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Illinois' Forest Resources, 2005

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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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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.

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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.*

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

[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.

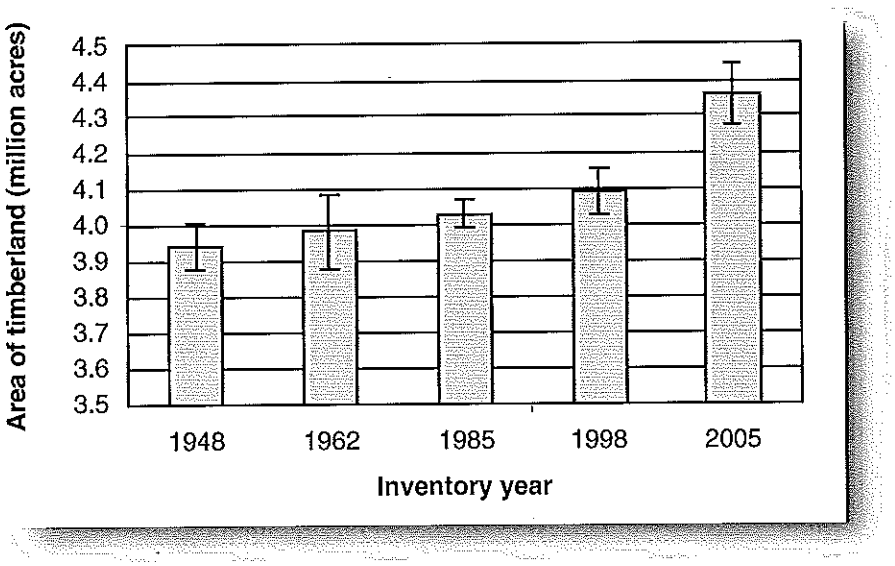


Figure 1.—*Area of timberland, Illinois, 1948-2005. The vertical line at the top of each bar represents the sample error associated with each inventory.*

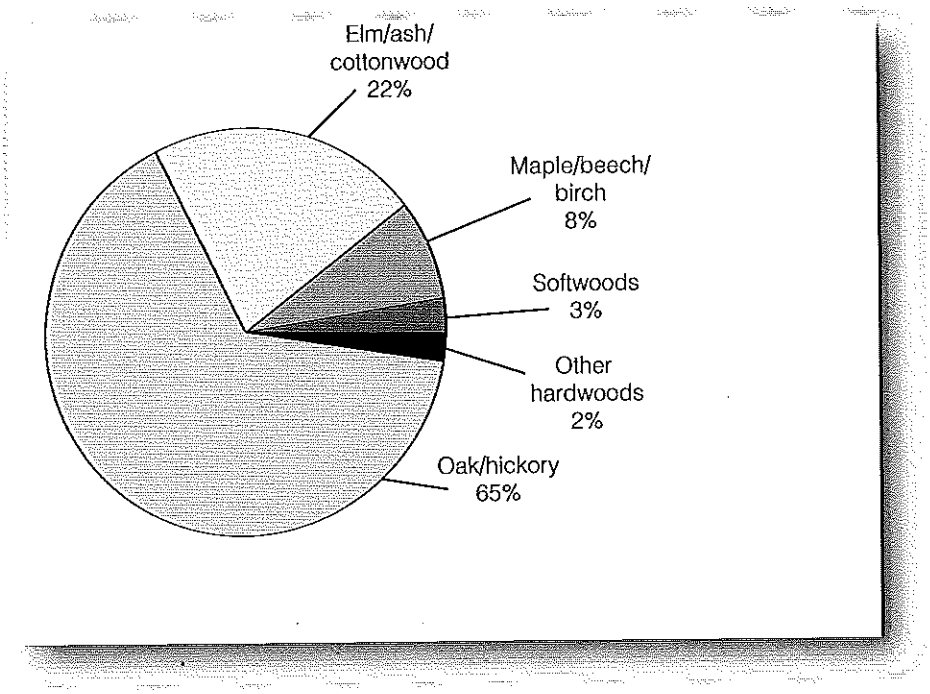


Figure 2.—*Area of timberland by forest type group, Illinois, 2005.*

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.

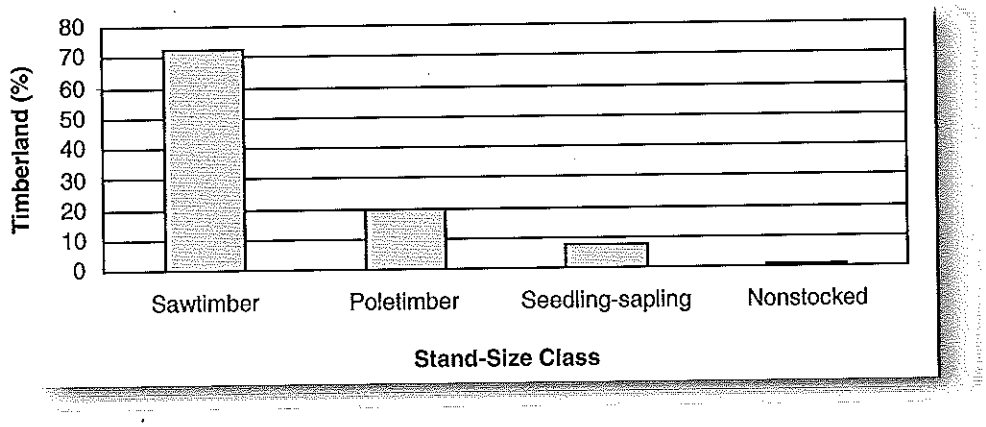
Although softwoods only account for about 3 percent of total timberland area, they contribute to increased biodiversity in what would otherwise be a sea of hardwoods (Table 3). Softwood timberland area is predominantly eastern redcedar, which occupies 31.5 thousand acres (28 percent). Shortleaf and white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

[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).*

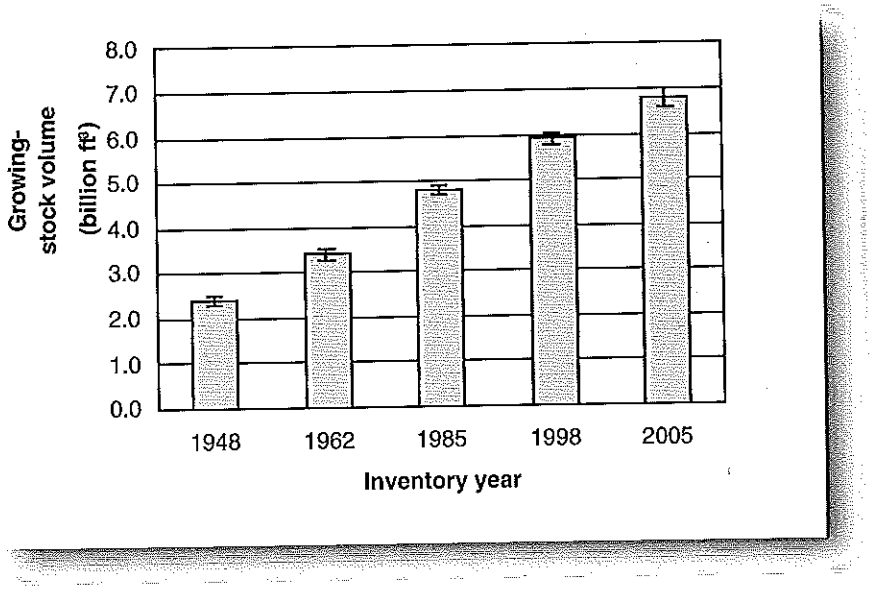


Figure 4.—*Growing-stock volume on timberland, Illinois, 1948-2005. The vertical line at the top of each bar represents the sample error associated with each inventory.*

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.

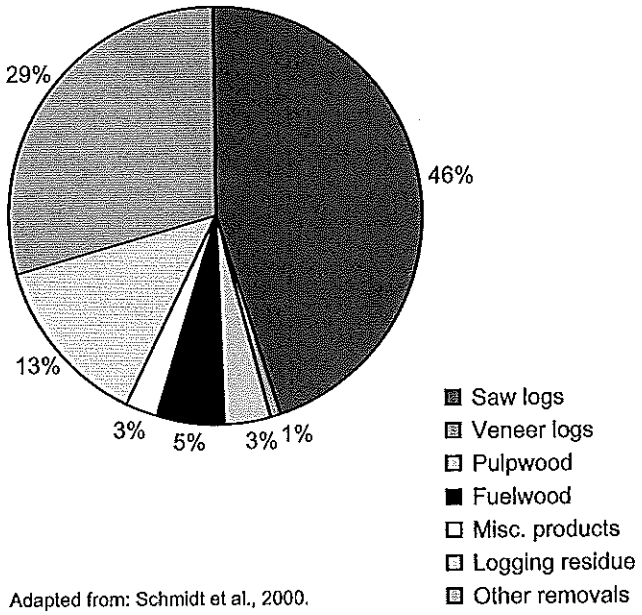
For fuelwood, the select white oaks species group was highest, followed by hickory and other red oaks. The volume of growing stock for logging residue by species group was similar to that of total removals, because logging residue is a by-product of removals and usage. The species most commonly removed 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.

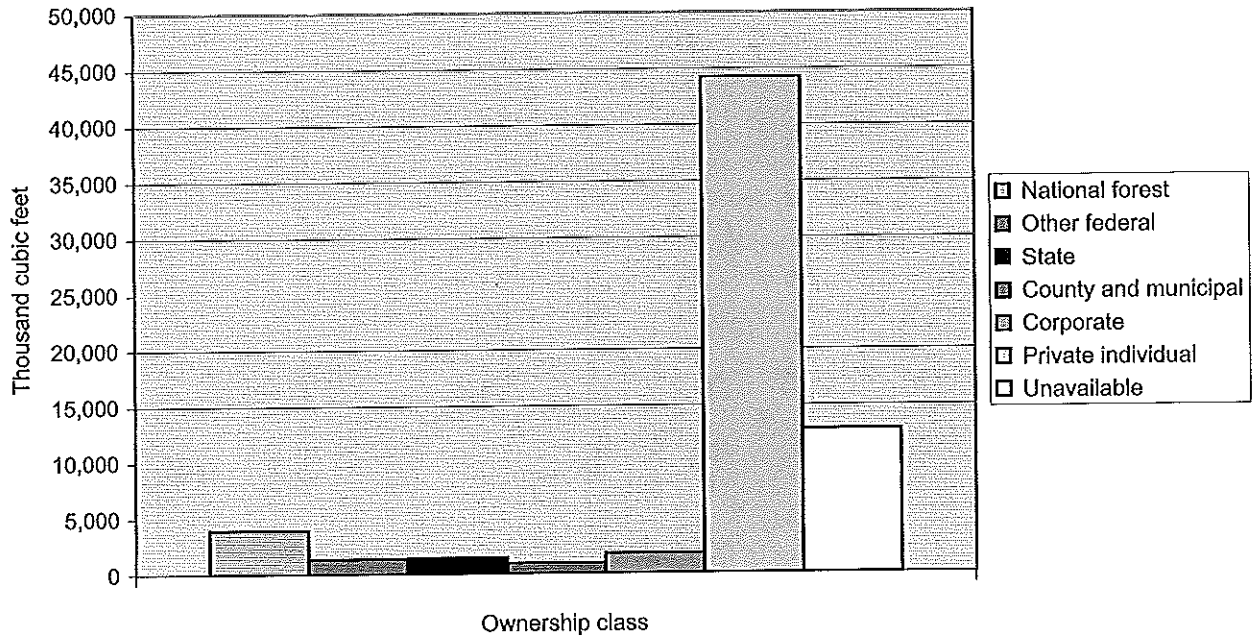
A total of 2,032 businesses in Illinois deal with forest resources (Table 23). The data for Table 23 are from information supplied by Dun & Bradstreet. Business establishments are categorized by a general business type and a specific business type. The general business types are forestry, lumber and 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.

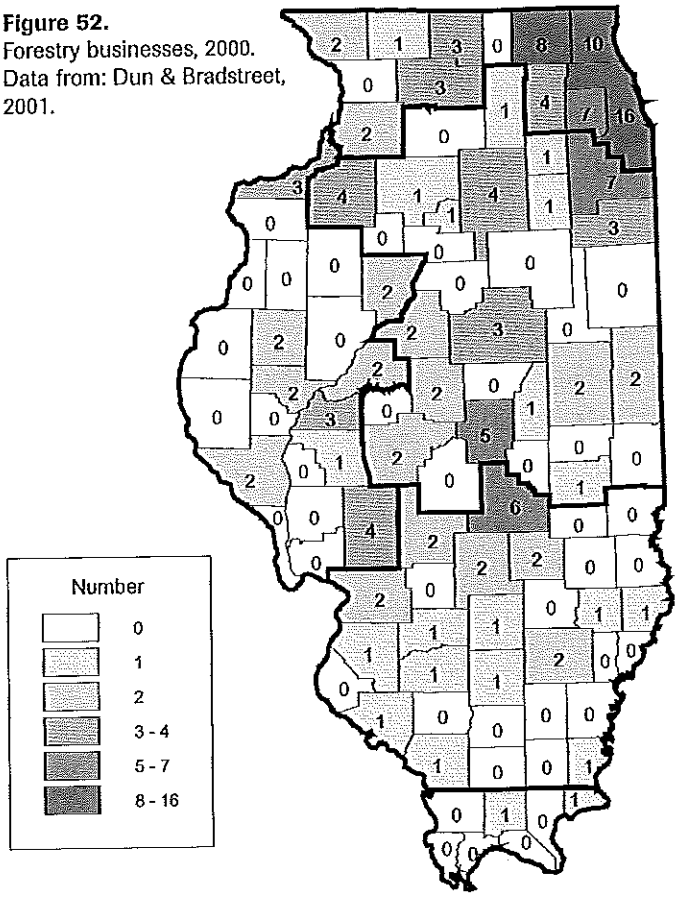


Figure 52.
Forestry businesses, 2000.
Data from: Dun & Bradstreet, 2001.

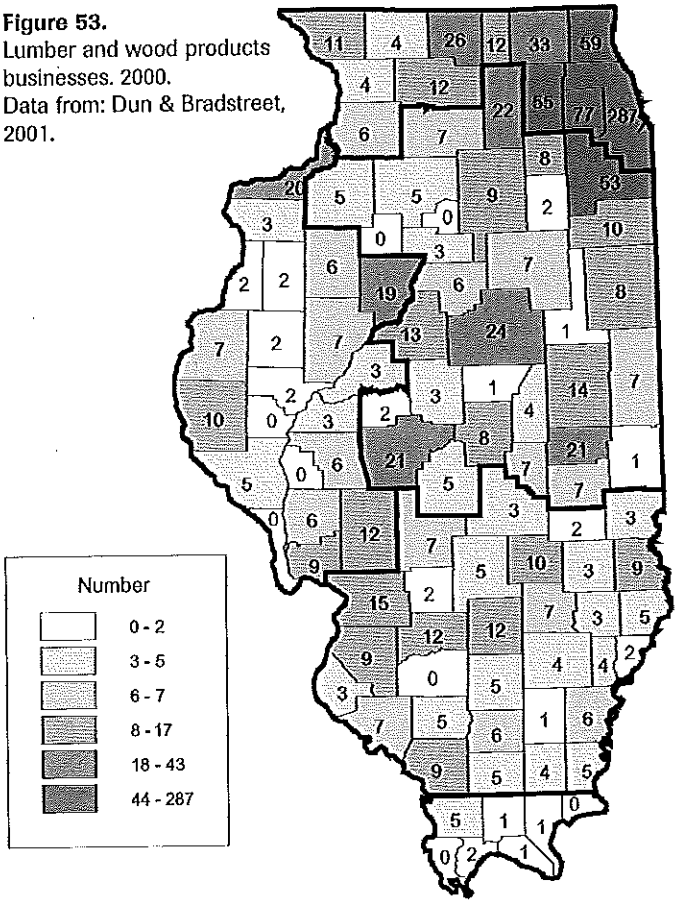


Figure 53.
Lumber and wood products businesses. 2000.
Data from: Dun & Bradstreet, 2001.

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.

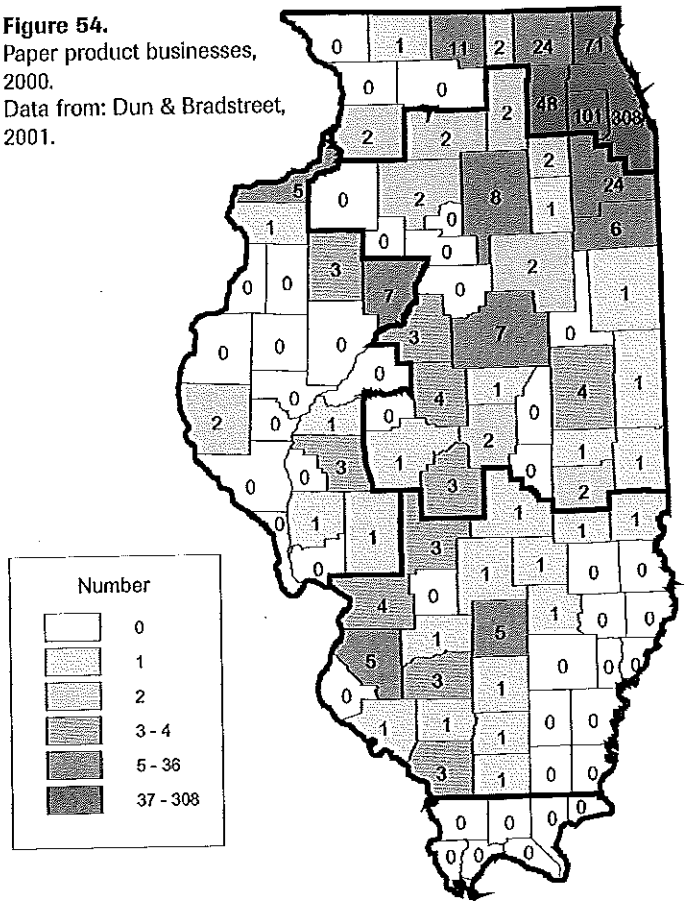
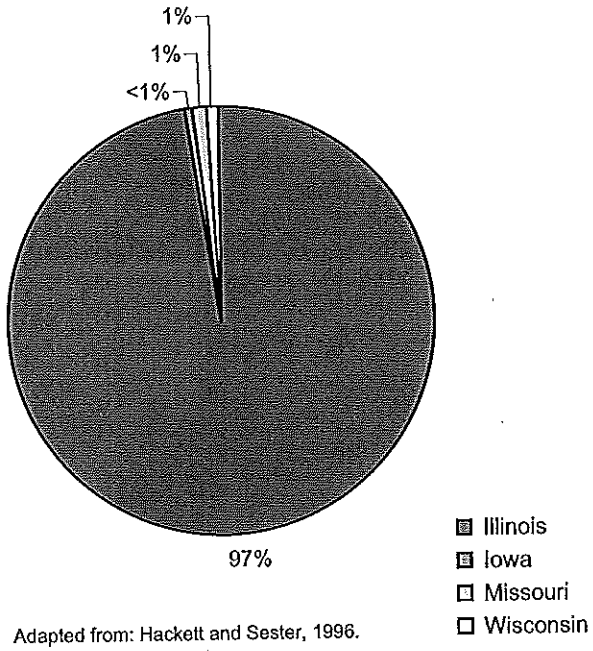


Figure 55.
Percentage of saw-log volume processed in Illinois by state of origin, 1996.



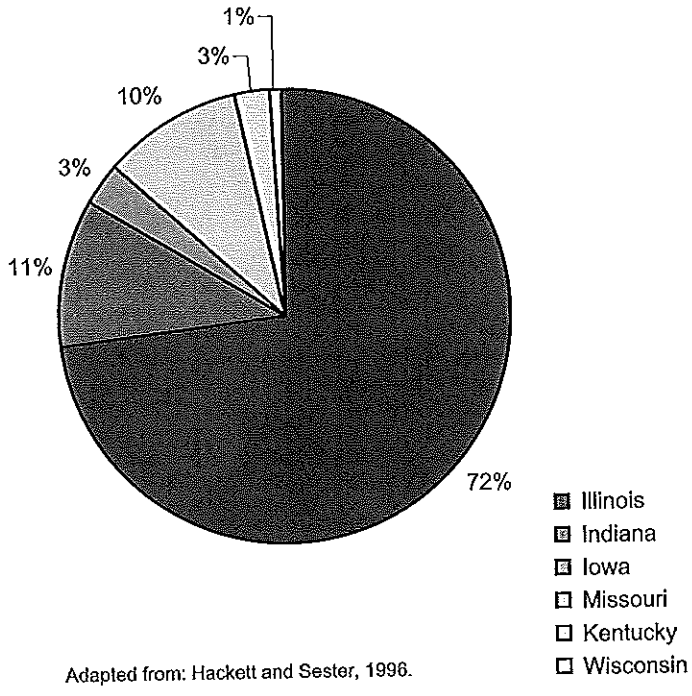
Adapted from: Hackett and Sester, 1996.

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.).

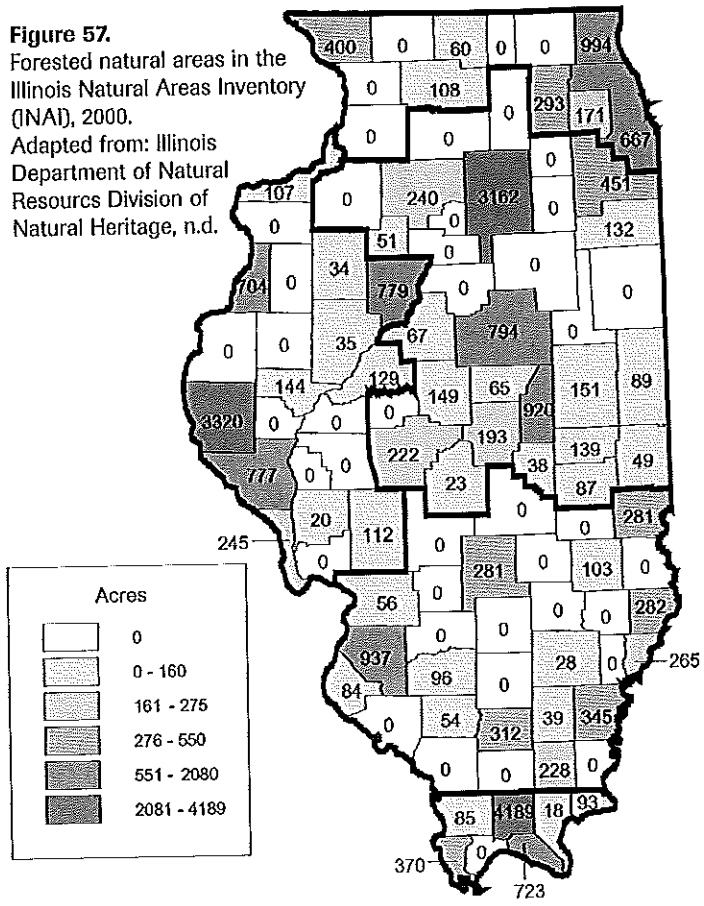
The forested areas on the Illinois Natural Areas Inventory (INAI) are valuable resources that serve as an example of the native forest vegetation in Illinois before European settlement. Table 24 shows the acreage in the various forest community types for the INAI. These community types are based on topographic 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 Resources 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.

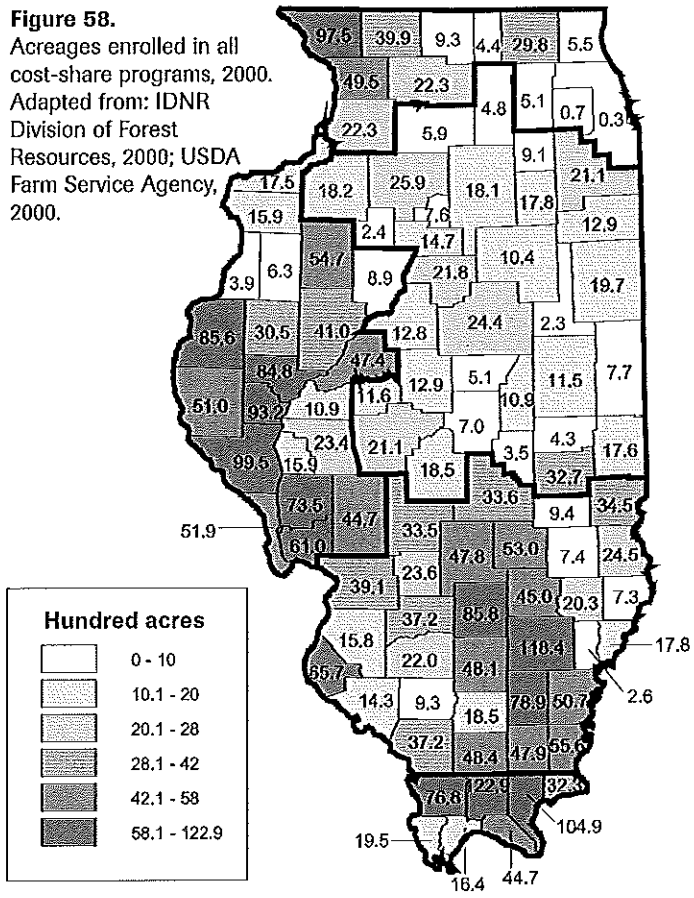
One of the most important programs is provided by the Forestry Development Act (FDA). This cost-share program is administered by the Illinois Department of Natural Resources Division of Forest Resources. Funds are obtained by collecting a harvest fee on all timber sales in Illinois. These funds then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

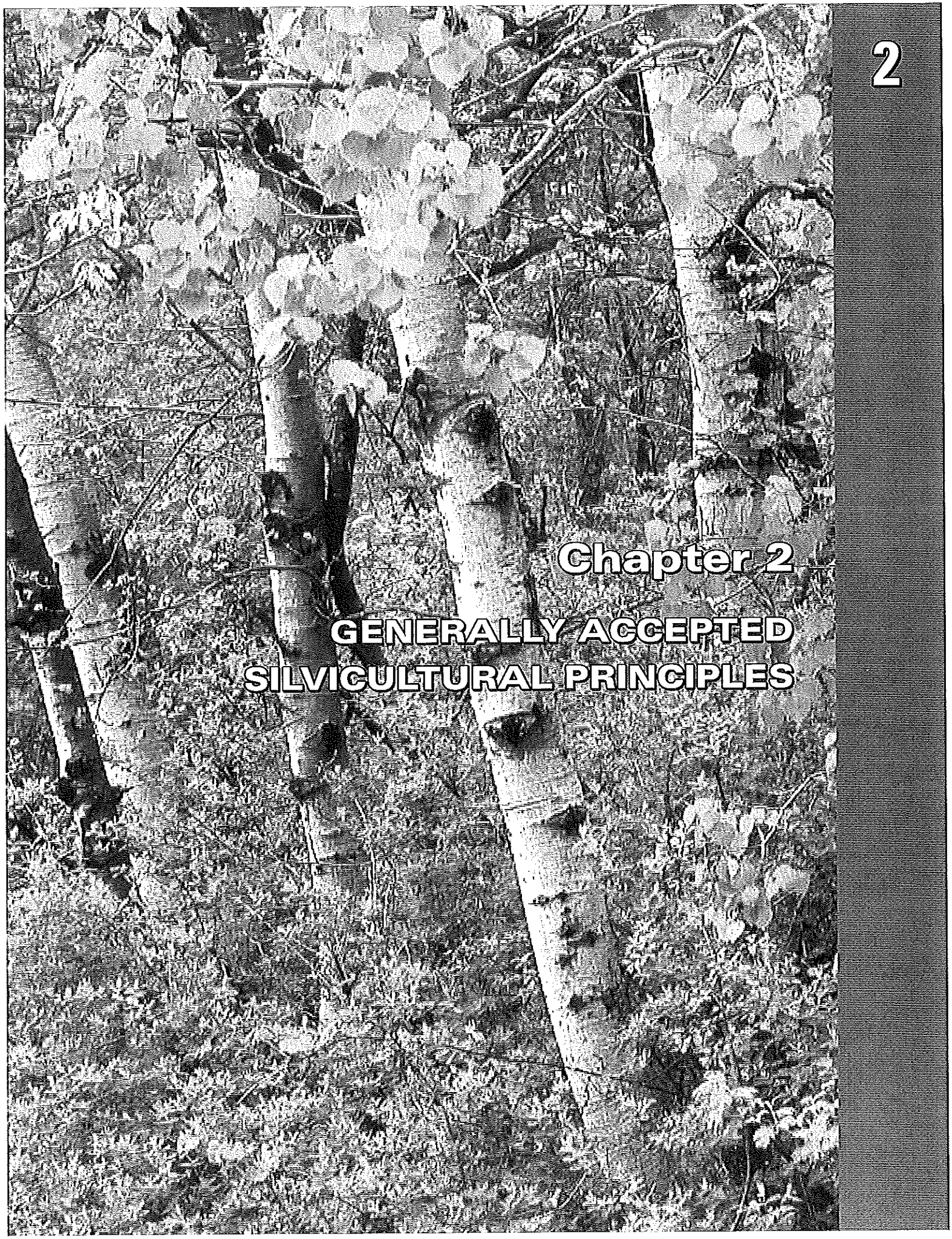
Another important cost-share program is the Conservation Reserve Program (CRP), which is a national program administered by the Commodity Credit Corporation (CCC) and the USDA Farm Service Agency (FSA). CRP provides cost sharing for a wide variety of resource conservation activities, many of which relate 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).

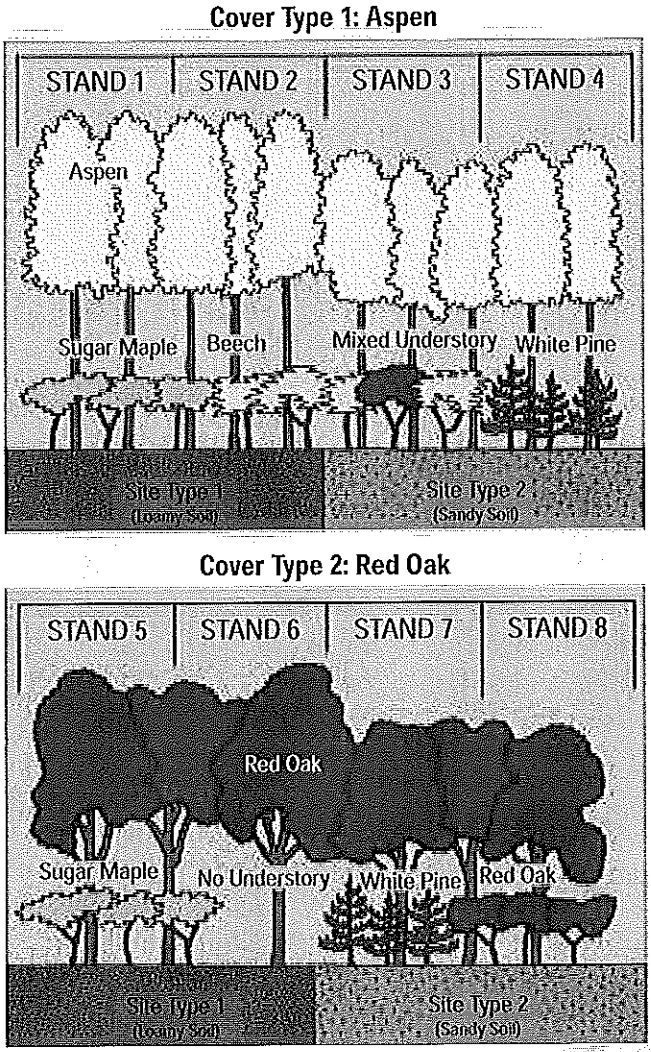


Figure 2-3: A schematic representation of two site types (loamy soil and sandy soil), two forest cover types (aspen and red oak), and eight stands. Each stand has unique composition and is defined by a specific combination of overstory and understory species. Each stand also can be considered as a unique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

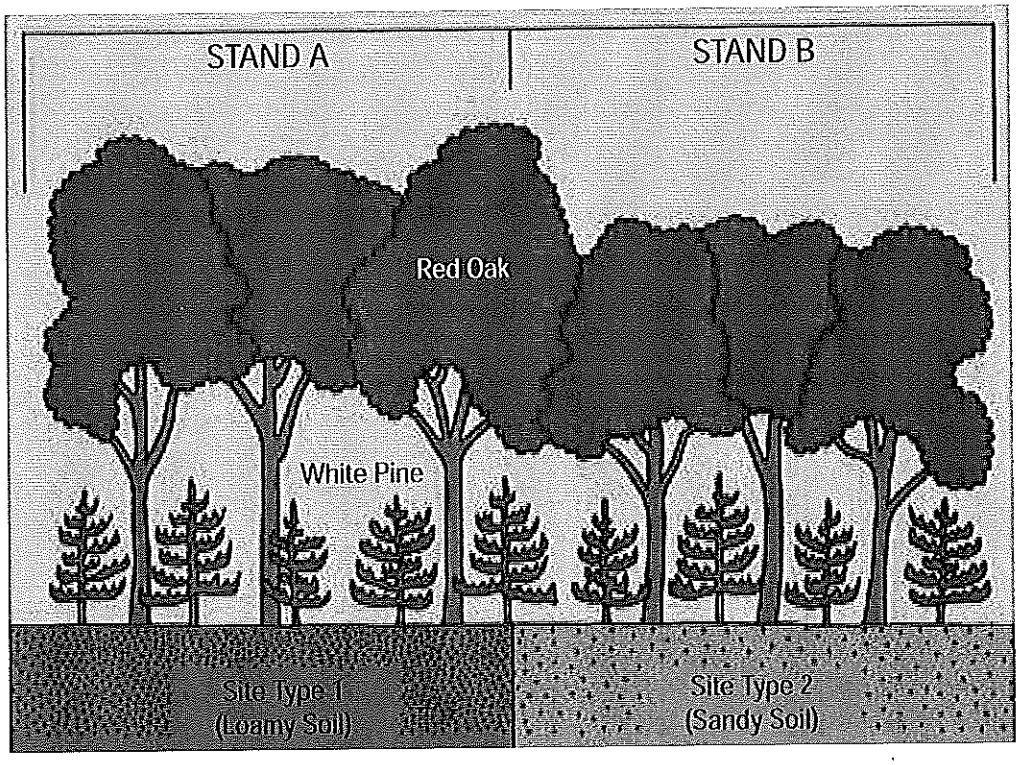


Figure 2-4: A single stand (red oak overstory with white pine regeneration) "straddles" two significantly different site types. Because ecological and silvicultural potentials differ for the two site types, the stand was split (A and B) to identify two ecological and silvicultural opportunity units.

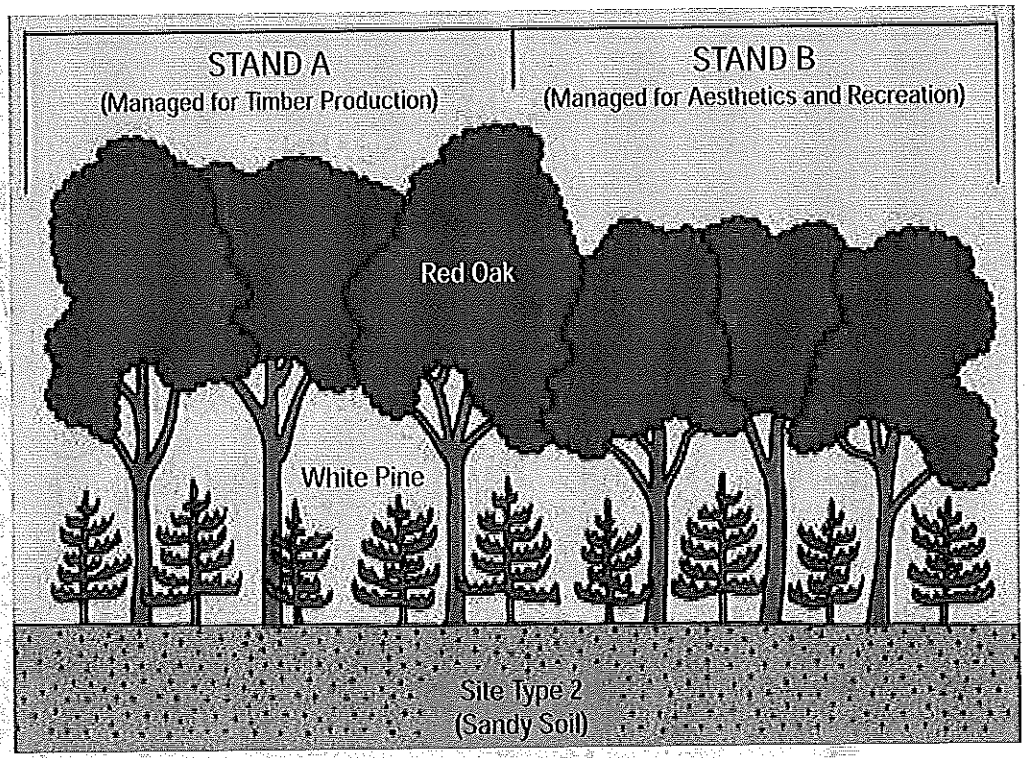


Figure 2-5: This stand is divided into two management units on the basis of different management objectives. E.g., in Stand A, oak will be harvested and white pine released to form a new crop, while in Stand B, oak overstory will be retained to provide a food source for wildlife and conditions for future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

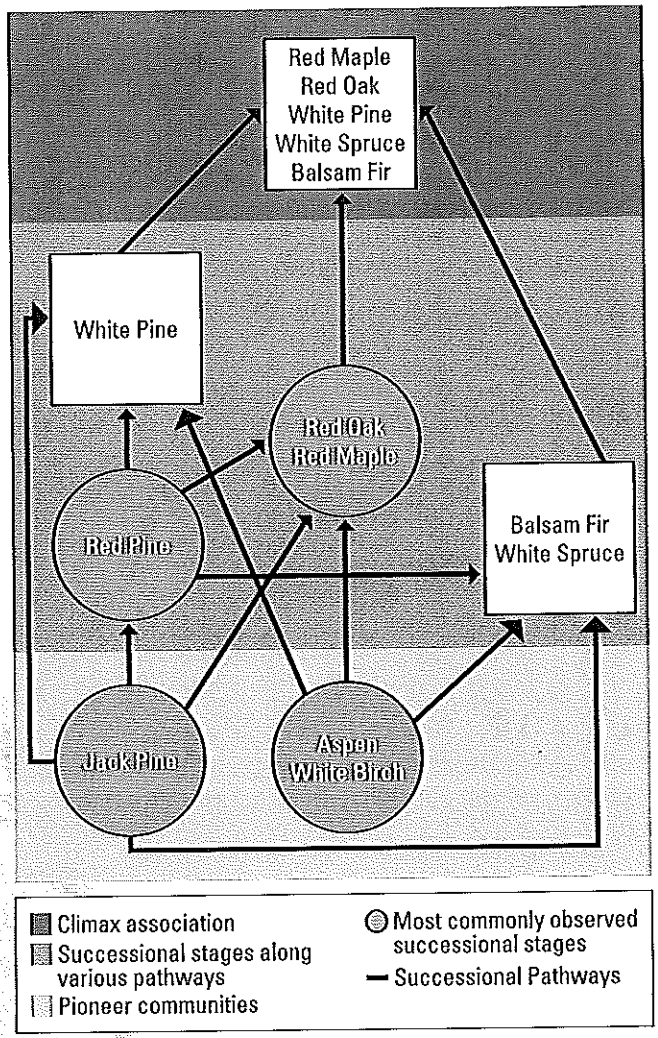


Figure 2-6: A generic example of the information available relative to the most commonly observed successional stages and probability of succession for a particular site type.

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.