) program conducted inventories of a state's forests on a periodic basis. In Illinois, periodic inventories were completed in 1948, 1962, 1985, and 1998 (Essex and Gansner 1965, Raile and Leatherberry 1988, Schmidt et al. 2000, Central States Forest Experiment Station 1949). When NRS-FIA began fieldwork for the fifth inventory of Illinois' forest resources in 2001, it initiated an annual inventory system in which one-fifth of the field plots (considered one panel) in the State are measured each year. A complete annual inventory consists of measurements and data compiled and reported for all plots in all five panels. Once all panels have been measured and the inventory is complete, a new inventory will begin and one panel of plots will be remeasured every year on a 5-year cycle. For example, in Illinois, the field plots measured in 2005 will be remeasured in 2010.

This report presents results from the completed fifth inventory (2001-05) of Illinois' forest resources. These results are estimates based on sampling techniques of Bechtold and Patterson (2005). Estimates were compiled assuming that the data from the 2001, 2002, 2003, 2004, and 2005 panels represent one sample. All of the tables in this report and many others can be generated at the Mapmaker Program at http://www.nrs.fs.fed.us/fia/data-tools/mapping-tools/default.asp.

As a result of ongoing efforts to improve the efficiency and reliability of the inventory, several changes in procedures and definitions have occurred since the last Illinois inventory in 1998 (Schmidt et al. 2000). These changes will have little impact on statewide estimates of forest area, timber volume and tree biomass; however, they may have significant impacts on plot classification variables such as forest type and stand-size class. For the purpose of growth, removal, and mortality estimates, the 1998 inventory (Schmidt et al. 2000) was processed using estimation/summary routines for the 2001-2005 panels. Because these changes allow limited comparison of inventory estimates among separate inventories in this report, it is inappropriate to directly compare all portions of the 2005 data with those published for earlier inventories.

RESULTS

Area

Prior to Euro-American settlement, Illinois was a mixture of tall grass prairie and eastern deciduous forest. Forests then occupied an estimated 14 million acres, or about 40 percent of the state's total land area (Illinois State Natural Survey Division 1960). For nearly 120 years (1800 to the 1920's), forest-land[1] area (which includes reserved and low-productivity land) declined, reaching a low of 3.0 million acres in 1924 (Telford 1926). By the 1950's, forest land was on the rise and in 1962 totaled an estimated 4.0 million acres. In 2005, forest land occupied 4.5 million acres, or about 13 percent of the state's total land area (Table 1, U.S. Census Bureau 2006). Most forest land in Illinois is privately owned. Currently, an estimated 169.0 thousand private landowners (Illinois Department of Natural Resources 2003) hold 3.7 million acres of the state's forest land (Table 1). Private landowners have been instrumental in the conservation and regeneration of Illinois' forests. Eighteen percent of forest land is publicly owned (Table 1). This ensures that people will have access to forest recreation opportunities, that wildlife habitat is maintained, and that forests remain a

[1] *Forest land is land that is at least 10-percent stocked with trees of any size, or that formerly had such tree cover and is not currently developed for a nonforest use. The minimum area for classification of forest land is 1 acre. In addition, strips of timber must have a crown width of at least 120 feet.*

THE AUTHORS

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vital component of the landscape and economy of Illinois. Public forest lands in Illinois are mostly within the Shawnee National Forest, state parks, county forest preserves, and park districts.

Forest land has three components:

1. Timberland[2]—forest land that is not restricted from harvesting by statute, administrative regulation, or designation and is capable of growing trees at a rate of 20 cubic feet (ft^3) per acre per year.

2. Reserved—forest land that is restricted from harvesting by statute, administrative regulation, or designation (e.g., state parks, national parks and lakeshores, and federal wilderness areas).

3. Other forest land—forest land that is not capable of growing trees at a rate of 20 ft^3 per acre per year and is not restricted from harvesting.

Illinois timberland totals 4.3 million acres and accounts for 96 percent of total forest land in the state (Table 2). Timberland has remained relatively stable since 1948, slowly increasing with successive inventories (Fig. 1). The remaining 4 percent of forest land, 162.2 thousand acres, is classified as reserved or other forest land. Most reserved forest land in Illinois is in county forest preserves, state parks, state natural areas, and on the Shawnee National Forest.

Most timberland stands in Illinois are dominated by hardwood trees; 97 percent of total timberland area is in the hardwood forest type group (Table 2). Hardwood timberland stands are largely of natural origin; only 23 thousand acres or 0.5 percent of hardwoods were planted. By contrast, 64 percent of the 112 thousand acres of timberland in the softwood type group were planted (Table 2).

Illinois timberland contains a variety of tree species. To facilitate describing forest composition, tree species are grouped into national forest-type groups that reflect the combination of species on a particular site. This classification is based on the species forming a plurality of live-tree stocking on the site. Three hardwood forest-type groups—oak/hickory, elm/ash/cottonwood, and maple/beech/birch—occupy 94 percent of timberland in Illinois (Fig. 2). The oak/hickory group alone occupies nearly two-thirds of timberland, the bulk of which is in the white oak/red oak/hickory forest type (1.5 million acres) (Table 3). The elm/ash/cottonwood forest-type group, which typically occurs on floodplains, is found on 22 percent of timberland (Fig. 2). Illinois floodplains in the

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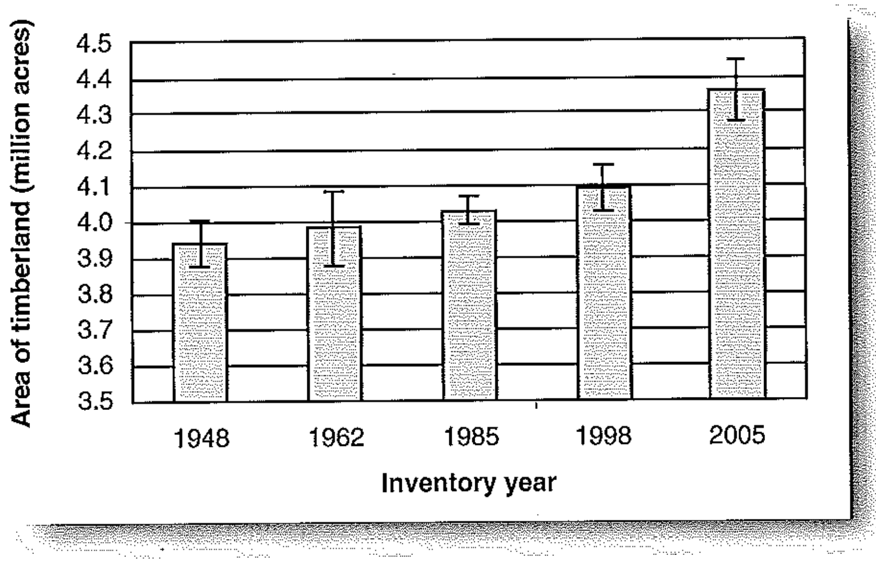
2 Timberland may not be equivalent to the area actually available for commercial timber harvesting or other access. The actual availability of land for various uses depends on owner decisions that consider economic, environmental, and social factors.

Figure 1.—*Area of timberland, Illinois, 1948-2005. The vertical line at the top of each bar represents the sample error associated with each inventory.*



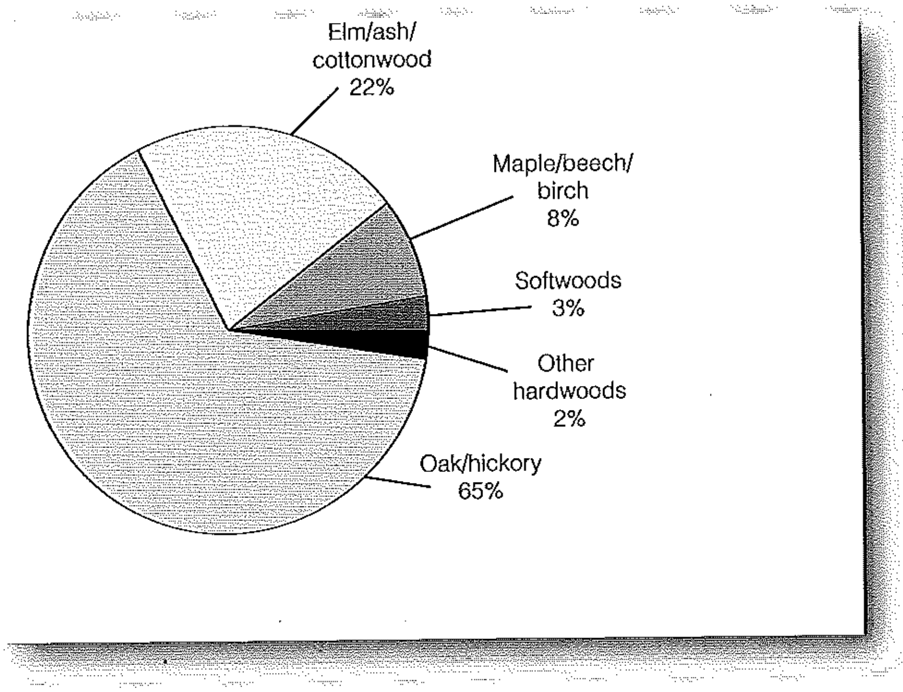


Figure 2.—*Area of timberland by forest type group, Illinois, 2005.*

elm/ash/cottonwood forest-type group are variable in composition; major species include silver maple, green ash, river birch, pin oak, pecan, sycamore, cottonwood, hackberry, and immature elm. Nearly 8 percent of timberland is represented by the maple/beech/birch forest-type group (Fig. 2). In northern Illinois, a large portion of this group is composed of the sugar maple/basswood forest type; stands along the eastern and southern borders of the state are dominated by sugar maple, beech, and tulip-poplar.

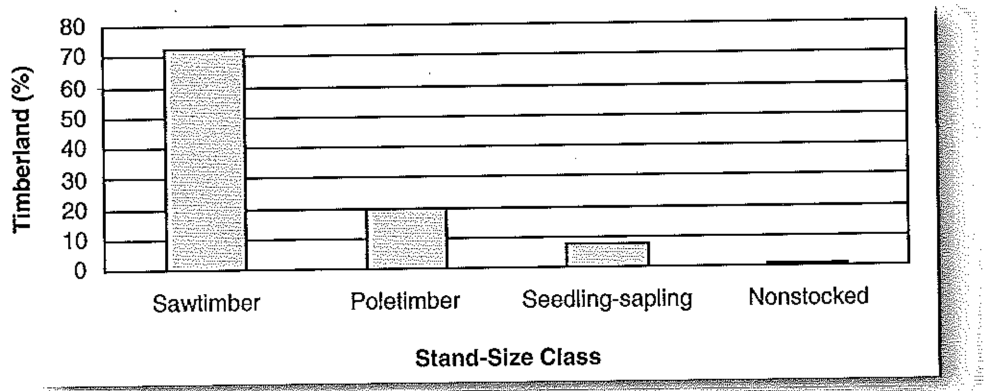
Although softwoods only account for about 3 percent of total timberland area, they contribute to increased biodiversity in what would otherwise be a sea of hardwoods (Table 3). Softwood timberland area is predominantly eastern redcedar, which occupies 31.5 thousand acres (28 percent). Shortleaf and white pine stands account for 26 and 22 percent of softwood timberland area, respectively (Table 3).

Stand-size class is a measure of the average diameter of the dominant trees in a stand. There are three classes: sawtimber—large trees, softwoods at least 9 inches in diameter at breast height (d.b.h.) and hardwoods at least 11 inches in d.b.h.; poletimber—medium trees, 5 inches in d.b.h. to sawtimber size; and sapling/seedling—small trees, 1 to 5 inches in d.b.h. or live trees less than 1 inch in d.b.h. that are expected to survive.

Timberland area in Illinois consists largely of stands with sawtimber-size trees. Sawtimber stands occupy 3.1 million acres, or 72 percent of timberland; this suggests that the majority of Illinois' forests are maturing (Table 3, Fig. 3). Mature stands are more likely to succumb to wind-throw, insects, or disease pathogens. Twenty percent of timberland area is made up of poletimber stands, 7.5 percent contains sapling-seedling stands, and the remaining 0.5 percent is nonstocked[3] (Table 3). The relatively small area of sapling-seedling stands may be related to how timber is harvested in much of the state. Often, mature timber is removed as single, scattered trees or in small groups. The lack of significant disturbances in hardwood stands may not open stands to progressive seedling development because smaller trees in the understory are generally outcompeted by larger, canopy dominant trees. Exceptions include species, such as sugar maple, which are tolerant of understory conditions and can take advantage of gaps in the canopy.

[3] *Nonstocked land is timberland that is less than 10-percent stocked with live trees.*

Figure 3.—*Stand-size class as a percentage of total timberland area, Illinois, 2005.*



Volume

Net volume is the gross volume less deductions for rot, sweep, or other defects that limit use for timber products. It is computed from a 1-foot stump to a 4-inch top diameter outside the bark for live trees at least 5 inches in d.b.h. Total net volume of live trees on forest land in Illinois is an estimated 7.9 billion ft^3, or 1,758 ft^3 per acre of forest land (Table 4). Eight of every 10 ft^3 of live volume is on privately owned forest land. Virtually all (97 percent) of the net volume of live trees is in hardwoods. Two species groups, other eastern soft hardwoods and select white oaks, are predominant; each represents about 16 percent of the total live-tree volume. The largest components of the other eastern soft hardwoods species group are American sycamore and American elm; white and bur oak dominate the select white oak group (Table 4).

Growing-stock volume has traditionally been used to ascertain wood volume. It is the amount of solid wood on timberland in commercial trees[4] 5 inches in d.b.h. or larger, from 1 foot above ground (stump) to a minimum 4-inch top diameter, with deductions for poor form or defect. Excluded are rough, rotten, and dead trees and trees of noncommercial species. Growing-stock volume on Illinois timberland totals 6.8 billion ft^3, or 90 percent of the total live volume on timberland (Table 5).

The remaining 10 percent of live-tree volume on timberland (746.6 million ft^3) is in cull trees. Cull trees are unsuitable for use as wood products due to poor form, rot, or defect, or because they are considered an undesirable species. The volume of cull trees is often used for commercial purposes. For instance, rough trees are sometimes harvested for chipping or to make pallets. Salvable dead trees contain 114.7 million ft^3 of wood volume (Table 5). Salvable dead trees are standing or down dead trees that are considered merchantable by regional standards. They have some commercial applications and serve as an important source of firewood. Salvable dead trees also play an important role in overall species diversity, providing habitat for a wealth of wildlife species, including cavity nesting birds and mammals that require den sites.

Total growing-stock volume has significantly increased in every inventory, rising from 2.4 billion ft^3 in 1948 to 6.8 billion ft^3 in 2005 (Fig. 4, Table 6). Currently, 97 percent of total growing-stock volume is in hardwood species. Sixty-eight percent of total growing-stock volume is contained in five forest types: white oak/red oak/hickory (37 percent), mixed upland hardwoods and silver maple/American elm (9 percent each), sugarberry/hackberry/elm/green ash (7 percent), and white oak (6 percent). Total net volume of softwood growing stock is 196.7 million ft^3. The majority of this volume is in softwood-dominated stands (174.6 million ft^3); however, a small amount (22.1 million ft^3) is in hardwood-dominated stands (Table 6).

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[4] *Commercial trees are tree species presently or prospectively suitable for industrial wood products (does not include species of typically small size, poor form, or inferior quality, e.g., hophornbeam, osage-orange, and redbud).*

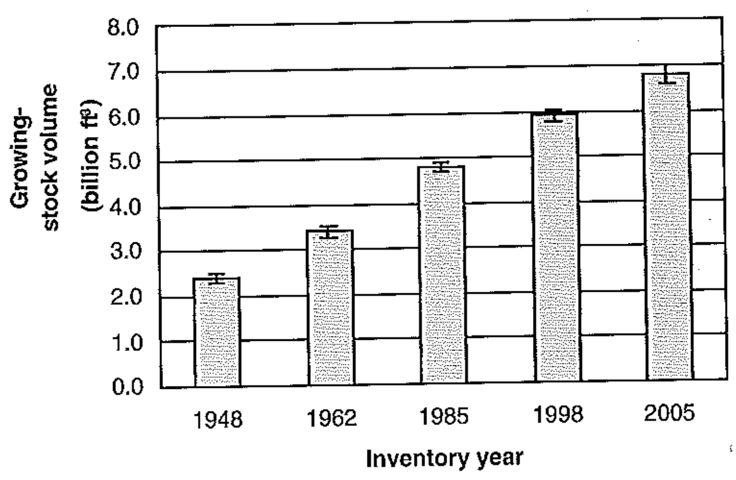


Figure 4.—*Growing-stock volume on timberland, Illinois, 1948-2005. The vertical line at the top of each bar represents the sample error associated with each inventory.*

More than one-fourth of growing-stock volume is in trees that are 21 inches or larger in d.b.h. (Table 7). A significant amount of this volume is in oak species, particularly white, black, and northern red oak, as well as in eastern cottonwood, silver maple, and American sycamore. Of the 3 percent of net volume of growing stock occupied by softwoods, 86 percent is in trees that are less than 17 inches in d.b.h. (Table 7).

Sawtimber volume is the volume of the saw log portion of live sawtimber in board feet and is generally measured using the International 1/4-inch rule. Net sawtimber volume on Illinois timberland totals 25.3 billion board feet; 96 percent of this volume is in hardwood species (Table 8). Half of the volume of sawtimber is in seven hardwood species—white oak (14 percent), black oak and silver maple (8 percent each), northern red oak (7 percent), eastern cottonwood (5 percent), and shagbark hickory and American sycamore (4 percent each) (Table 8).

Biomass

Live-tree aboveground biomass is estimated for growing-stock trees, nongrowing-stock trees, and live trees that are 1 to 5 inches in d.b.h. In 2005, the estimate of live-tree aboveground biomass on timberland in Illinois was 210.5 million dry tons, or an average of 48 dry tons per acre of timberland (Table 9). Eighty-three percent of tree biomass is in growing-stock trees, 11 percent is in nongrowing-stock trees, and approximately 6 percent is in trees less than 5 inches in d.b.h. (Table 9). For both growing-stock and nongrowing-stock trees, nearly three-fourths of total aboveground biomass is in the boles of trees. The remainder is in stumps, tops, and limbs. Ninety-eight percent (205.9 million dry tons) of live-tree aboveground biomass is in hardwood species (Table 9). Biomass estimates have become increasingly important for analyses of questions related to wood fiber availability for fuels, assessment of fuels in forest stands, and investigation of carbon sequestration by vegetative biomass and emissions reduction assurances.

Growth, Removals, and Mortality

Between 1998 and 2005, net growth (gross growth minus mortality) of growing stock on timberland increased by an average of 327 million ft^3/yr (Table 10). Ninety-eight percent of annual net growth was due to growth in hardwoods. Net softwood growth reached an average of 7.8 million ft^3/yr (Table 10). Overall, net growth was highest in the other eastern soft hardwoods species group (19 percent); this species group contains hackberry, American sycamore, and the elms. Other fast-growing species groups in Illinois include other select white oaks (42.0 million ft^3/yr), soft maples (33.7 million ft^3/yr), and cottonwood and aspen (30.4 million ft^3/yr) (Table 10).

Since 1998, growing stock has been removed from timberland at an average of 60.6 million ft^3/yr (Table 11). Virtually all removals were from hardwoods as softwood removals totaled 43 thousand ft^3/yr, or less than 0.1 percent of total removals. The other eastern soft hardwoods species group had the highest average annual removals at 10.8 million ft^3/yr, followed by the select white oaks at 10.2 million ft^3/yr. Oak species account for 36 percent of annual removals. Eighty-seven percent of growing-stock removals were on private land (Table 11).

Average annual mortality of growing stock on timberland from 1998 to 2005 was 86.6 million ft^3/yr (Table 12). Hardwood mortality accounted for 98 percent of the total, or 84.8 million ft^3/yr. Two percent of annual mortality, 1.7 million ft^3/yr, was in softwood species. Seventy-seven percent of softwood mortality was in the other yellow pines and the eastern white and red pine species groups (Table 12). On average, more than one-third of annual mortality occurred in the other eastern soft hardwood species group; much of this mortality is likely due to the death of elm trees. Twenty-one percent of total annual mortality was in oak species groups (Table 12).

FOREST HEALTH

The following information about the insects and pathogens affecting Illinois' forests was gathered from the 2005 Insect and Disease Conditions Report (http://www.na.fs.fed.us/fhp/pcond/) and the Central States Forest Health Watch newsletter (http://na.fs.fed.us/fhp/fhw/csfhw/) published by the USDA Forest Service's Northeastern Area, State and Private Forestry. Additional information was obtained from the national Forest Health Monitoring (FHM) program (http://fhm.fs.fed.us/) and the Illinois Department of Agriculture (http://www.agr.state.il.us/index.html). Several issues of concern in 2005 are highlighted here. For more information on the health of Illinois' forests, contact the Illinois Department of Natural Resources.

Native Insects

In 2005, populations of eastern tent caterpillar reached high densities in the southern third of Illinois. Insect activity completely defoliated black cherry trees in this region. Conversely, after an outbreak in southeastern Illinois in 2002, infestation by forest tent caterpillar was low. A viral infection from previous years has caused a collapse in population density from which this insect has not recovered.

Exotic Insects

Asian Longhorned Beetle

Asian longhorned beetle (ALB) was discovered in Chicago in 1998. Surveys conducted to locate infested trees show that eradication efforts have yielded a continued decrease in the number of new infestations of ALB since it was initially discovered. In 2005, there were no new infestations in Chicago. As a result of the continued pattern of reduced activity over several years, the majority of quarantined areas in the Chicago area have been deregulated. Oz Park, which had two infested trees in 2003, is the only remaining quarantined area. Surveys still continue in areas that were formerly quarantined. If ALB is not detected in the next 2 years, Illinois infestations will be classified as eradicated. For more information on the status of ALB in the United States, please visit the USDA Forest Service ALB webpage, http://www.na.fs.fed.us/fhp/alb/index.shtm.

Gypsy Moth

Gypsy moth, a native to Europe and Asia, was introduced to North America in 1869. Since that time, gypsy moth has spread across the Northeastern United States and populations have become established in northeastern counties in Illinois. As part of a joint program among the Forest Service, Illinois Department of Agriculture, and USDA Animal and Plant Health Inspection Service, nearly 30 thousand acres have been treated for gypsy moth under the "Slow the Spread" program. Traps placed in 85 counties in central and southern Illinois caught eight moths, a decrease from the previous year; each moth was caught from a different county. Overall, 2005 populations have remained spotty and have caused little noticeable defoliation. Additional information on gypsy moth can be found by visiting the USDA Forest Service gypsy moth webpage, http://www.fs.fed.us/ne/morgantown/4557/gmoth/.

Emerald Ash Borer

Discovered in southeastern Michigan in 2002, emerald ash borer (EAB) is a bark-boring beetle native to Asia. A pest of ash (*Fraxinus* spp.), larvae feed and produce galleries in the phloem and outer sapwood. This activity disrupts the flow of water and nutrients, girdling the tree and killing it. Depending on the severity of the infestation, ash mortality occurs within 1 to 3 years of initial infestation. The 2005 distribution of EAB extended from Michigan to Indiana and Ohio. In 2006, during the writing of this report, EAB was positively identified at four locations in northeastern Illinois and one location in Maryland. Based on its life history traits and the extent of its damage, EAB is believed to have been present in Illinois for 3 to 5 years before its discovery. Therefore, although surveys conducted in 2005 did not reveal evidence of the beetle, EAB was present in Illinois during the current inventory period.

The method of EAB introduction is unknown. However, beetles are believed to have been introduced to Illinois via firewood originating in Michigan. This type of human-assisted transportation of infested materials has rapidly increased the spread of EAB. The result of both natural and artificial spread, EAB has killed tens of millions of ash in infested zones since 2002. The entire Illinois ash resource, which consists of ash in urban and suburban settings and more than 130 million ash trees on forest land (a live-tree volume of 423 million ft^3), is at risk for substantial mortality. More information on EAB can be found at http://www.emeraldashborer.info.

Diseases

Oak Wilt

Oak wilt, caused by the fungus *Ceratocystis fagacearum*, continues to be the most important source of oak mortality in the Central United States. An endemic disease, oak wilt occurs in patches on the landscape; a suite of natural checks and balances keeps this disease from reaching epidemic proportions. All species of oak are susceptible to oak wilt; however, the disease occurs more frequently and progresses more rapidly in red oak species (O'Brien et al. 2000). Once the fungus is introduced to a tree, it enters the vascular system. The tree then plugs water-conducting tissues in an attempt to block fungal growth. This action disrupts the translocation of water from the roots to the canopy, causing foliage to wilt and die. The disease progresses rapidly and tree mortality occurs within a year of infection (O'Brien et al. 2000). Oak wilt has no cure, so prevention and early detection are important in maintaining tree health. Fungal spores are spread via root grafts or sap-feeding beetles. Injured trees or trees with fresh pruning wounds attract beetles. To avoid spread of the fungus by beetles, trees should not be pruned between April 15 and July 1 (O'Brien et al. 2000).

Dutch Elm Disease

Elm mortality resulting from Dutch elm disease (DED) continues to increase each year. Forty-five counties in Illinois reported moderate to heavy elm mortality in 2005. DED is caused by the fungi *Ophiostoma ulmi* and *O. novo-ulmi*. Susceptibility of elms varies by species. In general, American elm is highly susceptible (Haugen 1998). DED is spread overland by elm bark beetles that pick up fungal spores in diseased trees and deposit them in healthy trees as they bore through the inner bark and sapwood or fed in twig crotches. Local spread is facilitated by root grafts, which allow the fungus to readily move between trees. Following introduction of the fungus, the tree clogs water-conducting tissues in an attempt to block growth of the fungus. Water is then prevented from reaching the crown, causing leaves to wilt and die and leading to tree mortality. Trees are often killed before they reach sawtimber-size; thus, aging stands present a future health risk (Haugen 1998).

Sudden Oak Death

First reported in central California in 1995, sudden oak death (SOD) is caused by the fungal-like pathogen *Phytophthora ramorum*. Species susceptible to *P. ramorum* include a variety of oaks, Douglas-fir, and *Rhododendron* spp. as well as many other trees and shrubs (O'Brien et al. 2002). On oak species, *P. ramorum* causes bleeding cankers to form along the stem. Cankered trees can survive for one to several years following infection. However, mortality occurs within weeks of the onset of crown dieback. Established populations of *P. ramorum* are known to occur only on the West Coast (O'Brien et al. 2002), but transportation of infected nursery stock has introduced the SOD pathogen to nurseries in a number of eastern and southern states. All Illinois samples collected during the 2005 survey tested negative for *P. ramorum*. Additional information on SOD is available at the California Oak Mortality Task Force webpage, www.suddenoakdeath.org.

Weather

Drought

The summer of 2005 brought extreme drought conditions to west-central and northwestern Illinois. During the same period, southern Illinois experienced moderate to severe drought conditions. By the fall, drought conditions in the northern portion of Illinois were severe to extreme. Many trees in northern and central Illinois had smaller leaves and lost their leaves early (National Drought Mitigation Center 2006). Periods of prolonged drought increase the risk of forest fire and may have a significant impact on tree growth and tree health. Newly planted species, urban trees, and nonnative species are more susceptible to drought (National Drought Mitigation Center 2006).

SUMMARY

Continuing the trend that characterized the latter portion of the 20th century, Illinois timberland is increasing. With an estimated 4.3 million acres, the state's timberland area is dominated by hardwoods. The majority of hardwood stands are in oak/hickory forest types. Sawtimber stands occupy 72 percent of timberland, suggesting that Illinois' forests are maturing. Growing-stock volume is increasing and totals 6.8 billion ft^3. Illinois' forests face threats from native and nonnative insects and diseases. Oak wilt is among the state's major forest health concerns as it remains an important source of oak mortality. Although management programs for ALB have limited additional spread, EAB has emerged as a new threat to the diversity of Illinois' forests.

Benefits from Illinois Forest Resources

Many benefits are received from the forest resources of Illinois, ranging from lumber to natural areas for public enjoyment and relaxation. In addition, the forest resources of Illinois contribute financially to the state through jobs and income generated by forestry-related businesses and industries.

The wood harvested from Illinois timberland is used for a variety of goods and products. Forty-six percent of the current (1997) annual growing-stock removals were used for saw logs (Figure 50). Veneer logs, pulpwood, fuelwood, and miscellaneous products combined represent only 12 percent of the current volume of growing-stock removals, while logging residue accounts for 13 percent. Many industries make use of logging residue and convert it into usable products. Logging residue in the form of branches and other woody material left at the logging site eventually decomposes and returns valuable nutrients to the soil.

Other removals accounted for 29 percent of the growing-stock removals in 1997. Other removals include wood removed in timber-stand improvement cuttings (where undesirable trees are removed), trees removed during land clearing, and growing-stock trees on land removed from timberland classification between 1985 and 1998.

Table 22 shows the annual removals of growing stock from timberland for 1997, by species group and removal/product type. The latter is a class indicating what the removed volume of wood was used for. It should be noted that the difference in the volume of removals by species groups reported in Table 22 and Table 13 is due to the fact that in Table 13, the removal volume is an annual average based on the period between 1985 and 1998, whereas Table 22 is limited to the annual removals for 1997. Other red oaks had the highest volume of growing stock removed, followed by select white oaks. These two species groups also accounted for the highest average annual removals (Table 13).

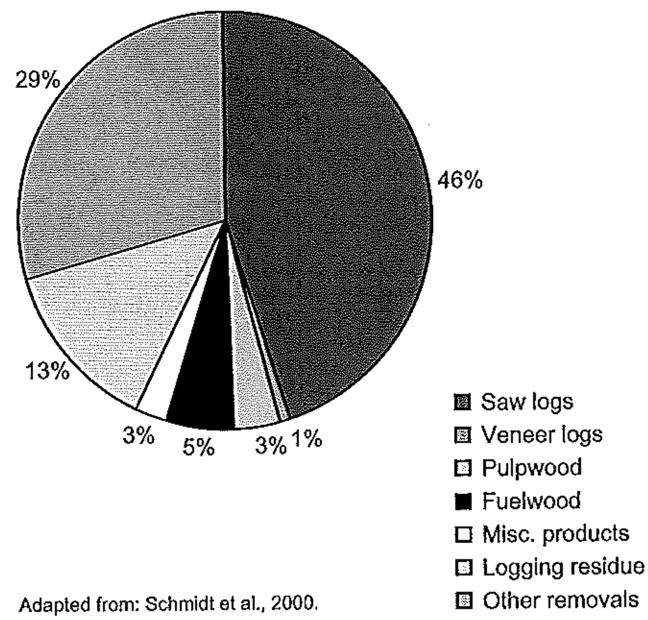
Of the 75,198 thousand cubic feet of growing-stock volume removed in 1997, 42,995 thousand cubic feet were used for products (Table 22). The remaining volume removed was in logging residue and other removals. For the majority of species groups, the largest portion of growing-stock volume removed was used for products. The highest volume removed for a product was saw logs. Other red oaks and select white oaks were the two highest species groups used for saw logs. Select white oaks had the highest volume used for veneer logs, followed by black walnut. The remaining three oak species groups also represented a significant portion of the volume used for veneer logs but not nearly as much as the select white oaks and black walnut species groups. The loblolly and shortleaf pine species group and the cottonwood and aspen species group had the highest volumes of wood used for pulpwood. Soft maples and elms are also important for pulpwood production.

For fuelwood, the select white oaks species group was highest, followed by hickory and other red oaks. The volume of growing stock for logging residue by species group was similar to that of total removals, because logging residue is a by-product of removals and usage. The species most commonly removed for nonproduct uses (other removals) were the other red oaks and the select white oaks. Some species groups had a higher portion of their total removal volume in the other removals category than in the product removals category. These species groups included loblolly and shortleaf pine, eastern redcedar, other eastern softwoods, elm, black cherry, basswood, and other hardwoods.

The private individual was responsible for the greatest average annual volume of growing stock removed (Figure 51). This is to be expected, considering that the private individual ownership class owns the vast majority of Illinois timberland (Figure 36). The unavailable class in Figure 51 has the second-highest removal volumes, followed by the National Forest and corporate ownership classes. In the unavailable class, wood volume was removed by undetermined sources. The National Forest had a higher removal volume than the corporate ownership class, even though the corporate ownership class owns more timberland (Figure 36). Corporations not related to the forest industry own 96 percent of the timberland acreage in the corporate ownership class. This may account for the lower volume of removals compared with that of the National Forest.

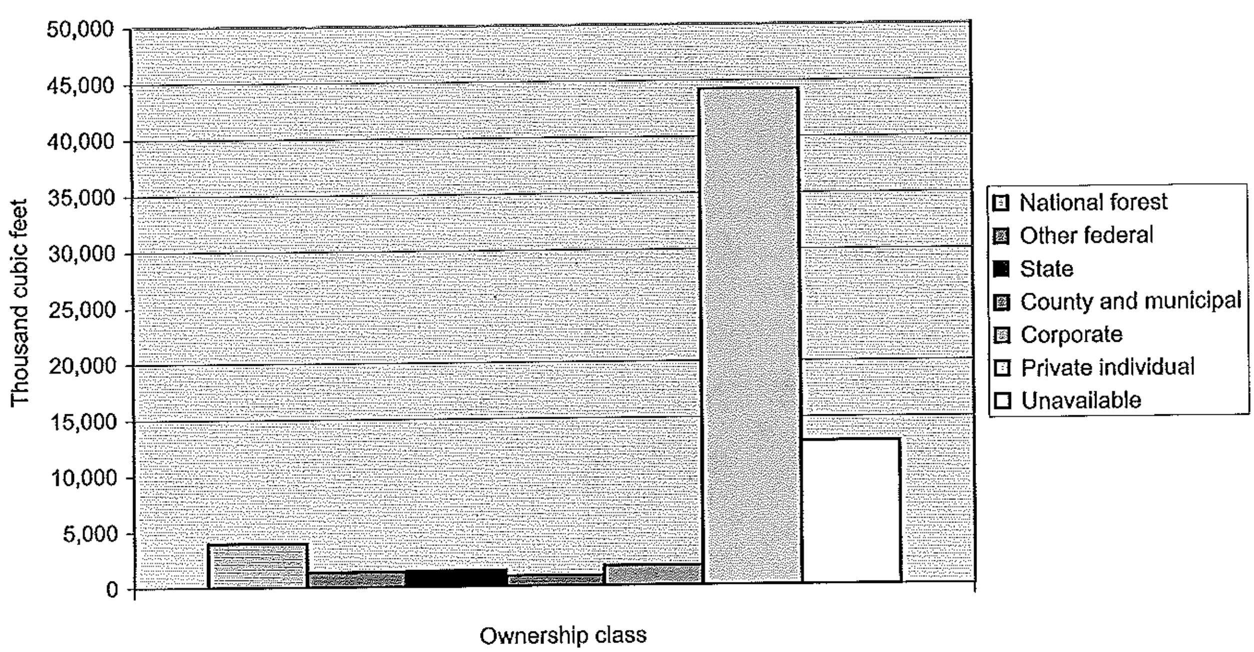
A total of 2,032 businesses in Illinois deal with forest resources (Table 23). The data for Table 23 are from information supplied by Dun & Bradstreet. Business establishments are categorized by a general business type and a specific business type. The general business types are forestry, lumber and wood products, and paper products. Forestry includes those businesses that deal directly with the forest resource itself, whereas lumber and wood products and paper products include businesses that convert the raw wood material into products used by consumers.

Figure 50.
Percentage of current and annual growing stock removals on timberland in Illinois by product/removal type, 1997.



Adapted from: Schmidt et al., 2000.

Figure 51.
Average annual removals of growing stock on timberland in Illinois from 1985 to 1997 by ownership class.



Adapted from: Schmidt et al., 2000.

The specific business type is a more detailed classification of the firms within each general business type. The majority of businesses in Illinois are in the lumber and wood products general type, but the paper products general type has both the highest sales volume (in 2000) and the greatest number of employees. Number of employees refers only to employees who work at a business's location in Illinois and does not include employees who work for a corporation at out-of-state locations.

The number of establishments in Table 23 is based on all businesses in Illinois that operate in any of the business types (general or specific) listed in the table. The primary business activity of some of the businesses summarized in this table is not forestry-related. Of the totals in the table, 12 thousand workers, $8 billion, and 253 establishments are from businesses whose primary business activity is different from the forestry-related one under which they are summarized. For these businesses, the forestry-related business type they are summarized under is a secondary or indirect business activity type. They perform their forestry-related activities as a secondary part of their operations instead of as the primary part. Some of these are companies that manufacture their own packaging for materials created in their primary business activity.

There are few businesses in Illinois that deal directly with the forest resource (Table 23). The majority of these are tree farms and timber tracts, where trees are grown for commercial harvest, and forest services. Many of the tree farms are Christmas tree farms. The low number of forest nurseries is due to the exclusion of nurseries that grow trees only for ornamental purposes. Businesses providing forestry services are those that can assist timberland owners with the various aspects of managing timber. As the importance of private ownership of Illinois timberland becomes recognized, a new opportunity for businesses in this field may exist. Figure 52 shows the number of forestry businesses by county. The majority of these businesses are in the Chicago area.

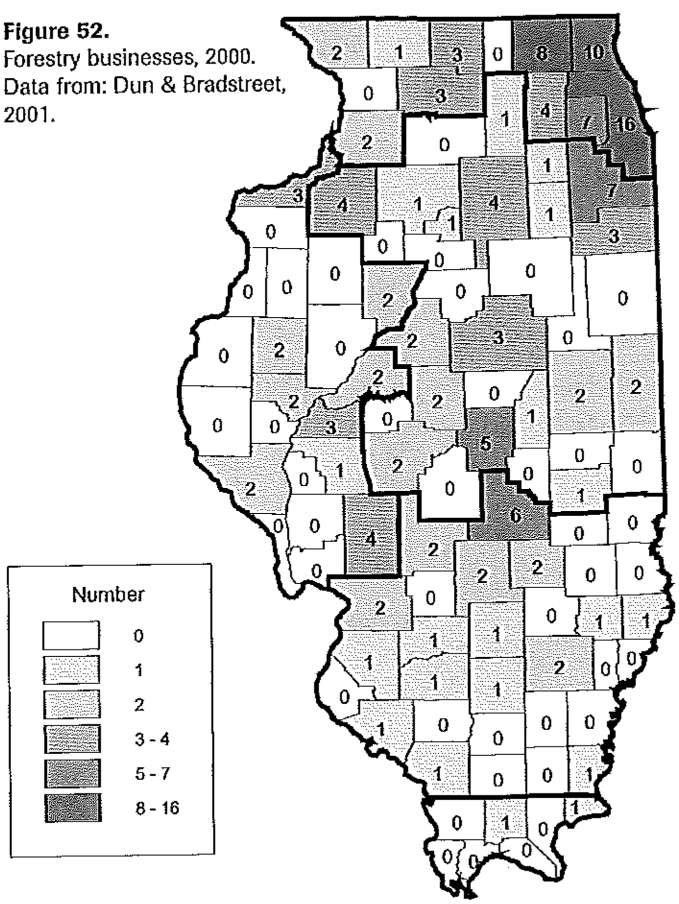


Figure 52.
Forestry businesses, 2000.
Data from: Dun & Bradstreet, 2001.

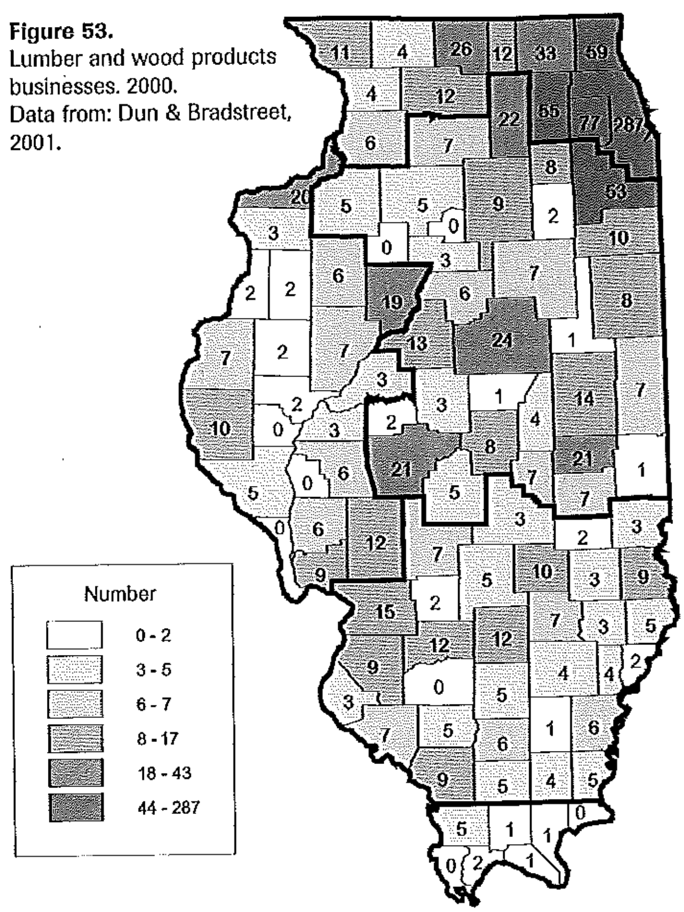


Figure 53.
Lumber and wood products businesses. 2000.
Data from: Dun & Bradstreet, 2001.

In the lumber and wood products general type, millwork has the most businesses, the highest annual sales volume, and the most employees (Table 23). Businesses that make wood kitchen cabinets and wood pallets and skids also have high numbers of employees in this general type. Structural wood members and reconstituted wood products also have large annual sales volumes. Figure 53 shows the number of lumber and wood products businesses by county for Illinois, and again the highest concentration is in the Chicago area.

Businesses involved in the manufacturing of paper products show a much higher annual sales volume than do the other two general types (Table 23). Companies that make miscellaneous paper products have the highest sales volume, followed by paperboard mills and paper mills. Manufacturers of corrugated and solid-fiber boxes employ the greatest number of people and have the highest number of establishments. Bag manufacturing and coated and laminated paper manufacturing businesses are also large employers. Many businesses manufacture paperboard products, and these businesses also employ large numbers of people. Most businesses that manufacture paper products are found in and around Chicago (Figure 54).

The forest resources of Illinois provide the majority of the total volume of saw logs used for products within the state (Figure 55). Iowa, Missouri, and Wisconsin combined provide only 3 percent of the saw-log volume used in Illinois' wood-using industries. However, only 72 percent of the total saw-log volume harvested in Illinois stays within the state for manufacturing (Figure 56). Indiana and Missouri combined receive 21 percent of the Illinois saw-log volume. Iowa and Kentucky are also significant importers of Illinois' saw logs. In effect, 72 percent of the saw-log volume produced in Illinois provides 97 percent of the saw-log volume used for manufacturing goods within the forest products industry in Illinois. The remaining percentage of saw-log volume produced is used by industries in other states. There is an opportunity for more wood-using industries in Illinois.

Figure 54.
Paper product businesses, 2000.
Data from: Dun & Bradstreet, 2001.

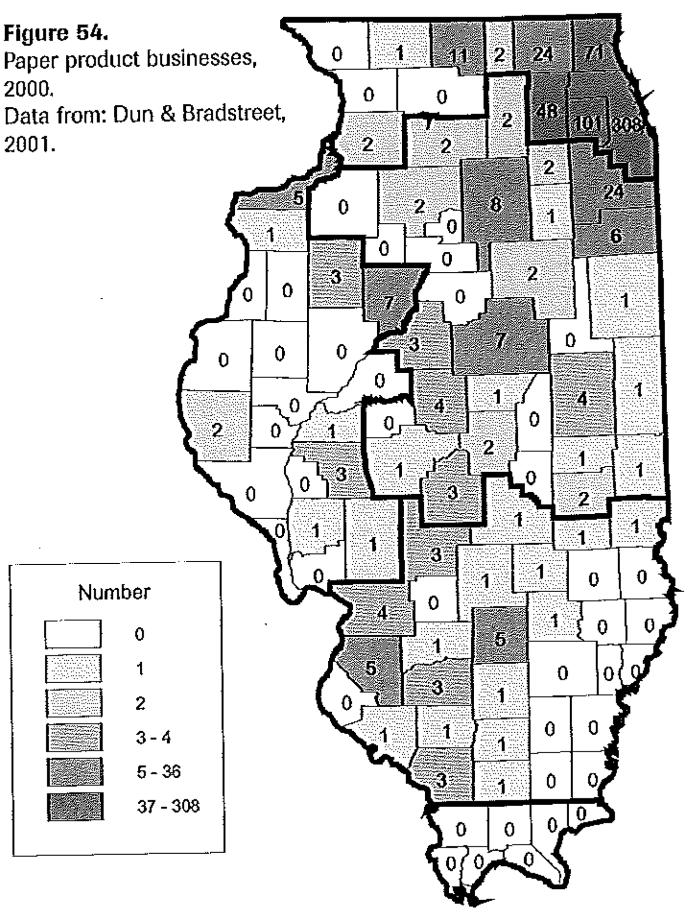
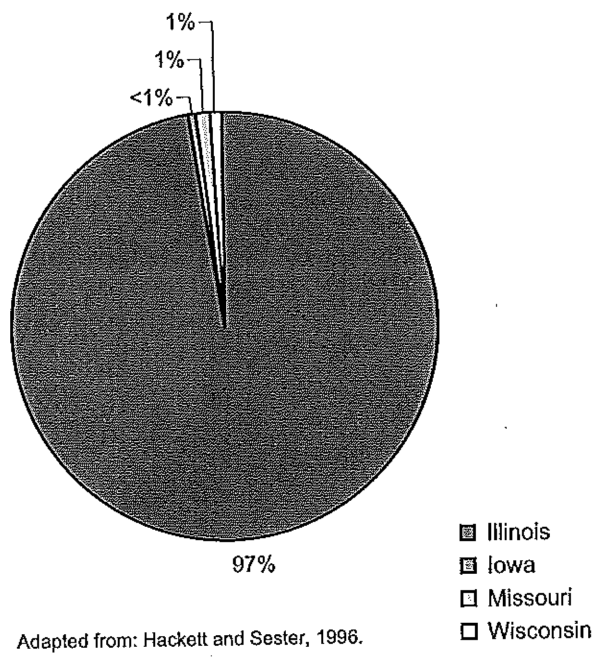


Figure 55.
Percentage of saw-log volume processed in Illinois by state of origin, 1996.



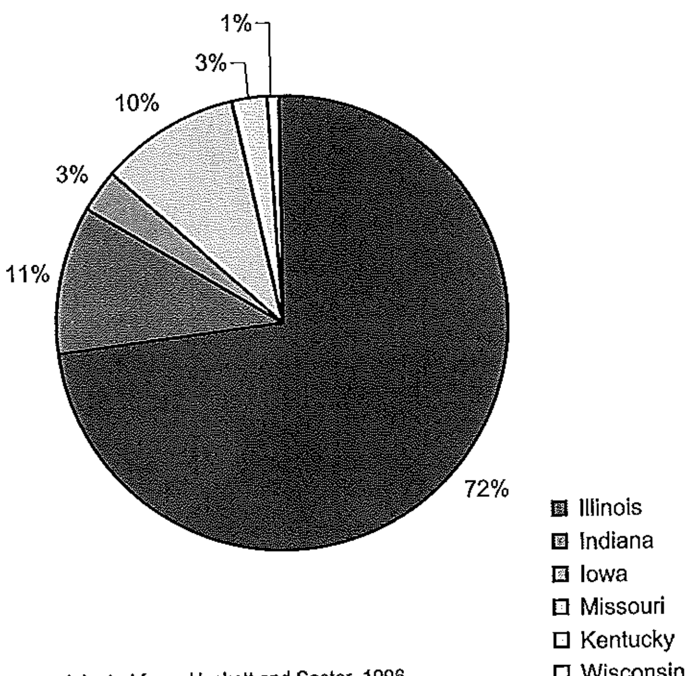
Adapted from: Hackett and Sester, 1996.

Not all the benefits received from the forest resources of Illinois are in the form of wood products. Many private landowners provide resources for hunting and fishing through sportsman club rents and leases. Some Illinois forests provide alternative products, such as medicinal plants and nuts, berries, fruits, and other edible plants and fungi.

Many benefits exist that are less quantifiable but no less important. A variety of benefits are derived from a healthy and viable forest resource. Noncommodity benefits include, but are not limited to, improved air and water quality, watershed protection, wildlife habitat, and recreational opportunities. There are 244.2 thousand acres of publically-owned reserved forest land (Table 3) available to the public as state parks, conservation areas, wildlife management areas, nature preserves, and recreational areas. This reserved forest land is well distributed throughout the state. Many recreational benefits exist within Illinois forests, where participants are involved in activities such as hiking, horseback riding, camping, fishing, and picnicking. The Illinois Department of Natural Resources estimates that more than 3.4 million Illinoisans spend in excess of $670 million participating in activities such as observing, feeding, and photographing wildlife. An estimated 350 thousand hunters and trappers spend more than 7.4 million days in Illinois each year. Their activities contribute as much as $627 million to the state's economy (Illinois Department of Natural Resources Office of Resource Conservation, n.d.).

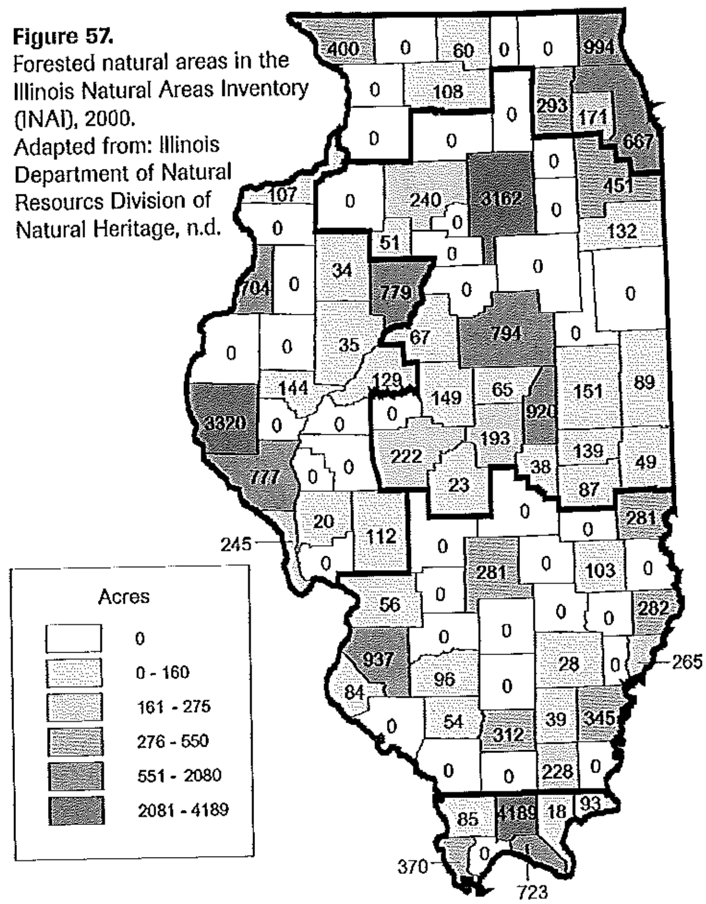
The forested areas on the Illinois Natural Areas Inventory (INAI) are valuable resources that serve as an example of the native forest vegetation in Illinois before European settlement. Table 24 shows the acreage in the various forest community types for the INAI. These community types are based on topographic position and soil moisture classes (White, 1978), rather than the dominant species within the forest that the USDA Forest Service uses. Wet-mesic floodplain forest has the highest acreage, followed by dry-mesic upland forest. Forest community types with small acreages include dry-mesic sand forest, xeric

Figure 56.
Percentage of saw-log volume harvested in Illinois by state of destination, 1996.



Adapted from: Hackett and Sester, 1996.

Figure 57.
Forested natural areas in the Illinois Natural Areas Inventory (INAI), 2000.
Adapted from: Illinois Department of Natural Resourcs Division of Natural Heritage, n.d.



upland forest, and wet-mesic upland forest. These areas represent very small remnants of original forest community types deserving protection. The total acreage of forested communities listed in the INAI is slightly less than 25 thousand acres. This is only 0.18 percent of the estimated 13.8 million acres of forest land in Illinois at the time of settlement. The acreage of INAI forest communities by county is shown in Figure 57, with the greatest number of acres in Johnson, Adams, and LaSalle Counties.

The importance of Illinois forest resources has not gone unnoticed. Many programs exist that help private landowners manage their timberland and plant trees to create future forest resources for Illinois. Many of these are cost-share programs, where the government pays part of the cost for activities related to proper forest management practices. The requirements of all programs, while differing in nature, specify certain management goals and objectives that must be met in order to receive cost-sharing benefits.

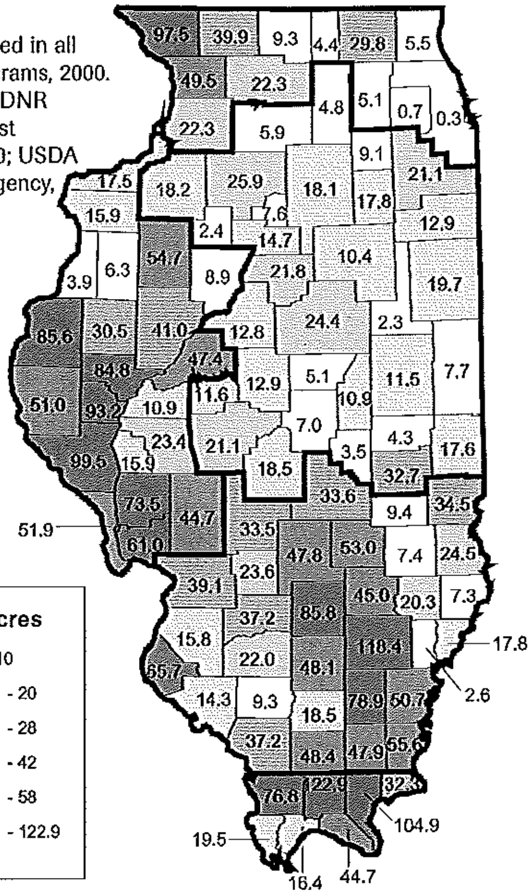
One of the most important programs is provided by the Forestry Development Act (FDA). This cost-share program is administered by the Illinois Department of Natural Resources Division of Forest Resources. Funds are obtained by collecting a harvest fee on all timber sales in Illinois. These funds then go to landowners who enroll in the program and can be used to help cover costs for a variety of forest management activities.

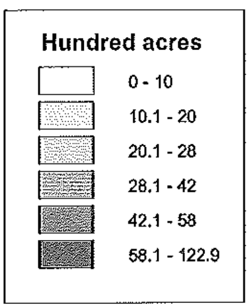
Another important cost-share program is the Conservation Reserve Program (CRP), which is a national program administered by the Commodity Credit Corporation (CCC) and the USDA Farm Service Agency (FSA). CRP provides cost sharing for a wide variety of resource conservation activities, many of which relate to forestry. In Illinois, the IDNR Division of Forest Resources administers management of forest land enrolled in CRP. An extension of CRP is the Conservation Reserve Enhancement Program (CREP), which focuses on geographic areas with specific environmental concerns. In Illinois this is the Illinois River. The Forestry Incentives Program (FIP) provides funds for timber stand improvements, tree planting, and natural regeneration on privately owned timberland and is administered by the USDA Natural Resources Conservation Service (NRCS).

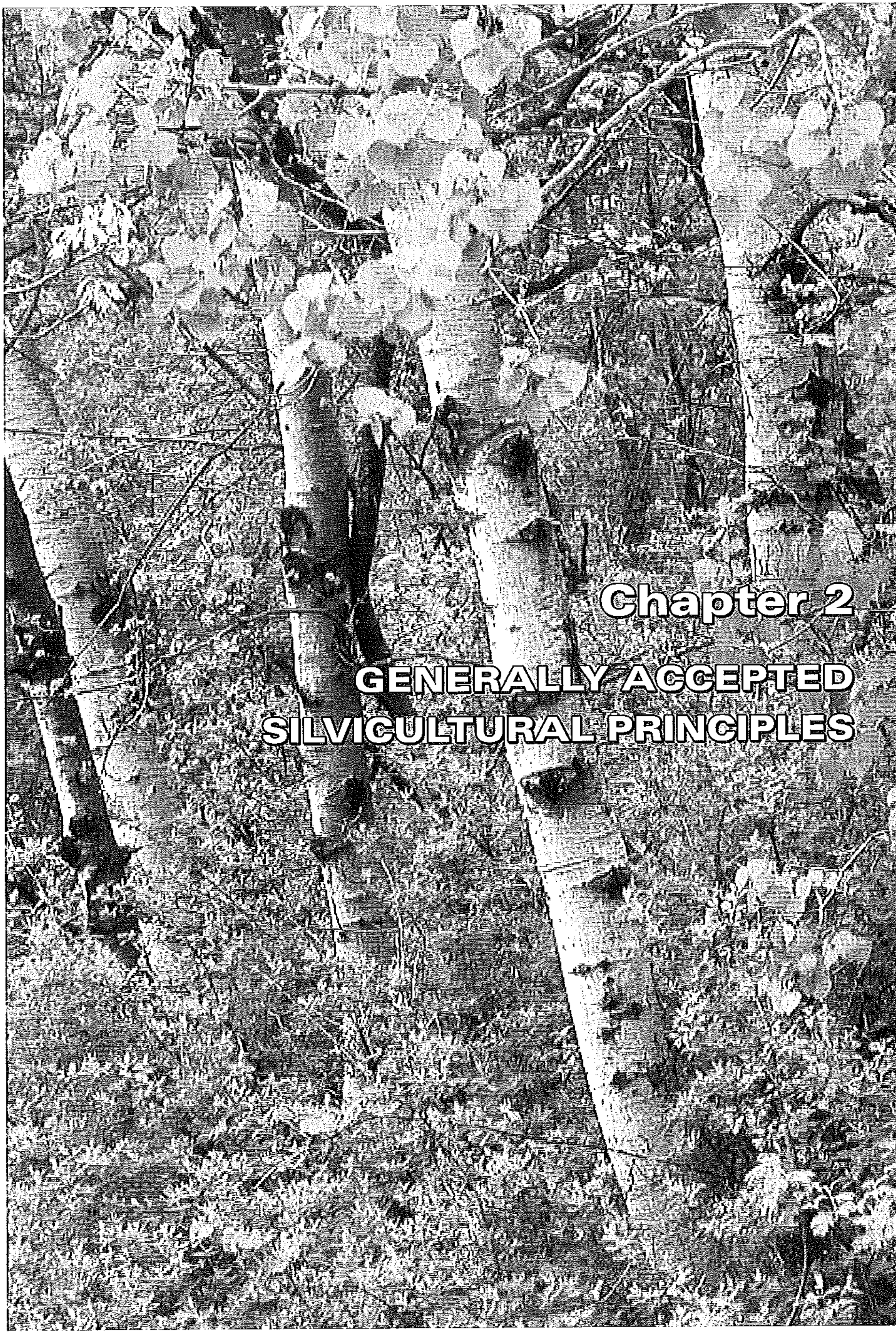
Table 25 shows the acreage of lands in Illinois by various management activities and the cost-share program under which the lands are enrolled. Caution should be used when interpreting Table 25, because lands enrolled in forestry-related practices under CRP or CREP are also often enrolled in the FDA program in Illinois. Those acreages cited under "FDA" are enrolled only in that program, while the majority of acres included under the headings "CRP," "CREP," "FIP," and "Other" are also enrolled in the FDA program. The IDNR Division of Forest Resources oversees the management of all forestry-related activities for these programs in Illinois. The category "Other" includes the following cost-share programs: Agricultural Conservation Program (ACP), Stewardship Incentives Program (SIP), and Wetlands Reserve Program (WRP). ACP and SIP are no longer being funded. The acreage listed represents the total number of acres enrolled in each program from the time of that program's inception to 2000.

The management activity under which the most acreage has been enrolled is tree planting. This will help provide future forest resources for Illinois. Timber stand improvement is also important, and all these acres are enrolled in the FDA and FIP programs. While not creating new forests for Illinois, this management activity is just as important because it improves the conditions of current forest resources in the state. The acres enrolled in riparian buffer zone protection help guard Illinois residents from the negative effects of soil erosion. The acreage enrolled in the combined cost-share programs for each county can be seen in Figure 58. The Southern Unglaciated, Western, and South Central Regions all have counties with large acreages enrolled. Johnson County has the highest enrollment, followed by Wayne and Pope Counties.

Figure 58.
Acreages enrolled in all cost-share programs, 2000. Adapted from: IDNR Division of Forest Resources, 2000; USDA Farm Service Agency, 2000.







2

Chapter 2

GENERALLY ACCEPTED SILVICULTURAL PRINCIPLES

SUSTAINABLE FORESTRY

FOREST ECOLOGY

The science concerned with 1) the forest as a biological community dominated by trees and other woody vegetation; 2) the interrelationships between various trees and other organisms constituting the community; and 3) the interrelationships between organisms and the physical environment in which they exist.

SUSTAINABLE FORESTRY

The practice of managing dynamic forest ecosystems to provide ecological, economic, social, and cultural benefits for present and future generations (from Ch.28.04(1)e, Wisconsin Statutes).

SILVICS

The study of the life history, characteristics and ecology of forest trees. It involves understanding how trees grow, reproduce and respond to environmental variations. The silvics of a particular tree species would describe the climatic range, temperature and light requirements, moisture needs, thermoperiodicity, soil conditions and topography, life history and development, commonly associated trees and shrubs, and any environmental, insect and/or disease factors that affect its growth and survival.

SILVICULTURE

The practice of controlling forest composition, structure and growth to maintain and enhance the forest's utility for any purpose.

Sustainable forestry practices must be based on compatible landowner objectives, the capabilities of each particular site and sound silviculture. Each of these factors is equally important.

Landowners' goals and objectives might encompass a wide range of values and benefits such as commercial products, recreation, aesthetics, wildlife habitat, endangered and threatened resources, and clean water. Understanding landowners' goals and objectives is essential to ensure that prescribed forestry practices are relevant and will endure over time. Landowners' goals and objectives must also be compatible with sustainable forestry defined as the management of dynamic forest ecosystems to provide ecological, economic, social, and cultural benefits for present and future generations. The silvicultural principles discussed in this guide assume that landowners are committed to sustainable forestry.

Site capabilities help define sustainable forestry practices. Each particular growing space has its own set of environmental conditions affecting tree growth. Factors like soil type, aspect and climate influence the moisture and nutrients available to individual trees and must be considered to ensure long-term forest health and vigor (see "Site Evaluation and Stand Delineation," page 17).

Silviculture is based on both forest ecology (relations between organisms) and the silvics (behavior or response) of individual tree species. Silvicultural systems are applied to stands of trees (rather than to individual trees) composed of species that commonly grow together. By definition, silviculture is the practice of controlling forest composition, structure and growth to maintain and enhance the forest's utility for any purpose. Silviculture is applied to accomplish specific landowner objectives.

The following sections of this guide will cover a number of silvicultural systems and harvest methods separately to facilitate the discussion of sound silviculture. These systems, however, are often most effective when used in combination to best accommodate differences between and even within stands. The ability to adapt silvicultural systems to address multiple objectives is limited only by one's imagination and creativity, making the practice of sustainable forestry both an art and a science. Table 2-1 (see page 41) summarizes the array of regeneration harvest methods generally considered acceptable for the forest cover types in Wisconsin.

LANDOWNER GOALS AND OBJECTIVES

Silviculture and forestry practices are not ends within themselves, but rather a means of achieving specific objectives in a landowner's overall goal to manage a forest on a sustainable basis. The test of a silvicultural prescription or recommended forestry practice is how well it meets the landowner's sustainable forestry goals and objectives.

As noted previously, landowner goals may be varied, reflecting a variety of forest values and benefits. Some goals may have a higher priority than others, but it is important to remember they are often interrelated, and generally depend on sound forestry practices to be realized.

Goals can be achieved by accomplishing specific objectives. For example, a goal of periodic income or maintenance of wild turkey habitat might be achieved through an objective to regenerate an oak timber type through small shelterwood harvests spread over time. Think of a silvicultural prescription as a site-specific "action plan" to accomplish objectives.

In developing goals, landowners should realize that although specific site characteristics of their land could make some objectives unsustainable, there might be other viable courses of action to choose from. It is up to the forester and other resource professionals to identify all options open to the landowner, and to use as much flexibility as possible in designing a silvicultural prescription that best addresses the full range of landowner goals (see Chapter 9: Forest Management Planning for more information).

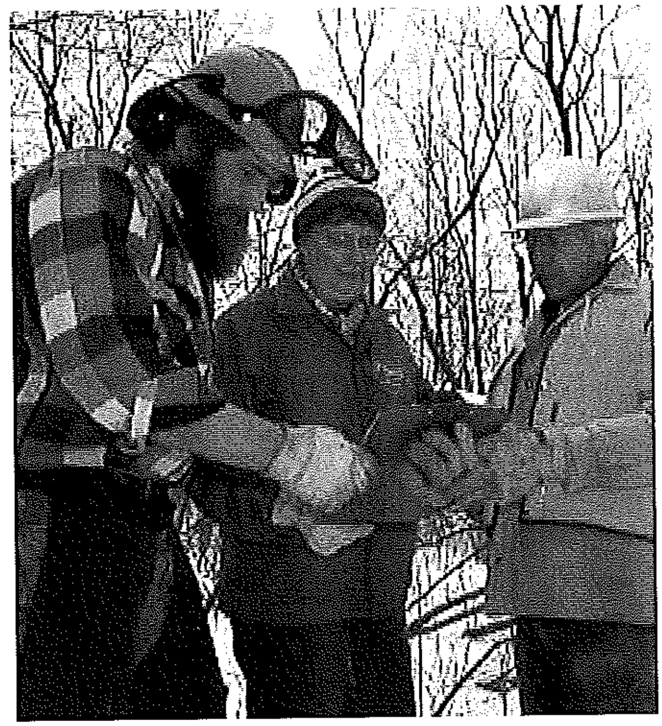


Figure 2-2: Landowners and resource managers should meet on-site prior to preparing a plan or conducting operations. Such meetings can help assure common understanding of landowner objectives, forestry prescriptions and site characteristics.

GOAL
A concise statement that describes a future desired condition normally expressed in broad, general terms that are timeless with no specific date by which the goal is to be achieved.

OBJECTIVE
Concise, time-specific statements of measurable, planned results that relate to overall goals.

Note: Generally, "goals" apply to an entire property and "objectives" to individual stands.

SITE EVALUATION AND STAND DELINEATION

Site capability determines what types of forestry practices are sustainable. A **site** is defined by the sum total of environmental conditions surrounding and available to the plants. A site is also a portion of land characterized by specific physical properties that affect ecosystem functions and differ from other portions of the land (Kotar, 1997).

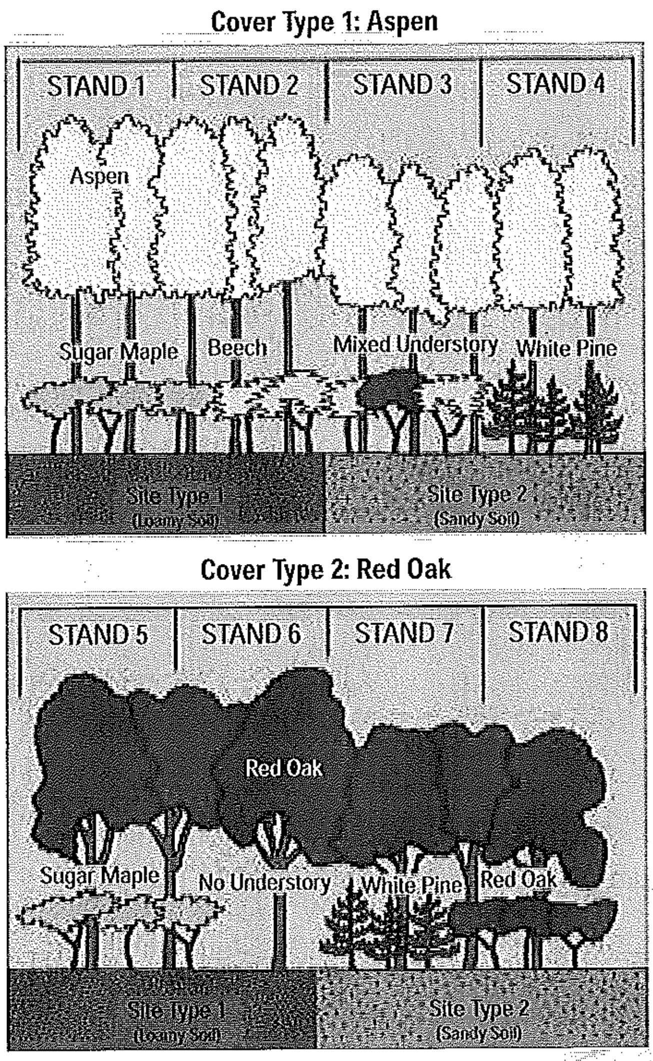


Figure 2-3: A schematic representation of two site types (loamy soil and sandy soil), two forest cover types (aspen and red oak), and eight stands. Each stand has unique composition and is defined by a specific combination of overstory and understory species. Each stand also can be considered as a unique ecological or silvicultural opportunity unit.

Forestry practices are carried out on a stand basis which determines where practices will occur. A **stand** may loosely be defined as a contiguous group of trees sufficiently uniform in species composition, arrangement of age classes, and general condition to be considered a homogeneous and distinguishable unit.

A stand is usually treated as a basic silvicultural unit. Stands are normally identified by the forest cover type involved (e.g., an "aspen stand," a "northern hardwood stand," or a "jack pine stand"). Cover types are discussed in more detail later in this chapter.

Forest stands are delineated through the use of aerial photographs, forest reconnaissance, inventory, and cruising. Sites are generally delineated based on soils, topography, landforms, geology, vegetation associations, and site index.

It is important to note that forest stands and sites often overlap each other. As illustrated in Figure 2-3, a single stand may occupy more than one site and a single site may support more than one stand.

Since a stand is the basic unit of silvicultural planning, care should be taken to ensure that it represents a uniform ecological opportunity unit. In other words, each specific site and stand combination has a unique set of silvicultural opportunities and constraints, which can be used to increase the number of outcomes available to the landowner. As shown in Figure 2-4 and Figure 2-5, defining stands by cover type and site type will facilitate the determination of management objectives.

Forest **site quality** is the sum total of all factors affecting the capacity to produce forests or other vegetation. Biotic and abiotic factors impact moisture, nutrient, and energy (light and heat) gradients, which determine vegetation growth and dynamics. Site quality affects tree growth, species composition and succession (plant community development). As site quality varies, so do forest management potentials and alternatives.

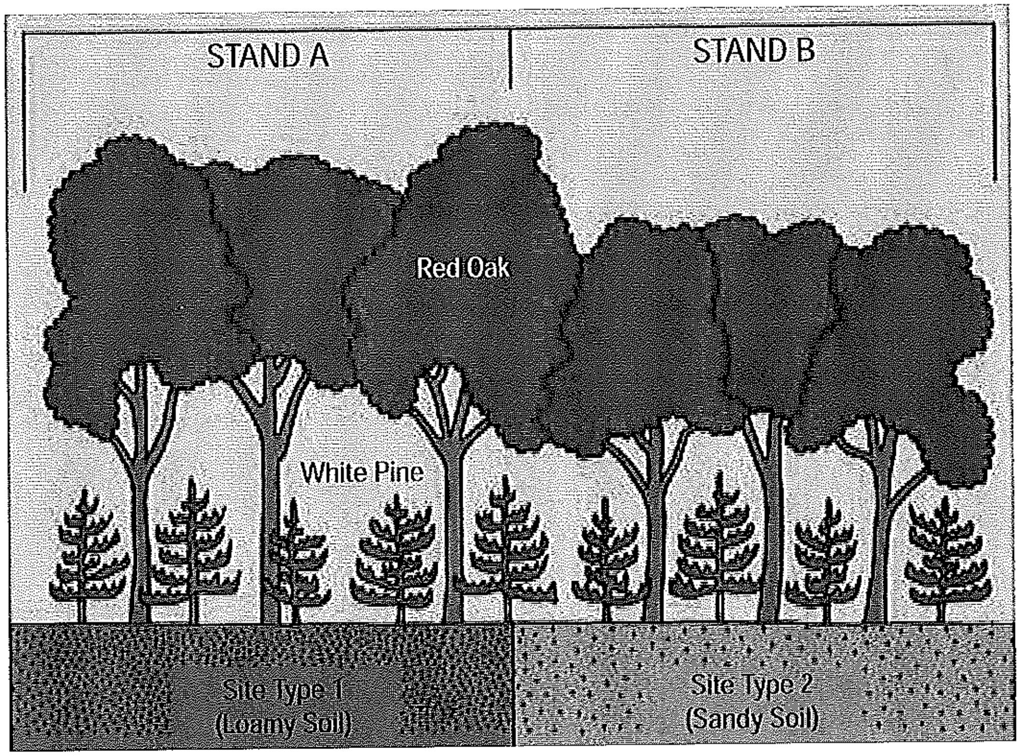


Figure 2-4: A single stand (red oak overstory with white pine regeneration) "straddles" two significantly different site types. Because ecological and silvicultural potentials differ for the two site types, the stand was split (A and B) to identify two ecological and silvicultural opportunity units.

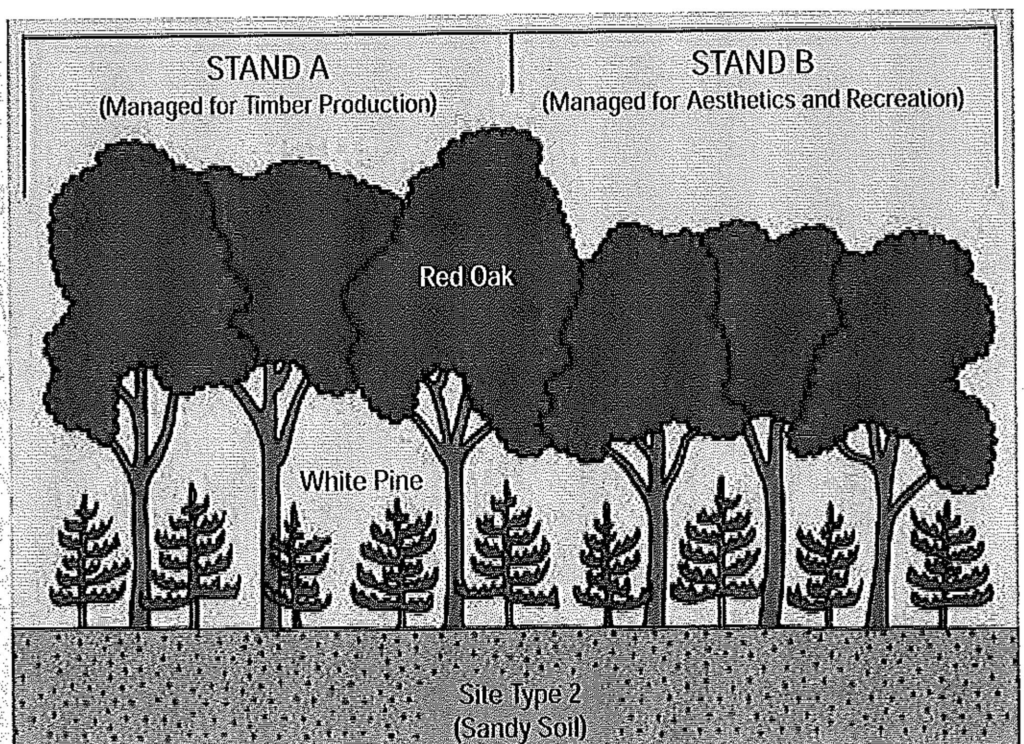


Figure 2-5: This stand is divided into two management units on the basis of different management objectives. E.g., in Stand A, oak will be harvested and white pine released to form a new crop, while in Stand B, oak overstory will be retained to provide a food source for wildlife and conditions for future old growth.

Forest site productivity is a measure of the rate of tree growth and overall wood volumes that can be expected on a given site. Productivity for a given species will generally vary between different sites as will productivity for different species on the same site.

There are direct and indirect ways to evaluate forest site quality and productivity:

- **Direct measures** of forest productivity such as historical yields and mean annual increment. These measurements are influenced by stand characteristics and may not be available.
- **Indirect measures** that relate environmental characteristics to tree growth and productivity are more commonly used. Indirect measures can be applied individually or in combination.
  - **Site Index:** Growth rates are measured and compared to tables that predict the height a particular species will attain at a given age.
  - **Vegetation Associations:** The number and relative density of key characteristic ground plants are measured, and a vegetative habitat type is identified. A great deal of inventory and other productivity date is available for each habitat type in Wisconsin.
  - **Physical Site Characteristics:** Examples include geology, landform, aspect, topography, and soil. These characteristics can be used to differentiate among types of sites that are significantly different with respect to their capabilities to support or produce different cover types or rate of tree growth. It is important to remember, however, that different combinations of individual site factors can result in functionally similar sites.

Regional site classification systems can provide tools to understand local site variability, impacts on site quality and productivity, and potential management alternatives.

Forest Cover Types and Silvicultural Alternatives

In a forested situation, tree species tend to occur in associations known as forest cover types. They range from a single tree species to several different species that commonly grow together on a specific site. The Department of Natural Resources recognizes 19 forest cover types statewide. It is important to understand that only a subset of these cover types will naturally occur on any given site, and, as a result, the range of sustainable management alternatives available are usually limited.

COMMON FOREST COVER TYPES FOUND IN WISCONSIN

Oak	Scrub oak	Northern hardwood
Aspen	White birch	Hemlock hardwood
Red pine	White pine	Central hardwoods
Jack pine	Red maple	Swamp hardwood
Cedar	Black spruce	Bottomland hardwoods
Walnut	Fir-spruce	Tamarack
Swamp conifer-balsam fir		

The forest cover type existing at a given point in time on a particular site will tend to change over time through the natural process of forest succession. Following a major disturbance such as fire or windstorm (or a silvicultural treatment designed to create similar conditions), a **pioneer community** normally invades a site. These communities (or forest cover types) are made up of sun-loving species able to rapidly establish themselves on an open, relatively competition-free, highly-disturbed site. Over time, the canopy begins to close and limit available sunlight, which results in other more shade-tolerant species becoming established.

As the original pioneer species are no longer able to compete, other **successional communities** better adapted to the changing microenvironment gradually replace them. A gradual transition to a number of different successional communities may occur as each gains a reproductive edge on the continually changing site conditions. At some point, after a long period free of disturbance, sites will transition to a potential **climax community** that is self-regenerating. This climax community will occupy the site until another disturbance creates conditions favoring re-establishment of a pioneer community (a major disturbance) or one of the earlier successional communities (a lesser disturbance).

In Wisconsin, these successional trends are fairly well understood for each ecological habitat type (site type). The pathways on some sites involve only a few stages; on others there may be several. Figure 2-6 is an example of the successional stages and trends on one particular site type.

An understanding of forest succession on a particular site can provide a great deal of useful information to a landowner evaluating potential management goals, and a forester developing the silvicultural prescriptions needed to achieve those goals. Referring to Figure 2-6, for example, one might reason:

- Only seven successional stages occur naturally on this site. Long-term management for quality northern hardwood or black walnut sawtimber, for example, would not be practical.
- Of the naturally occurring successional stages, some are currently more common at a landscape scale (as identified by the circles).
- Since a climax association is normally self-sustaining, maintaining an existing red maple, red oak, white pine, white spruce, and balsam fir type on this site would minimize regeneration costs.
- Based on the successional paths identified for this habitat type, the changes resulting from various levels of disturbance can be predicted. A partial removal of red pine overstory trees to release invading white pine, for example, would hasten the conversion from a red pine to a white pine timber type. On the other hand, a severe windstorm in a red oak-red maple stand might re-establish an aspen-white birch association for a period of time.
- Maintaining a pioneer or mid-successional stage would require a disturbance, such as active management, to overcome the natural tendency to convert to the next stage. Increasing light levels by maintaining a lower canopy density is needed to allow reseeding of the more light-demanding, earlier successional stages. Marking criteria would have to focus on releasing preferred species from more shade-tolerant species to ensure survival.
- Reversing the trend and going back to a previous successional stage would generally require a significant disturbance. Even-aged management would normally be needed to create conditions favorable for re-invasion by pioneer successional stages like aspen and white birch. Prescribed fire or mechanical scarification may be required to favor jack pine. Site preparation and planting would probably be needed to re-establish red pine. In general, the further succession is set back, the more disturbance and effort will be required.

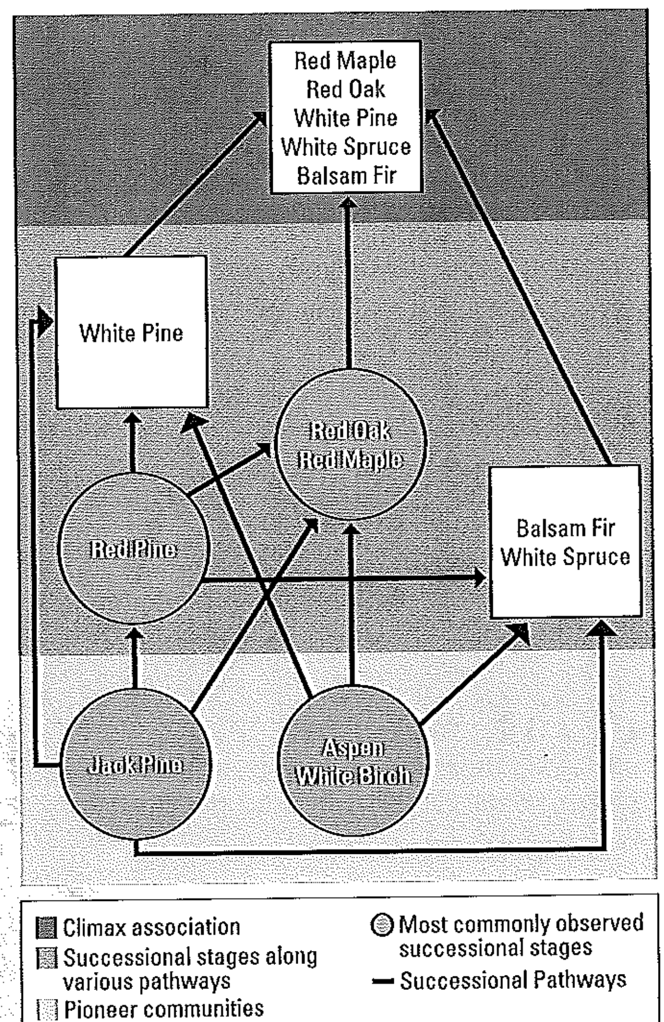


Figure 2-6: A generic example of the information available relative to the most commonly observed successional stages and probability of succession for a particular site type.

SILVICULTURAL SYSTEMS OVERVIEW

A **silvicultural system** is a planned program of vegetative manipulation carried out over the entire life of a stand. All silvicultural systems include three basic components: **harvest, regeneration and tending.** These components are designed to mimic natural processes and conditions fostering healthy, vigorous stands of trees. Typically, silvicultural systems are named after the regeneration method employed to create the conditions favorable for the establishment of a new stand.

A **harvest method** differs from a simple harvest cut in that it is specifically designed to accomplish two objectives – removal of trees from the existing stand, and the creation of conditions necessary to favor regeneration and establishment of a new stand. The method selected depends on the species to be regenerated or established in the new stand. Harvest methods vary from the complete removal of a stand in a single cut or in stages over several years, to the selection of individual trees or groups of trees on a periodic basis.

A **regeneration method** is a process by which a stand is established or renewed. The various methods include: 1) removal of the old stand; 2) establishment of a new one; and 3) any supplementary treatments of vegetation, logging residue, or soil applied to create conditions favorable for the establishment of reproduction. There are two general regeneration techniques:

- **Natural regeneration systems** rely on natural seeding or root/stump sprouts and are generally carried on concurrently with the harvest process. In some cases, additional follow-up activities (e.g., scarification, understory competition control, slash treatment, or prescribed fire) may be necessary.
- **Artificial regeneration systems** depend on the planting of tree seedlings or seeds. Generally, planting occurs on non-forested land or following complete removal and harvest of a forest overstory and results in an even-aged stand. Examples of artificial regeneration systems are:
    - **Afforestation:** Establishing a new forest on non-forested land.
    - **Reforestation and Conversion:** Forest type conversion when the desired species is not present or is inadequately represented to provide sufficient seed or vegetative reproduction.
    - **Reforestation and Re-establishment:** Forest type re-establishment when the desired species are difficult to regenerate, and it appears to be more efficient to utilize artificial regeneration than to depend on natural regeneration.

Table 2-1 (see page 41) shows the regeneration harvest methods described in this chapter as generally accepted for application to Wisconsin forest cover types.

Tending includes a variety of intermediate treatments that begin after regeneration is established and are implemented as needed throughout the rotation of a forest stand. These treatments include pruning, release, thinning/improvement, and salvage/sanitation. They are done to improve stand composition, structure, growth, quality and health, and to produce specific benefits desired by the landowner. Some tending operations are non-commercial (e.g., pruning, early release of crop trees, precommercial thinning), requiring outright investment by the landowner, and can be collectively referred to as timber stand improvement (TSI). Other tending operations, such as commercial thinning, can generate revenue for a landowner. Intermediate silvicultural treatments are discussed in detail in Chapter 16: Intermediate Silvicultural Treatments.

Several different silvicultural systems are discussed in detail in the next section of this chapter, emphasizing the particular rationale and goals of each. Although each system is discussed separately to aid in understanding, **it should be understood they are commonly used in combination to best accommodate site differences between and within stands.** Flexibility and imagination are key in tailoring silvicultural systems to address the host of values inherent in sustainable forest management.

Land measurement and survey

AN INTRODUCTION FOR WOODLAND OWNERS

J.J. Holmberg

Land measurement and survey relate to most areas of forest management. Knowing how land is measured and how to use maps and surveys is a necessary part of planning and implementing forest management activities.

SURVEY TYPES AND USES

Generally, surveying means gathering and processing information about the physical earth. It's the science of determining relative positions of existing points on the earth's surface or of establishing such points. Methods range from aerial and satellite systems to conventional ground methods. Survey professionals use a variety of methods to produce easy-to-use maps that are essential for effective land management. Surveys help you locate property boundaries, roads, structures, watercourses, and other physical characteristics of the land.

Familiarity with how property lines are marked is valuable. For example, when property lines cross roads, reference tags often indicate the location where the line and road intersect. Other important points often are marked in the forest with corner posts and with blazed, flagged, or posted lines between them.

Here we'll consider *plane surveys*. In plane surveying, the earth is assumed to be a flat horizontal surface (a plane). The calculations involved in plane surveying are relatively simple. For most purposes, plane surveys' level of accuracy is sufficient. When putting in a new road or logging 40 acres, for example, it generally doesn't matter if you are off by a fraction of a foot.

When surveying a large area, surveyors will calculate to compensate for the curvature of the earth's surface. This is called *geodetic surveying*. It is a technique used to determine relative positions of widely spaced points, and it takes into account the size and shape of the earth.

Another type of survey is *photogrammetric surveying*, which uses data obtained by cameras and other sensors. Photogrammetry has been used in natural-resource management for decades, and aerial photography is a must for planning purposes today.

Remote sensing, or use of satellite data, is a newer tool. Other survey types include:

- *Control surveys,* which serve as a reference framework for other surveys
- *Construction surveys,* which are used in civil engineering projects
- *Property surveys,* which establish property corners, lines, and areas of parcels
- *Cadastral surveys,* which are the most common type of property survey. They create, restore, mark, and define property lines of parcels of land to describe individual ownership. The official survey plat is a graphic representation drawn to scale that depicts the actual survey as described in the official field notes. The plat illustrates lot sizes and locations, bearings and distances, and corners, courses, and distances of surveyed lines. Most townships in the Northwest have one or more cadastral survey plats.

Joseph J. Holmberg, Extension forestry outreach educator, Oregon State University. Some material for this publication was drawn from the 2000 edition of *Watershed Stewardship: A Learning Guide* (Oregon State University Extension publication EM 8714), by Flaxen Conway, Derek Godwin, and Michael Cloughesy.

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- *Topographic surveys,* which are used to create the topographic maps commonly used in natural resource work
- *Route surveys,* which usually are required prior to construction of highways, railroads, pipelines, power lines, etc.
- *Hydrographic surveys,* which result in navigational charts and other maps of water bodies

Rectangular Survey System

Most of the United States (outside the 13 original colonies) has been surveyed using the *rectangular survey system* or the *Public Land Survey System.* This is the kind of survey you'll be most likely to work with.

In 1785, the Congress of the Confederation enacted a Land Ordinance for the public lands northwest of the Ohio River. The law provided for the survey of public lands into townships of 36 square miles each. The Ordinance also established the use of the Cadastral Survey Plat, a system for recording land patents and related records essential to the chain of title. The rectangular survey system and, in 1800, the tract book system for permanently recording titles became the standard for transferring public lands into private ownership as western migration progressed.

In 1789, Congress established the Treasury Department and gave it responsibility for overseeing the sale of public lands. The General Land Office (GLO) was created in 1812 within the Treasury Department to oversee the sale and transfer of public lands into private hands. The GLO was transferred to the new Department of Interior in 1849. In 1946, the Bureau of Land Management (BLM) was created by merging the GLO and the Grazing Service.

BLM cadastral surveyors still must perform and review surveys of all federal lands being transferred by sale, donation, acquisition, or exchange. The BLM continues to provide GLO land and mineral recordation services for federal lands. The Oregon State Office of the BLM maintains a complete collection of all land status records, cadastral survey records, and mining claim records for Oregon and Washington. The Idaho State Office maintains records for Idaho.

BLM status records are current only for federal lands. Once land leaves federal ownership, subsequent private title transfers, rights, and restrictions are recorded in the appropriate county assessor's office.

How the Rectangular System Works

The rectangular system sets up a grid, with the objective of obtaining approximately square *sections* of 1 square mile each (1 mile on a side). One mile = 5,280 feet.

To understand the rectangular survey system, you need to know about meridians and baselines. *Meridians* are north–south lines, and baselines are east–west lines. A *principal meridian* is a true north–south line that runs through an initial point to the limits of the area being covered. At 37 locations in the United States, an initial point has been established where a principal meridian and a baseline intersect. These points were located through astronomical observations and don't change. Using these 37 points, control can be established for surveys anywhere in the continental United States.

In Oregon and Washington, the rectangular survey system is referenced to the north–south Willamette Meridian and to the east–west Willamette Baseline. These two lines cross at an initial point called the Willamette Stone, located in the west hills of Portland. In Idaho, the system is referenced to the Boise Meridian and Baseline, the initial point of which is in Meridian, Idaho.

Townships are approximately 6 miles on each side. They're numbered from the baseline, starting with Township 1 North (T1N) north to the Canadian border and Township I South (TIS) south to the California and Nevada state lines. Ranges are numbered from the meridian west (e.g., R1W) and east (e.g., RIE).

From each initial point, a grid of townships is established north and south of the baseline and east and west of the principal meridian.

Thus, a township six grid locations north of the baseline and two grid locations west of the principal meridian would be designated as T6N, R2W Similarly, a township three grid locations south of the baseline and six grid locations east of the principal meridian would be designated as T3S, R6E (Figure 1).

Normal townships contain 36 sections. Each section is approximately 1 mile square and contains 640 acres. (One acre = 43,560 square feet.) All townships use the same system for numbering the sections within them. Sections are numbered beginning with number 1 in the northeast corner, going west to number 6, then south to 7, east to 12, south to 13, and so on (Figure 2).

Every section has four quarter corners, which usually are the midpoint on each of the lines forming the boundaries of the section. Sections can be divided into *quarters* and *halves* by connecting these points. With a line drawn north–south or east–west through the center of a section to connect two quarter corners, the section is divided into halves. Each half is identified by its location in the section (north half, south half, east half, or west half).

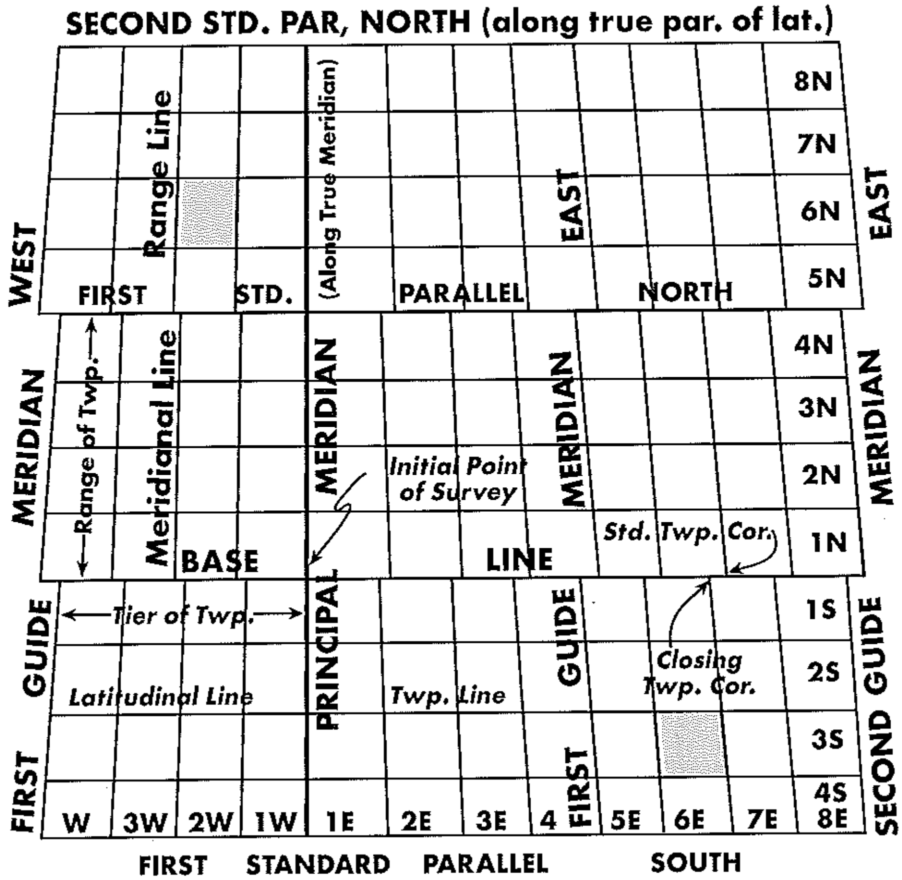

Figure 1.—An example of township and range numbering.

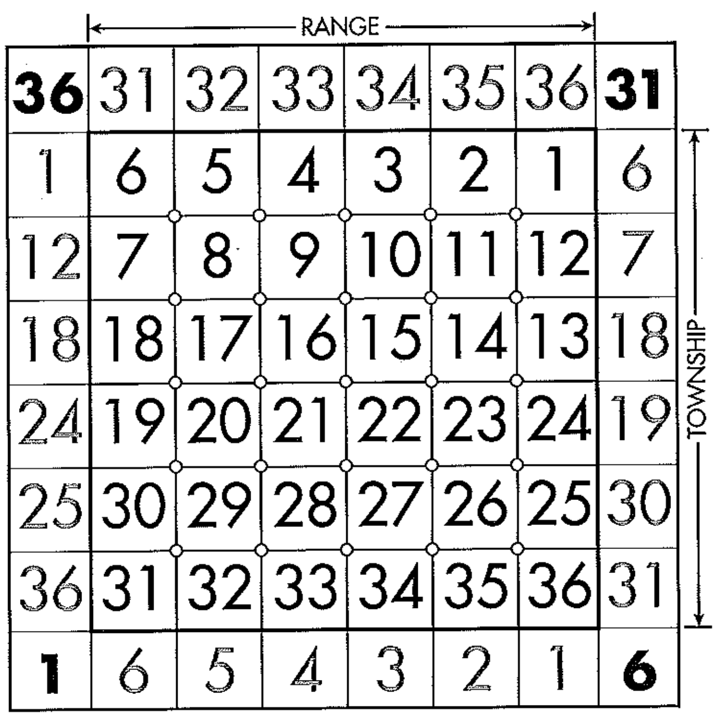

Figure 2.—Standard township plat.

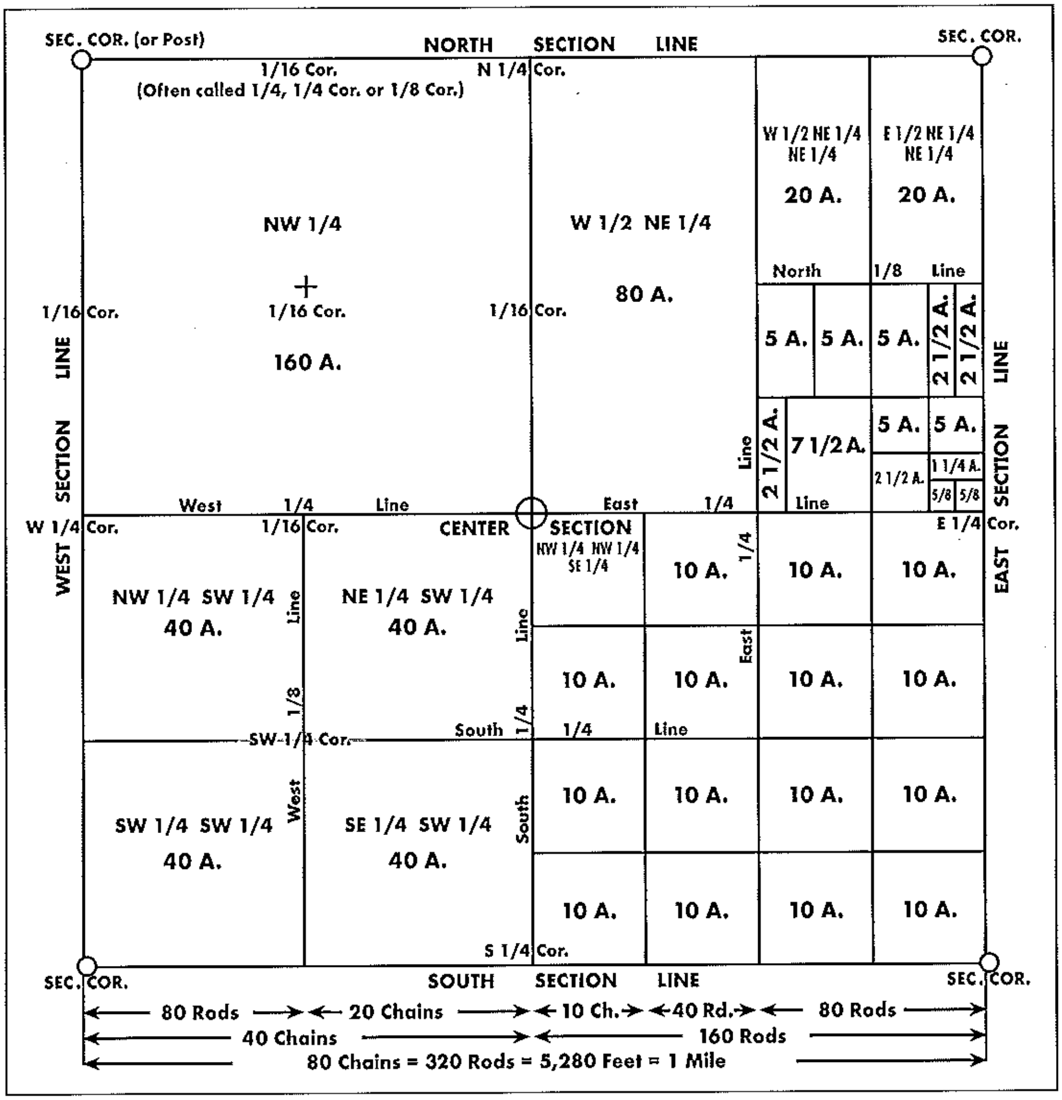

Figure 3.—Section of land (640 acres) showing minor subdivisions and corners.

With lines drawn north–south *and* east–west through the center of a section to connect all four quarter corners, the section is divided into quarters (Figure 3). Again, each quarter is identified by its location in the section (northeast quarter, southeast quarter, northwest quarter, or southwest quarter).

Halves and quarters can be subdivided further. Thus, a 40-acre block might be identified as SW1/4 NW1/4, Sec. 14, T2S, R3W, Willamette Meridian. A legal description then follows in parentheses. The legal description for small ownerships often includes a block identification that may not match the quarters of a section.

Sometimes the grid isn't perfect. For example, although every section basically is square and has four corners, these corners may or may not be shared with the adjoining section. And although each section should be 1 square mile and there are 640 acres in 1 square mile, not all sections have 640 acres. How can this be? The reason is that it can be difficult to match edges of adjoining townships if the townships were surveyed at different times. There also need to be adjustments because of the curvature of the earth. Often we have offset corners that act as a kind of "fudge factor" to avoid overlapping ownerships; then, the result is sections that don't have exactly 640 acres. These sections generally are along the western edge of the township.

THE LEGAL BASIS FOR SURVEYS

The federal survey system is based on two principles that provide the legal background for establishing land lines. The first principle is "Boundaries of public lands established and returned by duly appointed surveyors are unchangeable." In other words, if your land adjoins federal lands, and the federal land is surveyed correctly, the property line won't change, no matter what your licensed surveyor may say.

The second principle is "Original township and section corners established by surveyors must stand as the true corners which they were intended to represent, whether in the place shown by the field notes or not." This principle is required because interior lines are established off the section lines. Thus, if an original section line isn't correct, no other lines are correct.

For a survey to be legally binding, it needs to be conducted by a licensed cadastral surveyor and tied into an established corner.

Reading Maps

This section will help you learn to use maps to locate on-the-ground features at a scale typical of forest management projects.

Most project work requires you to use a variety of maps. You use large-scale maps to make landscape-level plans. After you determine the need for a project and see how it fits into the broader landscape, you'll need stand-level maps.

We'll discuss two kinds of stand-level maps: transportation maps and topographic maps.

Transportation Maps

Although a *transportation* map (Figure 4) typically covers a large area such as an entire state or county, it's also a stand-level tool because you can use it to locate areas where project work occurs.

Transportation maps vary in design depending on who owns the land. Each government agency usually uses a consistent design, but there's little consistency across agencies and even less among maps of private and public lands.

Typically, Forest Service maps concentrate on roads on National Forest lands and might not show other connecting roads. BLM maps do the same for BLM lands. This inconsistency can be a problem if you're working in an area with checkerboard ownership. Forest Service and BLM transportation maps are available at National Forest ranger districts and BLM district offices.

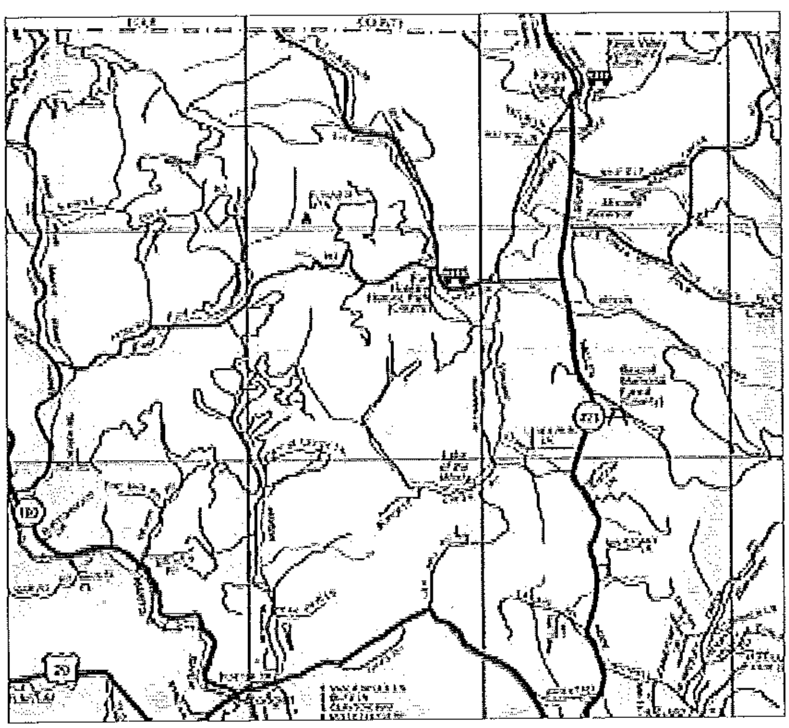

Figure 4.—An example of a transportation map.

TOPOGRAPHIC MAPS

Topographic (topo) maps show relief, hydrology, vegetation, and human-made structures (Figure 5).

Topo maps and transportation maps show many of the same features, although each puts more detail into different elements. When comparing topographic and transportation maps, for example, you see topographic features such as ridges and valleys on each. These features are much better defined on topo maps, however. Because topo maps show roads, they can be used as transportation maps. However, most topo maps aren't updated as frequently as transportation maps are.

The U.S. Geological Survey (USGS) produces topographic maps. Oregon, for example, is represented by 1,925 USGS topo maps, which depict natural and cultural features of the landscape.

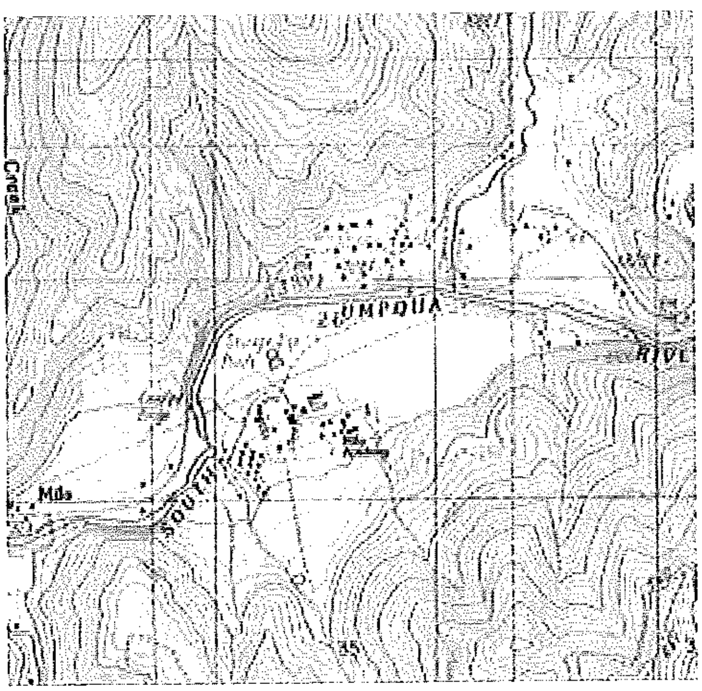

Figure 5.—An example of a topographic (topo) map.

Older USGS topo maps are available as 15-minute quadrangles (quads) with a scale of 1:48,000 (1 inch on the map represents 4,000 feet on the ground).

Newer USGS topo maps are available as 7.5-minute quads with a scale of 1:24,000 (1 inch on the map represents 2,000 feet on the ground). Please note that the 1:24,000 map is actually *twice* the scale of the 1:48,000 map, which might seem counterintuitive.

MAP SCALES AND DISTANCES

Distances measured from maps are accurate only if the map is drawn to scale. You also need to know the scale to convert map distance to ground distance.

Map scales are written either as a ratio (1:12,000) or a representation (1 inch = 1 mile). In the first case, 1 inch on the map represents 12,000 inches (1,000 feet) on the ground. In the second case, 1 inch on the map represents 1 mile on the ground. In either case, you can find the ground distance between two points on the map by measuring with a ruler and multiplying by the map scale.

To try this out, select two points on a topo map. Measure the map distance using a scale or ruler that shows inches and tenths of inches. Now multiply the measured distance by the map ratio. Convert inches to feet. You've calculated the horizontal ground distance between the two points.

Enlarging maps using a photocopier provides an accuracy suitable for most woodland management applications. For example, a 1:24,000-scale USGS topo map can be enlarged 200 percent to a 1:12,000-scale topo map. Distortion can be a problem, but the price is very reasonable. By enlarging a map 200 percent and photocopying it onto acetate, you can make topographic overlays to use with 1:12,000-scale aerial photos. Caution: If the scale is too large or too small, the map may not be of much use.

Direction

Maps are made with direction in mind, and the top of a map usually is oriented to north. If you know how to read the direction between two points on a map, then you can use a compass to find the same direction on the ground and move from point to point.

Direction is measured as *azimuths* or *bearings.* Azimuths are based on the 360 degrees of the compass. North can be described as either zero degrees or 360 degrees. Azimuths are read clockwise from north, so east is 90 degrees, south is 180 degrees, and west is 270 degrees.

Bearings are based on four 90-degree quadrants. Beginning from a north–south line, bearings are read from north to either east or west *or* from south to either east or west. For example, a bearing of N 45 degrees W is the same as an azimuth of 315 degrees, and a bearing of S 30 degrees E is the same as an azimuth of 150 degrees. Bearings are no more than 90 degrees because each quadrant contains only 90 degrees.

A lot of map work is done in azimuths rather than in bearings because azimuths can be read more easily from a map using a 360-degree protractor. For example, select two points on a map and draw a line true north–south through one of the points and a line between the two points. Lay the protractor oriented north–south on the north–south line with the center of the protractor on the point. Where the line crosses the edge of the protractor, read the true azimuth from point to point.

Azimuths between points taken from maps are accurate only if the maps are drawn to scale. The scale used doesn't matter. In fact, you can measure the azimuth between two points on a map without knowing the map scale.

Figure 6.—An aerial photo.

Using Aerial Photographs

Aerial photographs (Figure 6) can be used like detailed maps, but they usually contain some distortions that you must recognize and account for.

Aerial photos are used by all types of natural resource workers, from timber sale layout personnel to wildlife biologists. Aerial photos can be used to divide the land base into stand-level units by identifying vegetative communities. Satellite photos are used for broad-based planning efforts that look at the largest landscape scales.

Early photos were black and white. Now, high-resolution color photos show species, density, tree height, and many other attributes of a forest, stream, or landscape.

The present industry standard for stand-level photo coverage is a 1:12,000-scale color photograph. At this scale, with the aid of a hand lens, you can recognize an individual tree or brush clump as small as 2 feet in diameter. Permanent inventory plots throughout the forest usually are established by marking locations on the photo with a pinprick and then finding those locations on the ground.

The detail visible on aerial photos is limited only by the eyesight of the user. People with poor eyesight or those who are color blind have difficulty interpreting aerial photographs. They have to make an extra effort to recognize what they are seeing.

Most photographs are oriented with the top of the photo to north. The top of the photo has information about the flight line number, photo number, date of flight, and land ownership. When ownership is a more-or-less rectangular block with the long axis oriented east–west, the photos may be oriented east–west as well. The three basic camera angles for aerial photography are vertical, high oblique, and low oblique. The kind of photos we discuss here use a vertical angle; that is, the camera is aimed straight down.

Seeing topographic features on aerial photos

A unique feature of aerial photography is the ability to see three-dimensional images of the land base, which makes it possible to see the topography of the land. This feature makes aerial photos extremely useful not only for planning purposes but also for locating on-the-ground features.

Most people need overlapping photos and a tool called a *stereoscope* to see three-dimensional images. Overlapping images are obtained by following a flight line across the land base and taking pictures at predetermined intervals. People with good stereo vision and eyes of equal strength often can see three-dimensional images without a stereoscope.

Photo scales and distances

Because aerial photographs are like detailed maps, the principles of scale and distance are similar to those for maps. However, photos can create problems when you use them to measure scale and distance.

Most scale variation results from changes in elevation of the ground's surface. The airplane's altitude is based on the average elevation of the ground to achieve the desired scale (1:12,000). The plane maintains that elevation for all flight lines in a photo series. As the ground comes closer to the camera or gets farther away because of elevation changes, the photo scale changes.

You can adjust each photo's scale using on-the-ground measurements. On a photo, find a straight stretch of road. Put a pinprick at both ends of the road on the photo and also mark them on the ground. Then measure the ground distance from one end of the road to the other. Measure the same distance on the photo. Then determine the ratio between the ground distance and the photo distance between the two pinpricks. Use this ratio to determine the true photo scale. Be sure to compare apples to apples; that is, either convert both measurements to feet or both to inches.

Images on aerial photos are displaced slightly, either toward or away from the center of the photo (the *principal point*). This displacement increases as you move away from the principal point. You can find the principal point by projecting horizontal and vertical lines from the fiducial marks on each edge of the photo (for example, see the black triangle on the right edge of Figure 6).

When making measurements on a photo, it's important to use the center area near the principal point. For best accuracy, the two ends of the road or other line being measured should be on opposite sides of, and equally distant from, the principal point.

Distortions due to topography and camera tilt are removed in *orthophotographs*. Orthophotos look like any aerial photo, but directions and dimensions can be scaled from them.

Direction

Because aerial photographs are like detailed maps, you can obtain azimuths from photos just as you can from maps. However, be aware that most photos have some *crab* or *drift*. These are terms for misalignment that occurs when the camera or airplane is oriented incorrectly during aerial photography. This misalignment skews the orientation of the photo from true north–south or east–west.

You can determine a true baseline for each photo by finding a straight stretch of road, sighting down the road with a compass, and comparing the azimuth or bearing you read to the azimuth or bearing of the same stretch of road as measured from the photo.

Geographic Information System (GIS)

GIS stands for *Geographic Information System*. GIS uses digital geographic information stored on computers to make maps. GIS ties information about various resources to a digital base map. Information on each type of resource is stored as a mapping layer, like layers of acetate laid over a base map. Resource layers commonly include the public land survey system, topography, transportation, water, vegetation, geology, and land ownership. This allows complex analysis and modeling.

GIS is generally an application for owners of large properties, but some owners of smaller properties are finding it useful. To do planning on a landscape level, land managers look at the distribution of elements in ecosystems through both space and time. To do so, they need to be able to manage and manipulate vast amounts of data. GIS gives them this capability.

Decisions on natural-resource issues related to forestry require data on transportation networks, hydrography, boundaries, and elevations. State and federal agencies and local and tribal governments provide these data for the Digital Map Library, which is operated by the USGS State Service Center for Geographic Information Systems. The partnership helps eliminate duplication of effort, and it funds new data collection. Some data are free to the public, allowing people in rural areas access to information which they otherwise wouldn't be able to obtain readily.

Global Positioning System (GPS)

GPS stands for *Global Positioning System*. The GPS is a network of 24 satellites orbiting the earth, transmitting very precise time and position data day and night, in any weather, anywhere in the world. Signals from these satellites are broadcast to hand-held units on the ground. The hand-held receiver receives signals from three or more satellites and uses triangulation to determine the user's position on the earth.

Hand-held units vary in accuracy and cost as little as $100 or as much as $10,000. There are no setup or subscription fees to use GPS. The GPS receiver must receive the signal of at least three satellites to calculate latitude and longitude and from four or more satellites to determine altitude. Newer GPS receivers are accurate to within 1 meter or less.

GPS is changing rapidly and is updating geographic information systems; some hand-held GPS units feed land location data directly into GIS. As a botanist finds an endangered plant species, for example, he or she can enter its location into GIS using the GPS. A forester can use GPS to traverse a timber sale unit and feed that information directly into GIS. New applications are born daily in the GIS and GPS world.

SUMMARY

Forest managers need information on land measurement and survey. Surveys and maps help you locate property boundaries, roads, structures, and physical elements on the land.

Most of the United States has been surveyed using the rectangular survey system or the Public Land Survey system. The rectangular system sets up a grid, with the objective of obtaining approximately square sections of 1 square mile each. Sections can be divided further into halves and quarters.

Most forestry work requires you to use maps. You use large-scale maps to make landscape-level plans. After you see how your project area fits into the broader landscape, you'll use stand-level maps such as transportation maps and topographic maps.

Transportation maps are useful for locating areas where project work occurs. Maps are available from a variety of agencies, but they vary in design depending on who owns the land. Topographic (topo) maps show relief, hydrology, vegetation, and human-made structures. Topographic maps are available from the U.S. Geological Survey.

Distances measured from maps are accurate only if the map is drawn to scale. Map scales are written either as a ratio (1:12,000) or a representation (1 inch = 1 mile). You can find the ground distance between two points on the map by measuring with a ruler and multiplying by the map scale.

Direction is measured with azimuths and bearings. Azimuths are based on the 360 degrees of the compass, and bearings are based on four 90-degree quadrants. Most map work is done in azimuths because they can be read easily using a 360-degree protractor.

Aerial photographs can be used like detailed maps that show vegetation. With the aid of overlapping photos and a stereoscope, you can see three-dimensional images on aerial photos. However, aerial photos often contain distortions that you must recognize and account for.

Geographic information systems (GIS) use digital geographic information stored on computers to make maps. Information on each type of resource (e.g., topography, transportation, vegetation, or water) is stored as a mapping layer. GIS allows land managers to store and manipulate vast amounts of data that allow them to look at an ecosystem over both space and time.

Geographic positioning systems (GPS) use signals from satellites to locate a hand-held unit on the ground, thus determining the user's precise location.

For more information

Textbooks

Aerial Photography and Image Interpretation for Resource Management, by D.P. Paine (New York: Wiley, 1981).

Elementary Surveying, 9th ed., by P.R. Wolf and R.C. Brinker (New York: Harper Collins, 1994).

Interpretation of Aerial Photographs, 4th ed., by T.E. Avery and G.L. Berlin (Minneapolis: Burgess Publishing, 1985).

Map and photo sources

Local U.S. Forest Service, U.S. Bureau of Land Management, and state Department of Forestry or Natural Resources offices have transportation and topographic maps that show private and public ownership. However, since there are large blocks of private ownership that don't adjoin federal lands, maps of these lands may not be available from federal sources. You may be able to obtain limited GIS maps from these agencies for cooperatively developed projects.

Most Forest Service and BLM offices have aerial photos of their lands, which also often cover adjoining private lands as well. You may be able to borrow these photos and make color copies for field use. Again, large blocks of private lands would not be available. Copies usually can be obtained at high-quality copy shops.

The Oregon Department of Forestry publishes Forest Protection District Maps for most forested areas of Oregon. These maps generally are at a scale of 0.5 inch = 1 mile, except for northeast Oregon, where the scale is 0.625 inch = 1 mile. Protection District Maps show: most public and many private roads; Forest Service, BLM, county, and private road numbers; townships, ranges, and sections; streams, rivers, and lakes; other major topographic features; and public land ownership. These maps are available folded, unfolded, and even laminated from:

Graphics Services
Oregon Department of Forestry
2600 State Street
Salem, OR 97310
Tel. 503-945-7336

The Washington Department of Natural Resources publishes 1:100,000-scale quadrangle maps which depict state and federal lands, highways, roads, trails, recreation sites, water features, and geographic names. These maps are available at:

Washington Department
of Natural Resources
902-C 79th Avenue SE
Tumwater, WA 98501
Tel. 360-586-6360

Idaho geographical information is available from:

Idaho Water Center
322 East Front Street
Boise, ID 83720
Tel. 208-287-4800

Color and black-and-white aerial photographs for most of Oregon are available at various scales. You can purchase them from:

W.A.C.
520 Conger Street
Eugene, OR 97402
Tel. 541-342-5169
From Washington and Idaho, contact Walker and Associates at 206-244-2300.

Every county courthouse has maps showing ownership of each tax lot. These maps usually don't show roads, and their large scale makes them inappropriate for stand-level planning. Some counties now have GIS available.

USGS topographic maps are sold at various specialty and outdoor stores and are available directly from:

USGS Information Services
P.O. Box 25286
Denver, CO 80225

USGS information is available by phone at 1-800-USA-MAPS or online at http://store.usgs.gov/ The USGS also maintains an information database of aerial photographic coverage of the United States and its territories that dates back to the 1940s. You can obtain information on this database from the USGS addresses and phone numbers above.

USGS regional Earth Science Information Centers (ESIC) offer information and sales service for USGS map and earth science publications. They provide information about geologic, hydrologic, topographic, and land-use maps; books and reports; aerial, satellite, and radar images and related products; earth science and map data in digital format and related applications software; and geodetic data.

Numerous websites and computer software packages provide topographic and aerial photographic information. Some of the Web-based information is free. Mapping software is available from suppliers such as Ben Meadows (benmeadows.com), Forestry Suppliers (forestry-suppliers.com), and Terra Tech (terratech.net)

The Regional ESIC serving the Northwest is:
Menlo-Park ESIC
345 Middlefield Road
Menlo Park, CA 94025-3591
Tel. 650-329-4309

The USGS, in cooperation with state agencies and universities, operates a national network of state ESICs that provide state and local information about earth science products and services. The following state ESICs serve the Pacific Northwest.

Oregon

Map and Aerial Photography Library
University of Oregon
1501 Kincaid Street
Eugene, OR 97403-1299
Phone: 541-346-3051

Oregon Department of Geology
and Mineral Industries
Nature of the Northwest Information Center
800 NE Oregon Street, Suite 177
Portland, OR 97232
Tel. 503-872-2750

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