

# Ohio Forests

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# Ohio Forests

2006

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# Foreword

## Forests at a tipping point

Ohio's forests are a critical component of the state's natural resources. Covering nearly 8 million acres, or 30 percent of the state, these diverse forests support important biological communities and create habitat for wildlife, forest products, clean water, and opportunities for recreation. Essential to making sound decisions about Ohio's forests is credible information. Forest Inventory and Analysis (FIA) data help fill this need. Such data tell us where we are and where we are going, and they provide the basis for making informed decisions about how we can sustain our forests for future generations.

The fifth inventory of Ohio's forests suggests that we are at a tipping point. Ohio's forests hold more wood, provide more wildlife habitat, and store more carbon than 15 years ago. Yet, for the first time since the 1940s, the acreage of Ohio's forest land has not increased, and some parts of the state have seen large losses in forest cover. More Ohioans than ever own forest land and enjoy the many benefits that forests provide. But, as Ohio's forest lands are subdivided and fragmented, the ability of these forests to provide timber, wildlife habitat, recreation, and solitude is reduced. Oak-hickory forests make up over one-half of the state's forests. Oaks as seedlings and saplings, however, have declined in abundance, and oaks will likely play a smaller role in Ohio's future forests. The quality and value of our timber has increased during the past 15 years, and landowners intend to harvest trees on one-fifth of Ohio's forested acres in the next 5 years. However, only 4 percent of forest landowners have a formal management plan for their forests, and fewer than one in seven seeks any sort of advice before making decisions that will affect them and their forests for decades.

John F. Kennedy said: "It is our task in our time and in our generation, to hand down undiminished to those who come after us, as was handed down to us by those who went before, the natural wealth and beauty which is ours." The data presented in this report clearly highlight the challenges our forests face: fragmentation, uninformed management, loss of oak, invasive species, and a host of other concerns. How we address these concerns, how we balance forest conservation and sustainable use, will determine the forests that future generations experience and the benefits they receive. Doubtless, the FIA reports of tomorrow will document the successes, or the failures, of the choices we make today.

David Lytle, Ph.D.,  
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# Introduction



Maintaining openings to improve wildlife habitat on the Wayne National Forest; photo by Kari Kirschbaum, U.S. Forest Service

This is the fifth inventory of Ohio's forests, the first using a new annualized inventory system. Previous inventories were completed for 1952 (Hutchison and Morgan 1956), 1968 (Kingsley and Mayer 1970), 1979 (Dennis and Birch 1981), and 1991 (Griffith et al. 1993). These inventories provided a snapshot of the forest for specific periods in time after which no new information was available until the next full inventory of the State. Henceforth, inventory data for the State will be updated annually and full remeasurement of all inventory plots will occur every 5 years. FIA landscape-level information is the only forest inventory that uses a permanent network of ground plots. Data are collected consistently across the Nation enabling comparisons among states and regions. Having current inventory information always available should help in making better decisions about Ohio forests and planning for the future.

## Highlights

### ⊕ On the Plus Side

- Ohio's forests have doubled in area since the 1942 inventory to now total 7.9 million acres and cover 30 percent of the State's land.
- Ninety-seven percent of Ohio's forest land is classified as productive timberland and potentially available for timber harvesting.
- Public ownership of forest land has steadily increased, tripling since 1952. Publicly owned forests now total 952,500 acres or 12 percent of the State's forest land.
- Representing the largest ownership category, family forest owners hold 5.8 million acres—accounting for 73 percent of the State's forest land.
- Most stands are well stocked with trees of commercial importance. Since 1991, stocking levels have increased as acreage has shifted to fully stocked and overstocked levels.
- Since 1991, numbers of trees in the larger diameter classes have continued to increase while numbers of trees have decreased in the 6- and 8-inch classes.
- There are few areas in Ohio where any one species represents more than half the stocking of live trees. This diverse mix of species reduces the impact of insects and diseases that target a single tree species.
- The current growing-stock inventory is the highest recorded in Ohio since FIA began. Growing-stock volume totals 12.3 billion cubic feet, which is 22 percent more than in 1991 and averages 1,603 cubic feet per acre.
- Timber growth is concentrated on sawtimber-size trees (more than 11 inches in d.b.h.). Since 1991 the saw log portion of growing-stock volume increased by 35 percent to 41 billion board feet.
- Yellow-poplar continues to lead in volume followed by red maple and sugar maple.

- Volume increases for the maples are larger than for the oaks, although all species of oak increased in volume.
- The portion of sawtimber volume in high-quality tree grades 1 and 2 increased from 32 percent in 1991 to 43 percent in 2006.
- Ohio's forests are accumulating substantial amounts of biomass. These stores of carbon will receive more attention as we seek sources for renewable energy and ways to offset carbon dioxide emissions.
- During the last 50 years in Ohio, the growth of trees has greatly outpaced mortality and removals. The growth-to-removals ratio averaged 2:1 for 1991-2006.
- Net growth exceeded removals for all major species except elm, which had negative growth due to high mortality.
- The high growth-to-removals ratios for red maple, sugar maple, and yellow-poplar show these species will increase in importance in Ohio's forests.
- Tree mortality rates in Ohio have increased since previous inventories, although they are still comparable to those in surrounding states.
- Because hard mast production increases as trees become larger, we can assume that hard mast production has increased in Ohio because of increases in the number of large-diameter oaks and hickories.
- The down woody fuel loadings in Ohio's forests are neither exceedingly high nor different from those found in neighboring states.
- A total of 92 million cubic feet of wood was harvested from Ohio's forests in 2006 and used for products. Although this total is nearly the same amount as the 1989 harvest, production shifted from pulpwood to saw logs.
- Markets for saw logs in Ohio have been strong as indicated by a stable harvest from Ohio's forests and a continuation of log imports surpassing exports.

## Issues to Watch

- Trends in land use change indicate that the area of forest land in Ohio may be near a peak.
- The large amount of forest land in small private holdings makes the delivery of government programs difficult and forest management less economical. These difficulties will likely be exacerbated by further parcelization of Ohio's forest land, which is indicated by increasing numbers of owners and increases in acreage in holdings of fewer than 50 acres.
- The turnover of forest land to an increasing number of new owners will create a need for more education, advice, and other services to family forest owners.
- The combination of increasing numbers of forest land owners owning smaller parcels of land (parcelization), decreasing forest patch sizes (fragmentation), and increasing proximity to human populations, roads, and other urban areas (urbanization) is making forest land more difficult to manage for timber and wildlife as well as making traditional access to forests for recreation more difficult.
- More than half of Ohio's forest land occurs in census blocks with more than 50 people per square mile.
- The 2.0 million acres (13 percent) of timberland that are poorly stocked with commercially important species represent a loss of potential growth, although these forests still contribute to forest diversity.
- Shaded conditions created by overstory trees are stressing a large portion of trees below 10 inches in diameter. Most trees in the 2-, 4-, 6-, and 8-inch diameter classes are in an overtopped or intermediate crown position.
- In the current inventory, oaks represent more than one-third of the trees 20 inches and larger in diameter, but only 5 percent of trees in the 2- and 4-inch diameter classes.

- A lack of oaks in the small diameter classes means that as large oaks are harvested or die, they likely will be replaced by species such as red and sugar maples that dominate the lower diameter classes.
- Future losses of oaks will affect wildlife populations and wood-using industries that now depend on oak.
- Future tree quality may be affected by changes in species composition. Red and sugar maples had some of the largest increases in volume but typically grade poorer than other major species.
- Nearly a third of removals are due to conversion of timberland to nonforest uses, which threatens sustainability because such changes are usually permanent.
- American beech mortality is expected to increase significantly as the beech scale insect spreads by about 9.1 miles/year.
- Future defoliation events caused by the gypsy moth caterpillar and the potential arrival of Sudden Oak Death in the eastern United States are of particular concern to the oak resource in Ohio.
- Emerald ash borer, a lethal pest found in Ohio, will increase ash mortality in both urban and forested landscapes. It will likely cause significant financial costs to municipalities, property owners, and the forest products industries in the State.
- Because white ash is the leading species in the Northwestern and Southwestern geographic units of the State, future mortality caused by the emerald ash borer will likely be significant in these areas.



## FOREST LAND FEATURES



## Dynamics of the Forest Land Base

### Background

The amount of forest land in Ohio and percentage of land under forest cover are crucial measures in assessing forest resources and are vital for making informed decisions about forests. These measures are the foundation for estimating numbers of trees, wood volume, and biomass. Trends in forest land area are an indication of forest sustainability, ecosystem health, and land use practices. Gains and losses in forest area directly affect the ability of forests to provide goods and services, including wood products, wildlife habitat, recreation, watershed protection, and more.

FIA groups counties that have similar forest cover, soil, and economic conditions into geographic units. In Ohio, the Southwestern, Northwestern, and Northeastern Units are well suited for agriculture and are commonly known as Ohio's cornbelt and dairy regions. Terrain in these glaciated units is mostly level to rolling with rich soils. Ohio's topography generally becomes rougher from west to east, with the South-Central, Southeastern, and East-Central Units encompassing Ohio's hill country. These units are mostly unglaciated and form the foothills of the Allegheny Mountains to the east.

### What we found

Ohio forests have doubled in area since 1942 to now total 7.9 million acres, or 30 percent of the State's land. Successive inventories have shown forest land area consistently increasing, although the most recent inventory shows a slowing in this trend. The 100,000-acre increase since 1991 is smaller than past increases and not large enough to make the 2006 estimate statistically different from 1991 (Fig. 1). Increases in forest land have corresponded with decreases in farm land. Since 1950, the amount of land in farms has decreased by 7.2 million acres (includes farm woodlots) (Fig. 2), while forest land has increased by 2.5 million acres. Although much former farm land has been developed to meet the needs of a growing population, a substantial portion has been left untended and has reverted to forest through natural regeneration. These new forests have increased total forest land in the State and negated losses of forest to development.



Ohio farmland; photo by Richard Widmann, U.S. Forest Service

Figure 1.—Area of forest land in Ohio by inventory year, 1952, 1968, 1979, and 2006 with approximations of forest land area given for 1900 and 1940 (Kingsley and Mayer 1970) (error bars represent 67-percent confidence intervals around the estimates).

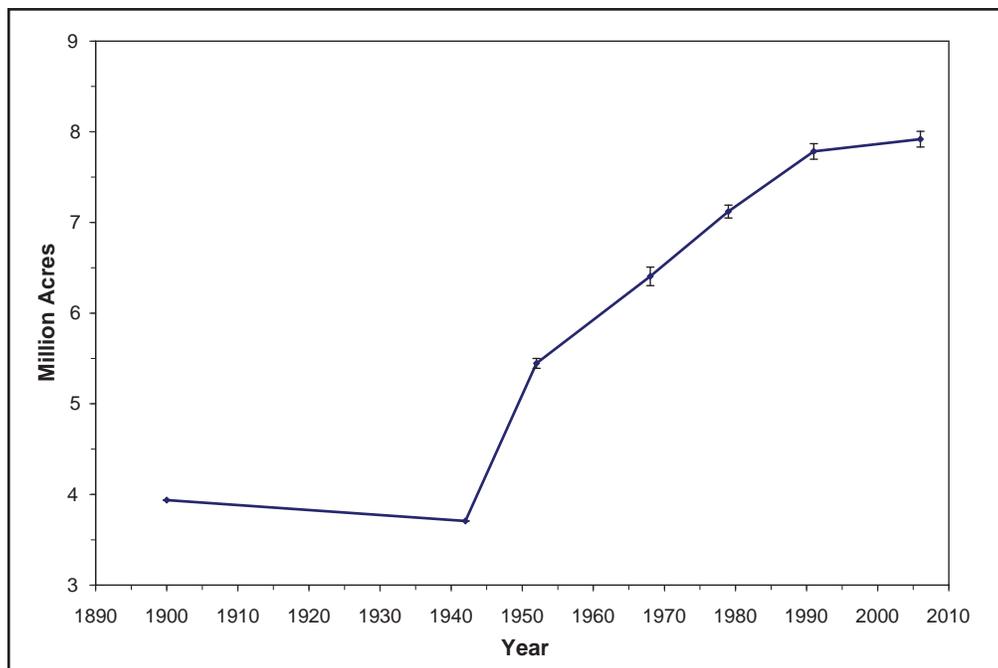
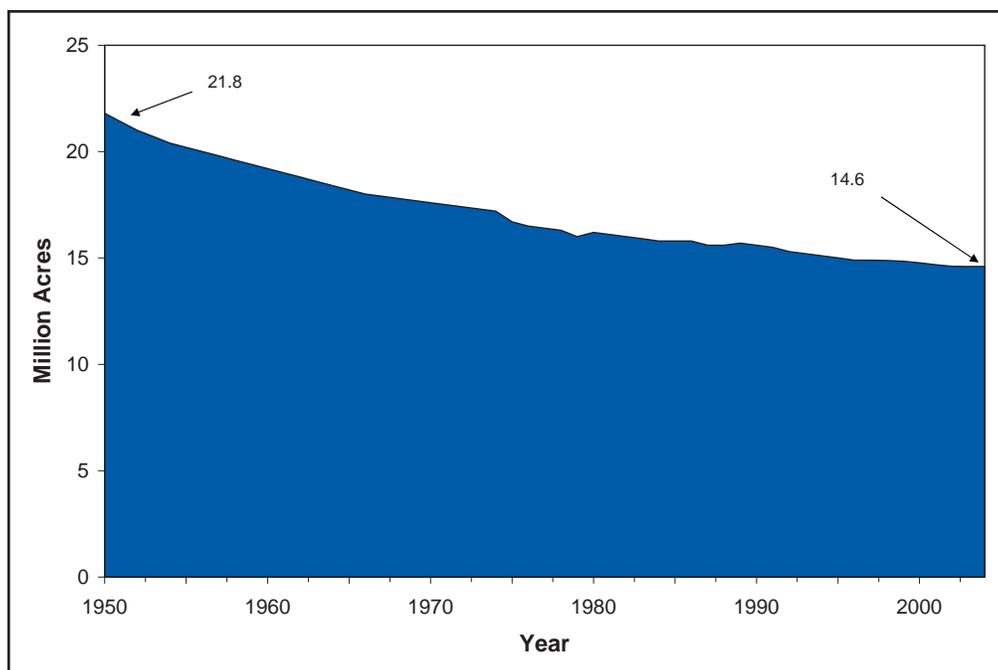


Figure 2.—Acreage in farms (includes farm woodlots), Ohio, 1950-2005 (source: National Agriculture Statistics Service).



The percentage of land in forest cover increases from northwest to southeast in Ohio (Fig. 3, 4). The East-Central, Southeastern, and South-Central Units account for two-thirds of the State’s forest land. Gains in forest land occurred in the Northeastern, East-Central, Southeastern, and Southwestern Units of the State; decreases occurred in the Northwestern and South-Central Units (Fig. 5). The Northwestern Unit is the least forested portion of the State and has lost the largest percentage of forest acreage since 1991.

What this means

Across the State, losses of forest land due to development have been more than offset by gains in forest land because of abandoned farm land reverting to forests. Because of increased development and a slowing in farm land losses, recent changes in total forest land have been small. These trends may indicate that the area of forest land in Ohio is peaking. Future changes in Ohio’s forest land will depend on the pace of land development and to a great extent on the economics of farming. Small percentage changes in the area of nonforest land can significantly affect forest land area, especially in sparsely forested areas like Ohio’s Northwestern Unit. Recent proposals to increase agricultural biofuels, such as growing switchgrass as feed stock for ethanol production, may promote the conversion of forest land to agriculture uses; although long term, the production of cellulosic ethanol from forests could promote the planting of trees on agricultural lands.

Figure 3.—Distribution of forest land in Ohio based on the Multi-Resolution Land Characteristics project, 1992. The MRLC uses data from the Landsat satellite to map land across the Nation.

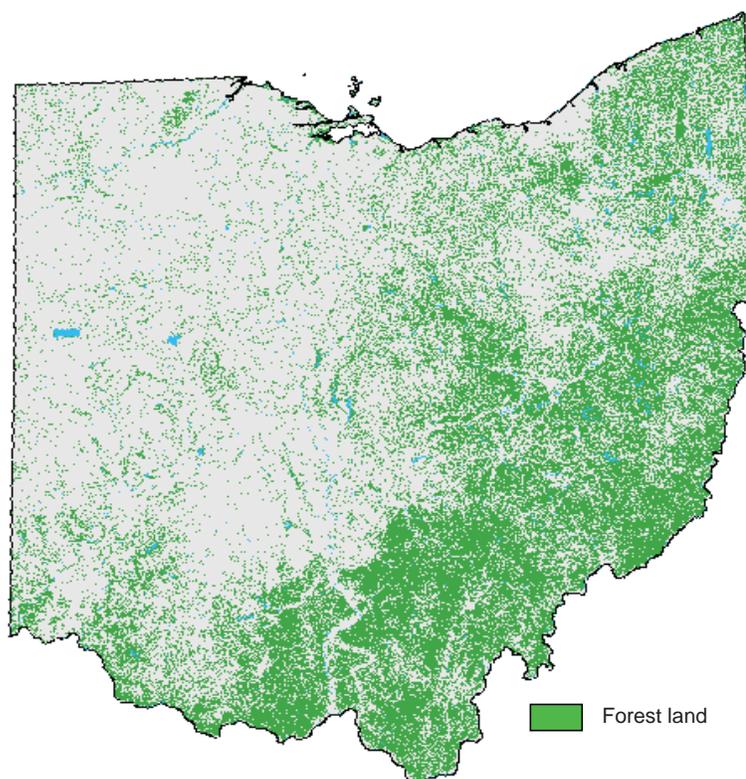


Figure 4.—Acreage of forest land and percentage of land in forest by FIA unit, Ohio, 2006.

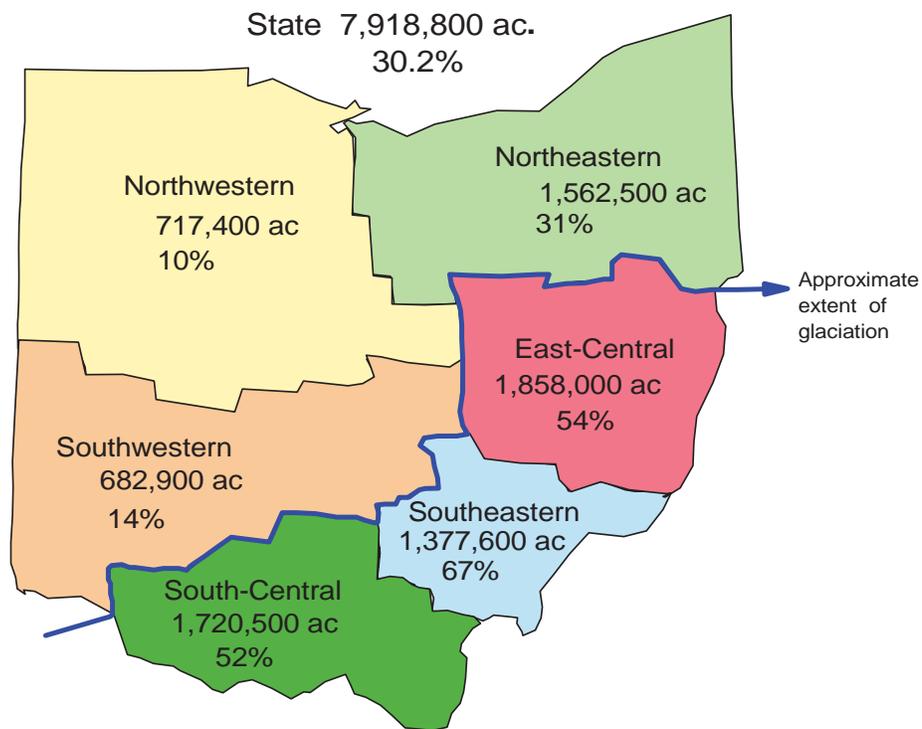
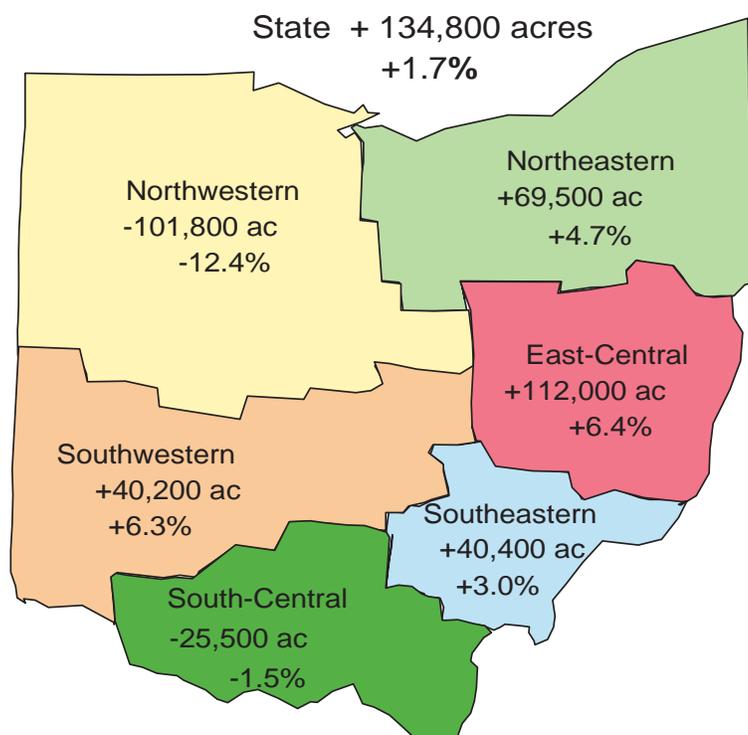


Figure 5.—Change in forest land area by FIA unit, Ohio, 1991-2006.



## Potential Productivity and Availability of Forest Land

### Background

Ohio's forest land is broadly classified into three components that describe the potential of the land to grow timber products: reserved forest land, timberland, and other forest land. Two criteria are used to make these designations: site productivity (productive/unproductive) and reserved status (reserved/unreserved). Forest land where harvesting is restricted by statute or administrative designation is classified as reserved forest land regardless of its productivity class. Most land in this category is in state parks, national parks and recreation areas, and designated natural areas on the Wayne National Forest. FIA does not use the harvesting intentions of private owners as a criterion for determining whether forests should be classified as reserved. Forest land without legal harvesting restrictions and capable of growing trees at a rate of at least 20 cubic feet per acre (equivalent to about ¼ cord) per year is classified as timberland. The other forest land category is unreserved and low in productivity. It is incapable of growing trees at a rate of 20 cubic feet per acre per year. In Ohio, this includes wet areas where water inhibits tree growth and some strip-mined areas with extremely degraded soil. These categories help increase our understanding of the availability of forest resources and in forest management planning.

### What we found

Ninety-seven percent of Ohio's forest land, 7.7 million acres, is classified as timberland, an increase of 57,000 acres since 1991 (Fig. 6). However, this increase is not large enough to make the two estimates statistically different. The amount of forest land reserved from harvesting has increased with each successive inventory and now represents 1 percent of the total land area and 3 percent of forest land. Other forest land is relatively rare and amounts to less than 1 percent of total forest land.

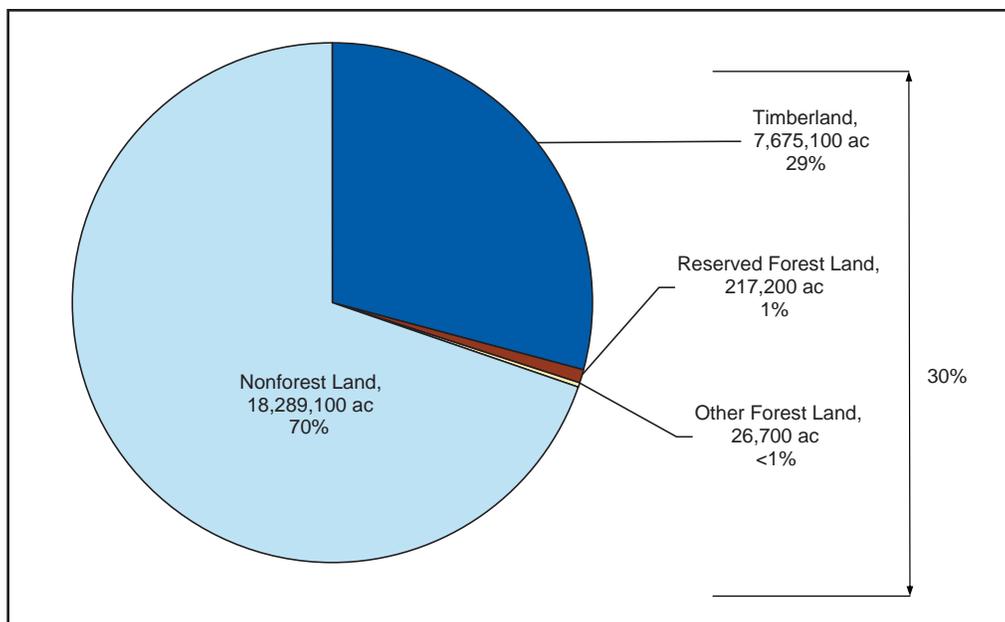
### What this means

Most of Ohio's forest land is potentially available for timber harvesting and is classified as timberland. Because most forest land is classified as timberland, major trends occurring on timberland also apply to forest land. Additions to reserved forest land usually come from the reclassification of timberland. But because losses in timberland to reserved forest land have been small, they have been overwhelmed by additions to timberland area from agriculture. Trees growing on timberland represent the resource base upon which the forest products industry relies and are considered potentially available for harvesting. Discussions later in this report on urbanization and the woodland owner study provide more details on how much timberland is actually available and being actively managed for timber products.



Typical stand of saw log size white oak in southeastern Ohio; photo by Richard Widmann, U.S. Forest Service

Figure 6.—Land area by major use, Ohio, 2006.



## Ownership of Forest Land

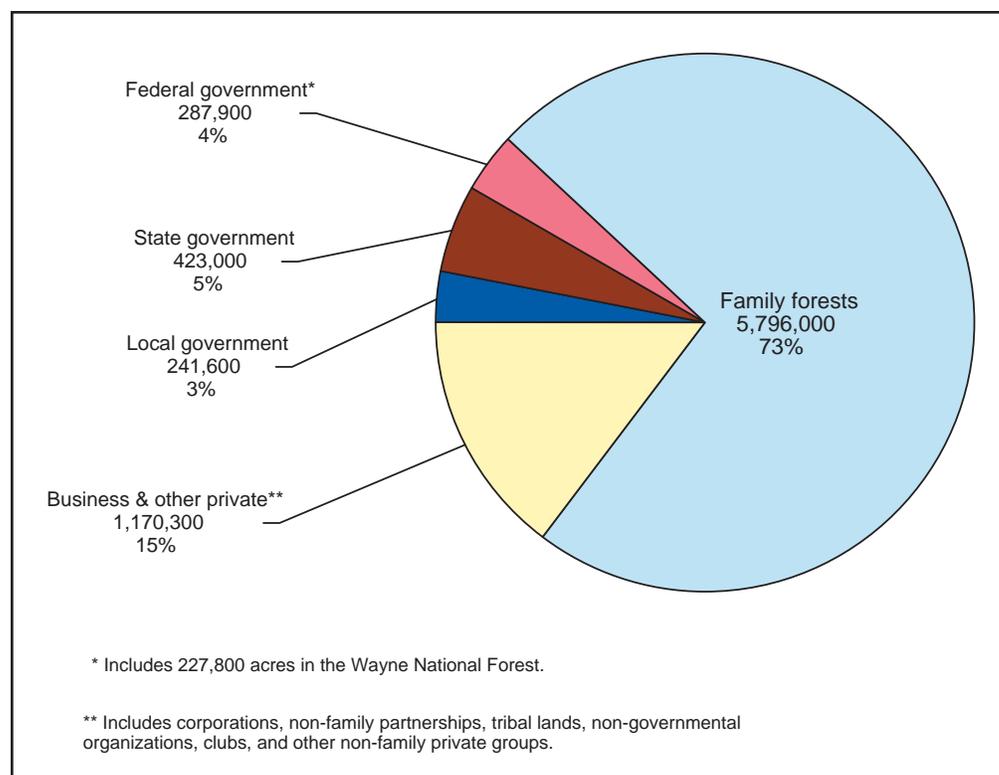
### Background

How land is managed is primarily the owner’s decision. Owners decide who they will allow on their land and what types of activities will take place. Therefore, to a large extent, the availability and quality of forest resources are determined by landowners, including recreational opportunities, timber, and wildlife habitat. Owners’ decisions are influenced by their management objectives, size of land holdings, and form of ownership. Public and private owners often have different goals that reflect their priorities and management practices. Family forest owners are further influenced by their age, education, and life experiences. The National Woodland Owner Survey (NWOS) conducted by the Forest Service studies private forest landowners’ attitudes, management objectives, and concerns. This survey has recently focused on understanding what is important to family owned forests.

### What we found

Publicly owned forests represent a relatively small portion of Ohio’s forests. Public owners hold 952,500 acres, or 12 percent of the State’s forest land. The Federal Government holds 287,900 acres, amounting to 4 percent of the forest land in the State (Fig. 7). Included in this are 227,800 acres of forest land in the Wayne National Forest. The State of Ohio holds 423,000 acres (5 percent) in various state agencies including state parks and forests, and local governments hold 241,600 acres (3 percent). Public ownership of forest land has steadily increased, tripling since 1952.

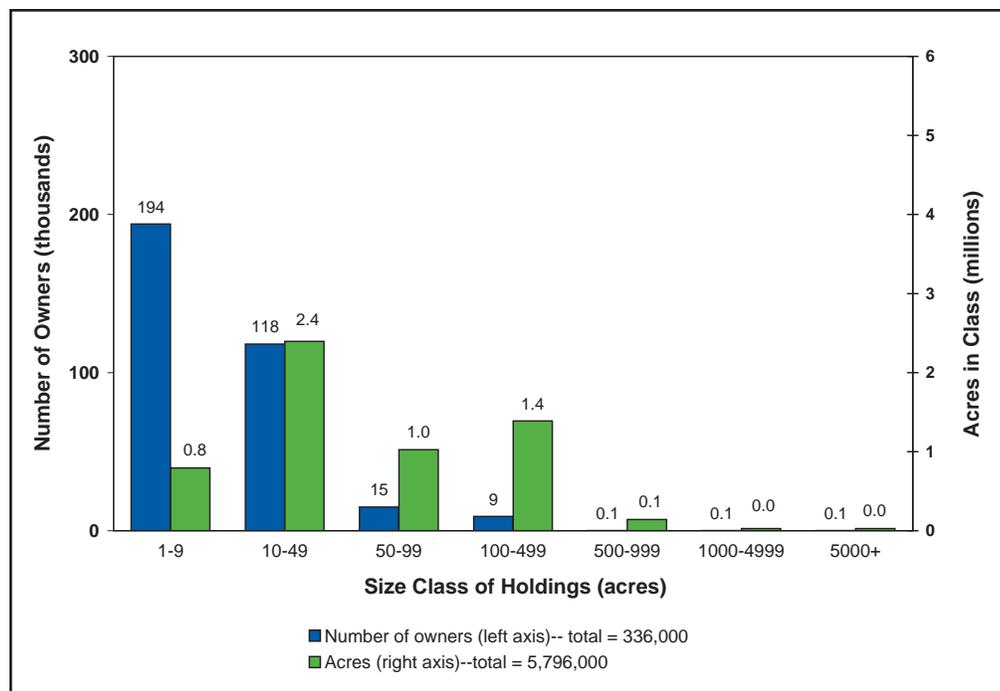
Figure 7.—Ownership of forest land by major ownership category, Ohio, 2006.



In Ohio, 345,000 private individuals and enterprises own 88 percent of the State’s forest land. Of this, businesses hold an estimated 1.2 million acres—15 percent of the forest land. This category includes corporations, non-family partnerships, tribal lands, non-governmental organizations, clubs, and other private non-family groups. Representing the largest ownership category, family forest owners hold 5.8 million acres, accounting for 73 percent of the State’s forest land.

The NWOS found that there are 336,000 family owned forests in Ohio (Fig. 8). This category is represented by individuals, farmers, and small family corporations and partnerships. Ninety-three percent of these owners hold fewer than 50 acres. These small holdings total 3.2 million acres and make up 55 percent of the family forest land in the State. Owners with 50 to 100 acres hold 1 million acres and number 15,000. About a quarter of the family forest acreage (1.6 million acres) is held by about 9,000 owners with forested holdings exceeding 100 acres. Since 1991, the number of owners and acreage in family forest holdings of fewer than 50 acres have increased by 10 and 6 percent, respectively, while the number of owners and acreage in holdings of 50 acres and larger have decreased (Birch 1996). From a list of 12 reasons for owning forest land, “part of home or cabin” ranked first by number of ownerships and “aesthetic enjoyment” ranked first by area owned (Fig. 9). Owning forest land for

Figure 8.—Number of family forest owners and acres of forest land by size of forest land holdings, Ohio, 2006.



nature protection, as part of a farm, and for privacy also ranked high. Timber production ranked low in importance to Ohio's family forest owners; it was ranked as important or very important by only 13 percent of owners who hold 19 percent of the acreage. However, 51 percent of owners holding 60 percent of the family forest land reported harvesting trees and 27 percent of owners had harvested saw logs (Fig. 10).



Field crews get permission before going on private land; U.S. Forest Service, Forest Inventory and Analysis

Written management plans exist on just 8 percent of the family owned forest land, and only 13 percent of the owners holding 21 percent of the family forest acreage have sought management advice (Fig. 11). The State Division of Forestry led as a source of management advice. Family owned forests are frequently associated with a residence or farm (Fig. 12). Seventy-nine percent of owners with 68 percent of family forest acreage

Figure 9.—Percentage of family forest owners and acres of forest land by reasons given for owning forest land ranked as very important or important, Ohio, 2006.

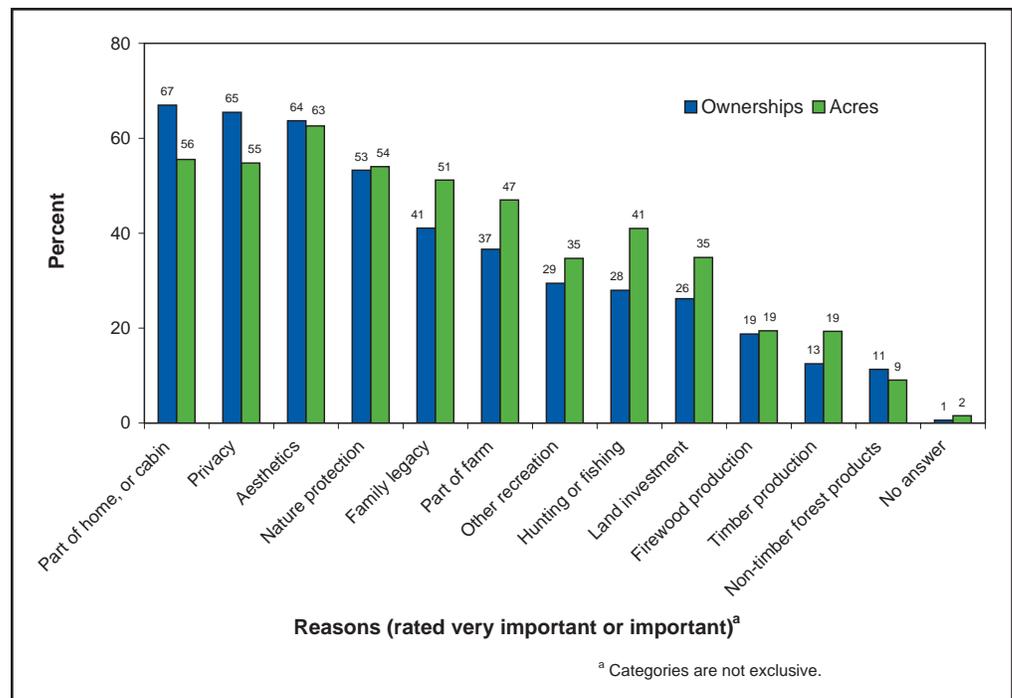


Figure 10.—Percentage of family forest owners and acres of forest land by harvesting experience and products harvested, Ohio, 2006.

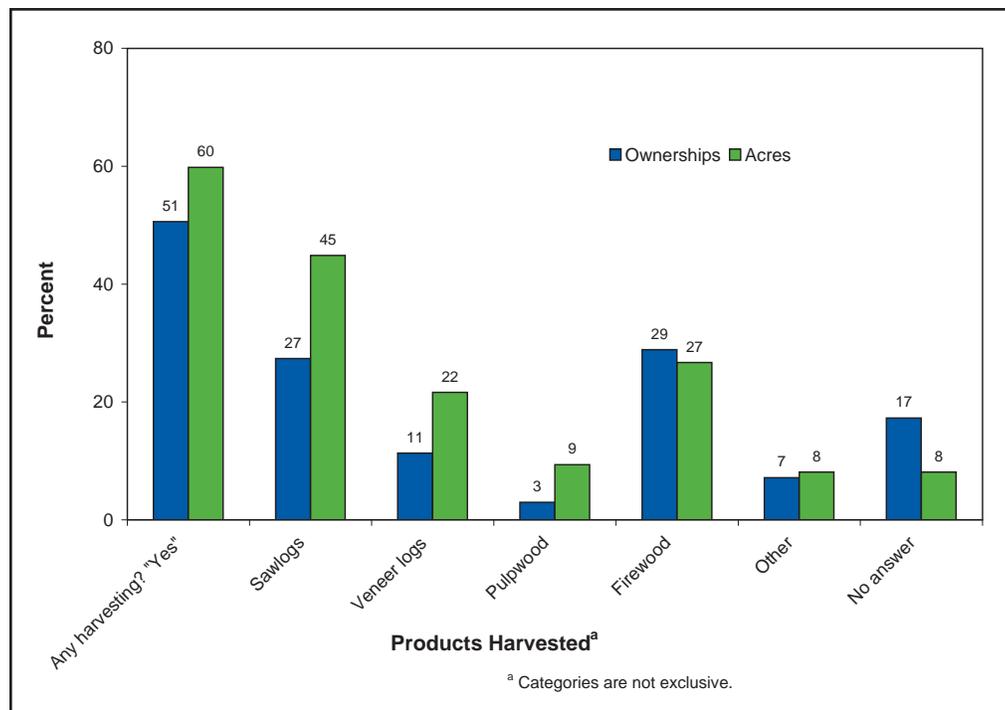
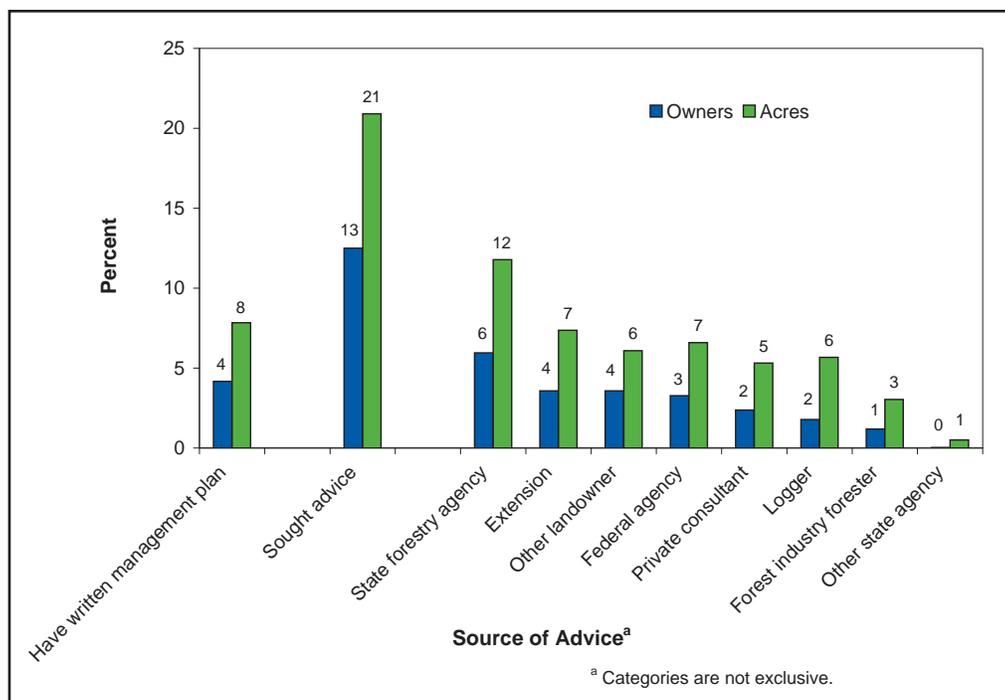


Figure 11.—Percentage of family forest owners and acres of forest land who have a written management plan, who have sought advice, and advice source, Ohio, 2006.



said that their forests are associated with their primary residence. Twenty-nine percent of Ohio’s family forest owners are at least 65 years old (Fig. 13). This group controls 35 percent or 2.0 million acres of family forest acreage. The tenure of family forest owners is fairly long: 40 percent of the acreage has been held for 25 years or longer and 9 percent has been held for 50 years or longer (Fig. 14). Chief concerns of family forest owners were trespassing, dumping, property taxes, family legacy, and insects/diseases (Fig. 15). When owners were asked about activities taking place on their land in the past 5 years, private recreation, tree planting, and posting land ranked high (Fig. 16). And when asked about activity planned for their land in the next 5 years, 13 percent of owners holding 16 percent of the family forest land said they plan to transfer it; 51 percent of owners with 46 percent of the area indicated “minimal activity” (Fig. 17). Harvesting either saw logs or pulpwood was planned on 19 percent of the land.

What this means

Because most of Ohio’s forest land is held by thousands of private landowners, decisions by these owners will have a great influence on Ohio’s future forest. The large amount of forest land in small private holdings makes it difficult to deliver government programs and makes forest management less economical. These difficulties will likely be exacerbated by further parcelization of Ohio’s forest land, which is indicated by increasing numbers of owners and increases in acreage in holdings of fewer than 50

Figure 12.—Percentage of family forest owners and acres of forest land that are associated with a farm, primary residence, or secondary residence, Ohio, 2006.

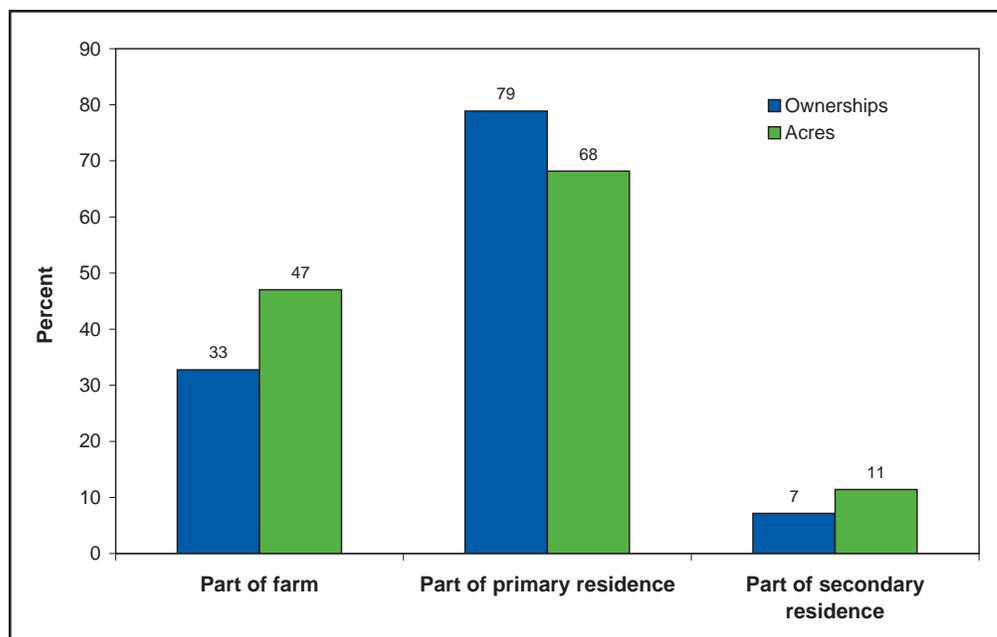


Figure 13.—Percentage of family forest owners and acres of forest land by age of owners, Ohio, 2006.

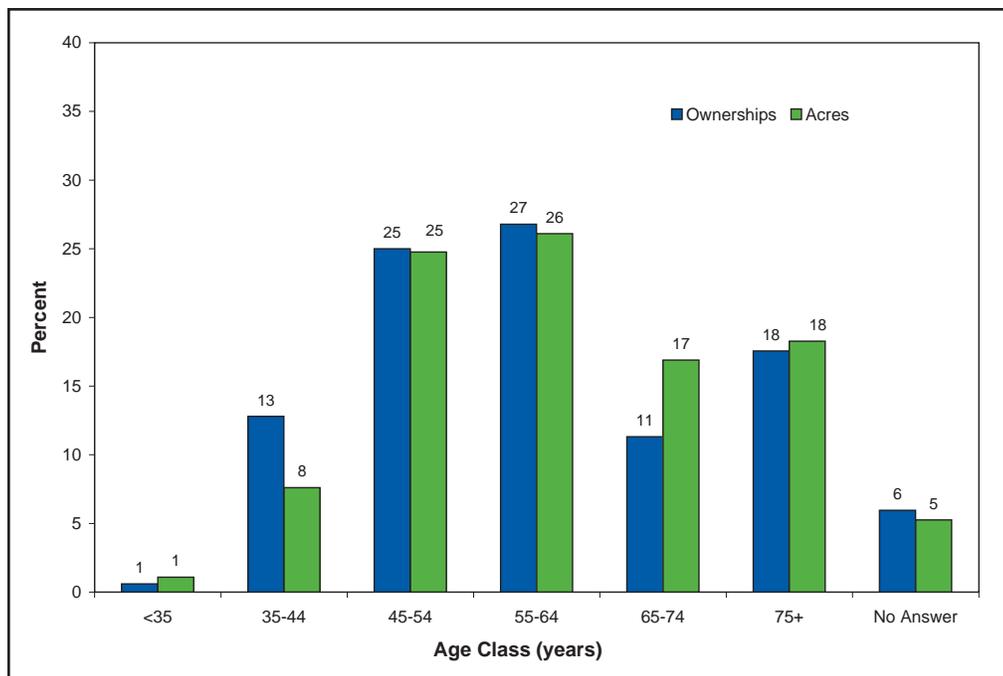
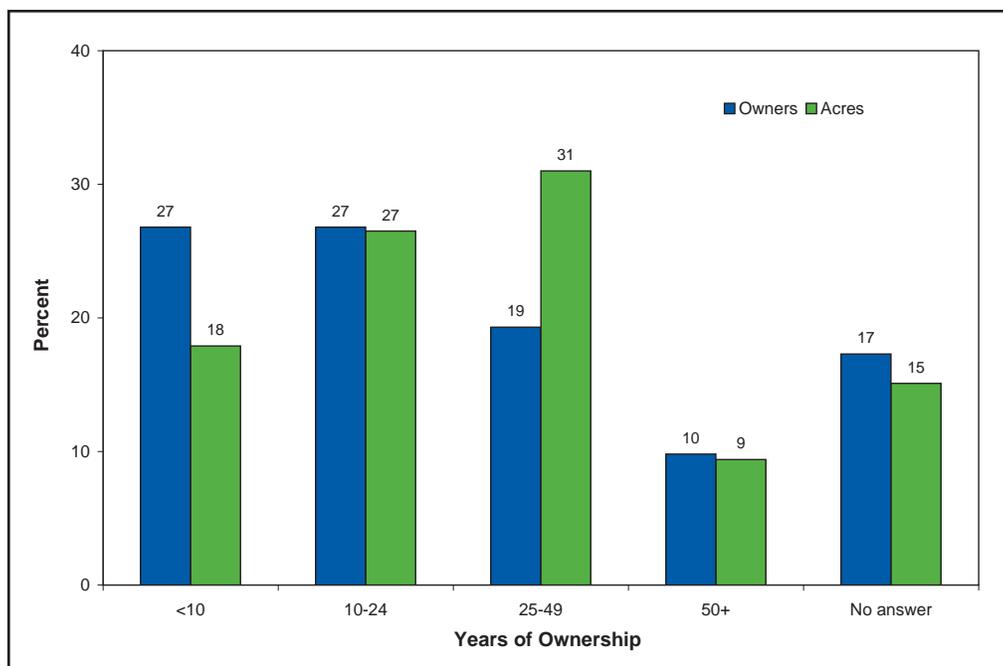


Figure 14.—Percentage of family forest owners and acres of forest land by tenure of owners, Ohio, 2006.



acres. Continuation of this trend will make future access to Ohio’s timber resource more difficult for Ohio’s timber industries and for recreation. Unlike owners of large tracts, owners of small parcels of land are less likely to manage their forests or allow access to their land by others for activities such as hiking, hunting, and fishing.

The low priority given by landowners to timber production does not mean that landowners will not harvest trees. The relatively high number of owners that actually harvest trees shows that when conditions are right most landowners will harvest trees, although the low priority given to timber production probably means that these harvests are not part of a long-term management plan.

The large number of owners who are 65+ years old and the large amount of land held by owners who are planning to transfer ownership in the next 5 years foretell a large turnover of forest land. At the time ownership is transferred, forest land is vulnerable to parcelization and unsustainable harvesting practices. The turnover of forest land to an increasing number of new owners will make it more difficult to provide advice, education, and services to family forest owners.

Figure 15.—Percentage of family forest owners and acres of forest land by concerns rated as important or very important, Ohio, 2006.

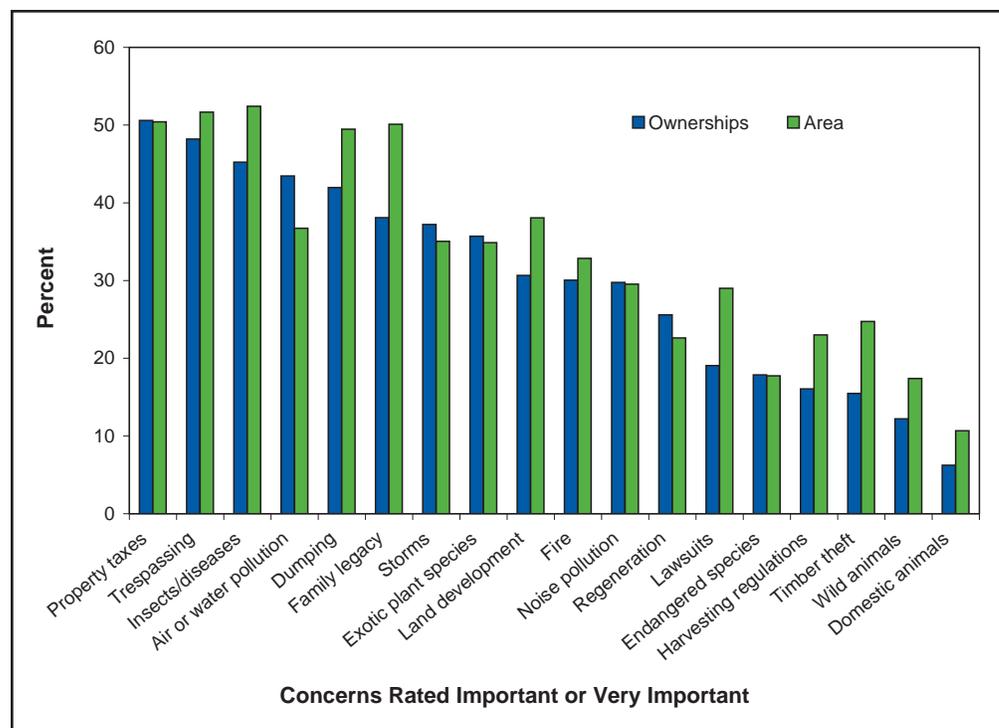


Figure 16.—Percentage of family forest owners and acres of forest land by activity in past 5 years, Ohio, 2006.

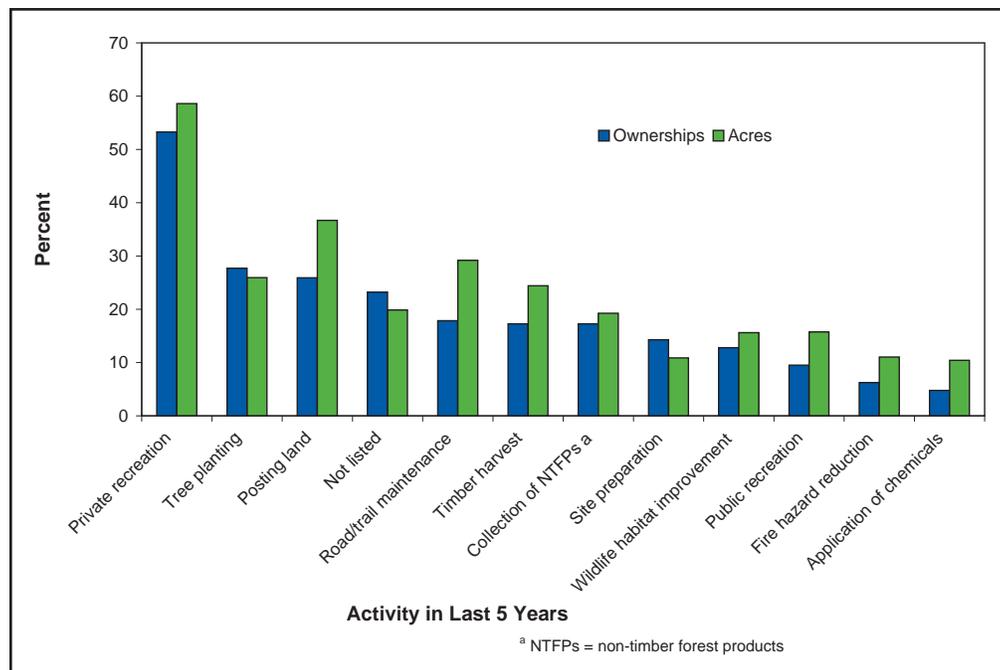
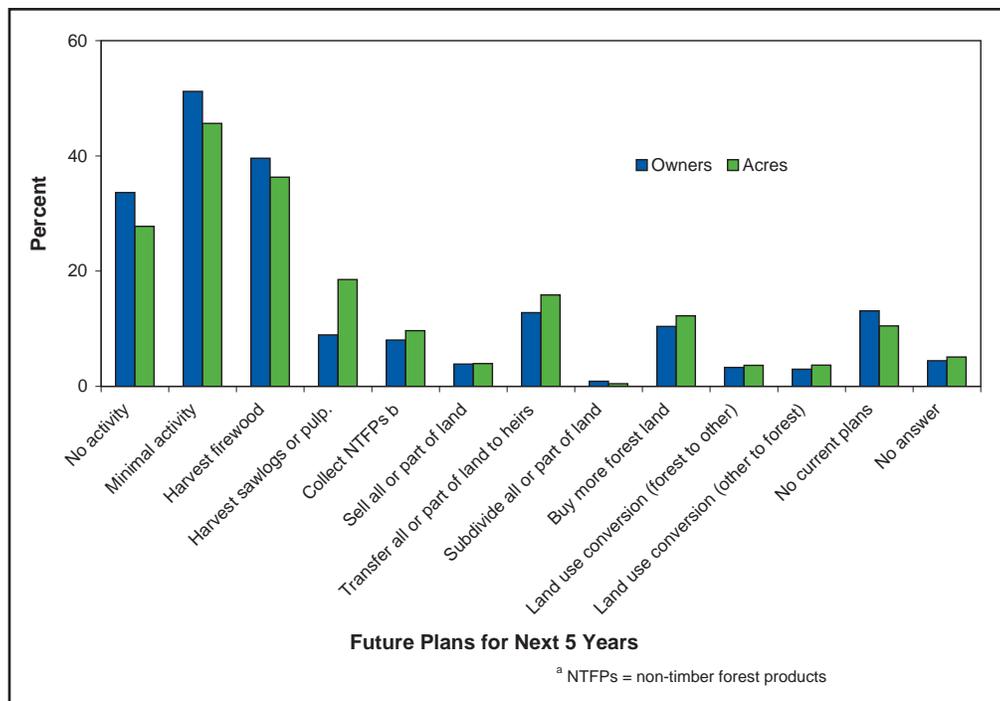


Figure 17.—Percentage of family forest owners and acres of forest land by plans for next 5 years, Ohio, 2006.



## Urbanization and Fragmentation of Forest Land

### Background

Urban forests are valued because they create more livable cities and towns by providing services such as cooling and cleaning air, absorbing storm water, reducing noise, enhancing aesthetics, and acting as buffers between development. However, the effect of urbanization on forests goes beyond just the loss of land to development. Proximity to urban development impacts a forest's quality, character, and function, and affects the goods and services we consciously and unconsciously derive from forest land. Characteristics such as value for wildlife and ability to conserve biodiversity can be substantially impaired. As development occurs, remaining forests are often subdivided into smaller tracts. This division of contiguous forest land into smaller noncontiguous patches is called fragmentation. It and parcelization (the division of large ownerships into many smaller ones) are growing concerns throughout the United States. Fragmentation of forest land, particularly by urban uses, degrades watersheds, increases site disturbances, favors invasion by exotic plant species, and reduces forest interior habitat while increasing edge habitat. For example, wildlife biologists believe that fragmentation is a contributing factor in the decline of bird species that prefer forest interiors. Using remotely sensed data, FIA scientists have investigated forest characteristics associated with urbanization.

### What we found

The population of Ohio is growing, and urban development is expanding into rural areas and changing the character of many of its forests. These changes are referred to as urbanization. The extent of urbanization can be depicted as a gradient of population densities. Figure 18 displays forest land by the population per square mile of the census block in which it occurs. The highest local population densities are associated with forest land in and surrounding Ohio's major cities and towns. Most low population density forest land occurs in Ohio's hill country in the southeastern portion of the State, but even in this heavily forested portion of Ohio, most forest land occurs in census blocks with at least 25 people per square mile. Some small forested patches with low population densities also occur in the heavily farmed northwestern portion of the State. More than half of Ohio's forest land occurs in census blocks with more than 50 people per square mile.

One way to characterize the distribution and fragmentation of forest land is to look at how large each patch of forest land is and how frequently those sizes occur. There is a clear distinction in patch size between the glaciated and unglaciated portions of the State. In the Northwestern Unit, nearly half the forest land occurs in patches of fewer than 50 acres; in the South-Central Unit, 65 percent of the forested land cover is in patches of more than 1,000 acres (Fig. 19). Note that the techniques used in this analysis to measure patch size may not discern breaks in the contiguous forest that are hidden by forest canopy, such as some roads.

Figure 18.—Forest land in Ohio by the population density of the census block it is located in (U.S. Bureau of Census 2002).

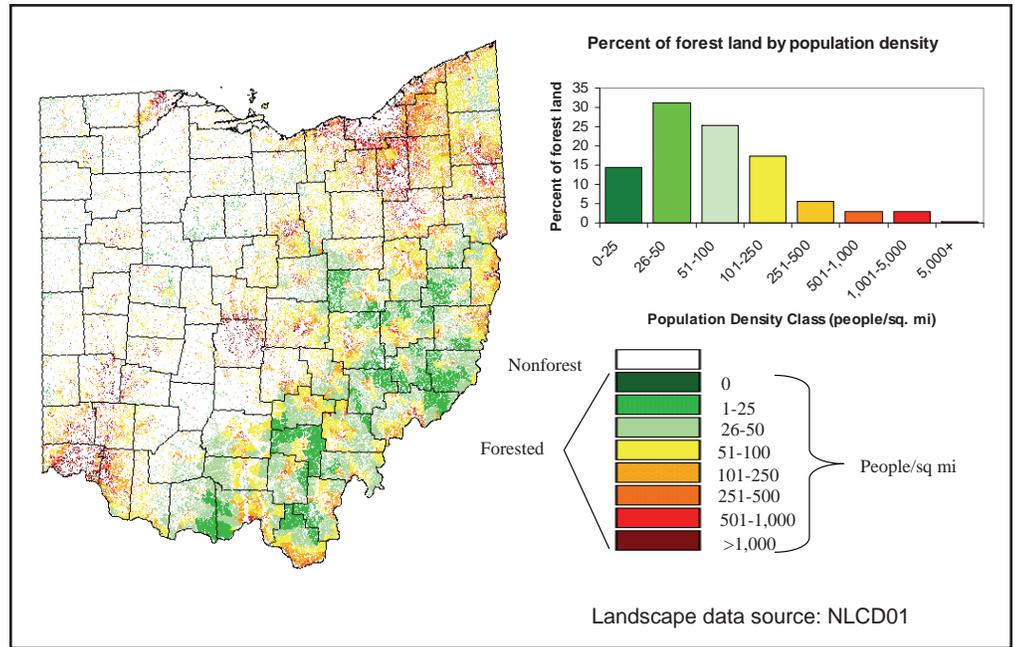
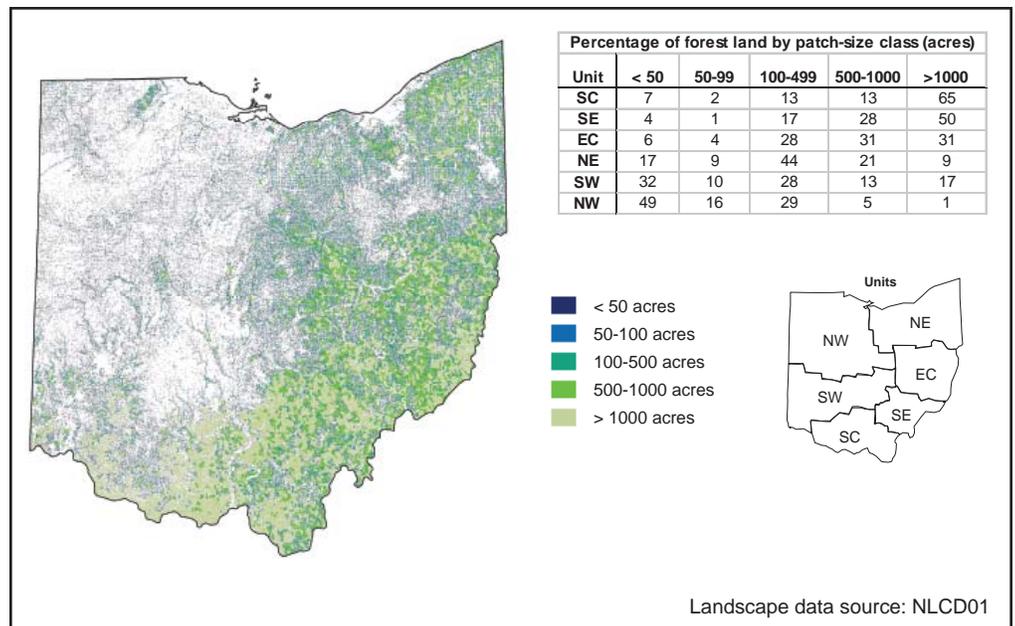


Figure 19.—Forest land in Ohio by average size of forest patches, map, and percentage by size class and unit.



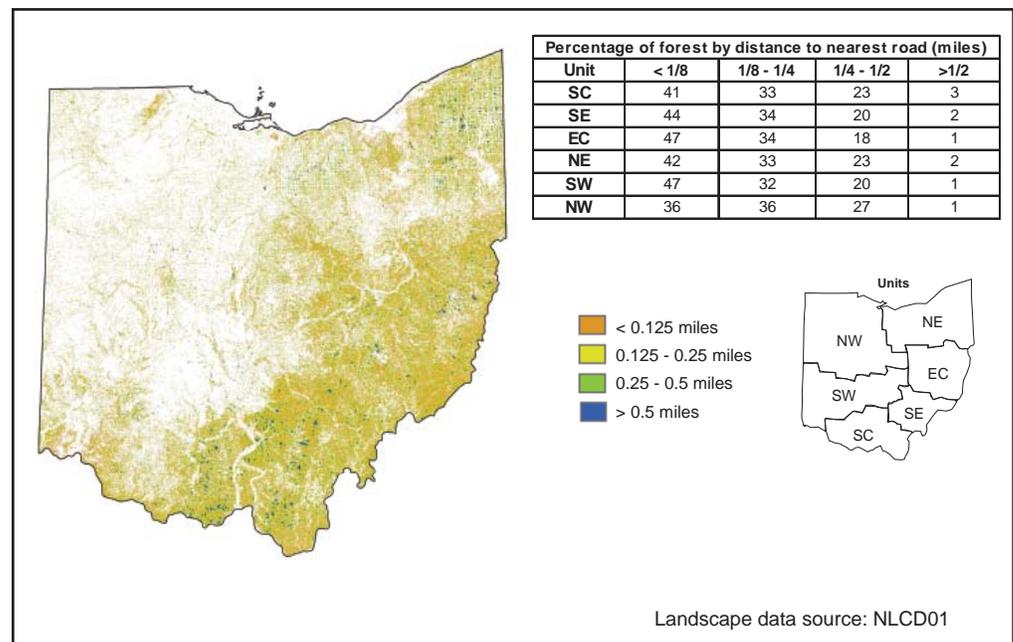
Another way to measure urbanization and fragmentation is to look at the distance forest land is to the nearest road. In Ohio, most forest land is close to a road—only about a fourth of the forest land is more than 0.25 miles from a road (Fig. 20).

As forest land is fragmented by roads and other development, forest patch size decreases and larger portions of the forest are influenced by edge conditions. As the amount of forest edge increases, the amount of interior forest habitat decreases. Most of Ohio’s forest interior habitat occurs in the three unglaciated units where at least 40 percent of the forest area is more than 90 m (295 feet) from a forest edge. This contrasts with the glaciated units where at least three-fourths of the forest land is within 90 m of the forest edge (Fig. 21).

What this means

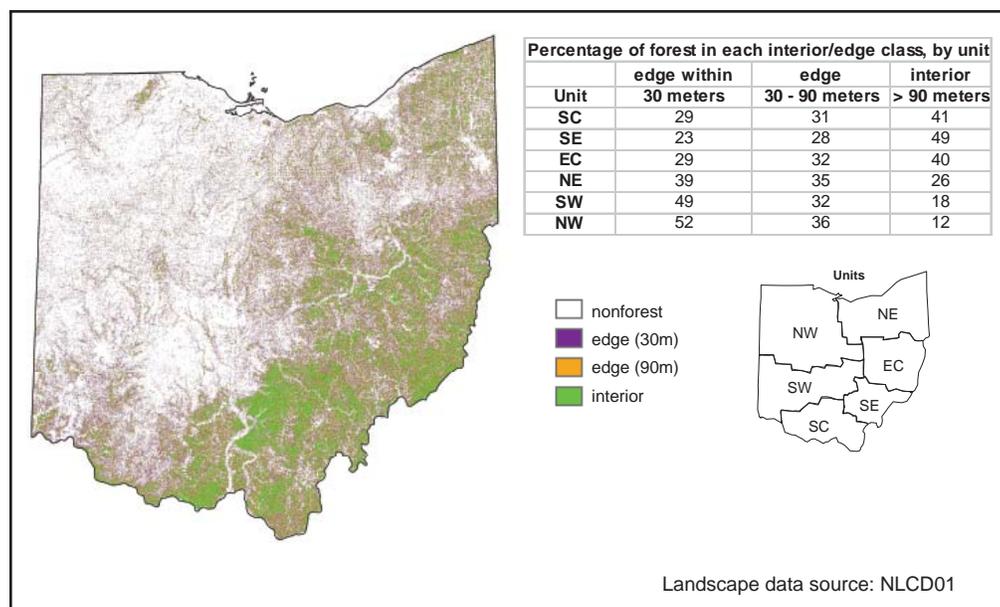
Urbanization is having an increasing impact on the quantity and quality of goods and services provided by Ohio’s forests. The combination of increasing numbers of forest land owners who own smaller parcels of land (parcelization), decreasing forest patch sizes (fragmentation), and increasing proximity to human populations, roads,

Figure 20.—Forest land in Ohio by distance to nearest road, map, and percentage by distance class and unit.



and other urban areas (urbanization) is making forest land more difficult to manage for timber and wildlife as well as making traditional access to forests for recreation more difficult. This is occurring at the same time more demands are being placed on forests to produce products and services ranging from timber to wildlife habitat to clean water and air. Because more people are living among the forests, forest managers will have to contend with more people-related issues. Urban development, particularly development that is poorly planned, has been shown to degrade wildlife habitats and watershed quality, affect the spread of forest invasive pests and diseases, impact forest function, and change how forest management decisions are made (Nowak et al. 2005). “As the landscape becomes more urbanized, forest management objectives likely will shift from commodity-based management toward more ecosystem services” (Nowak and Walton 2005). In Ohio, current forest conditions favor species that thrive in forest edges and have become accustomed to living beside humans. These habitats are less favorable to species that prefer interior forest conditions. Urbanization and fragmentation also make it more difficult for plant species to migrate across the landscape in response to changes in climate.

Figure 21.—Forest land in Ohio by distance to forest edge and interior forest, map, and percentage by distance class and unit.





## FOREST RESOURCE ATTRIBUTES



Tar Hollow State Park; photo used with permission by the Ohio Department of Natural Resources, Division of Forestry.  
Inset: Yellow trout lily; photo by Richard Widmann, U.S. Forest Service.

## Forest Structure—How Dense are the Woods?

### Background

How well forests are populated with trees is determined by measures of trunk diameter (measured at 4½ feet above the ground and referred to as diameter at breast height (d.b.h.)) and numbers of trees. These measures are used to determine levels of stocking. Stocking levels indicate how well a site is being utilized to grow trees. Stocking levels for Ohio's forests are provided in this report using all live trees and by including only growing-stock trees. Growing-stock trees are economically important and do not include noncommercial species (i.e., hawthorn, mulberry, and Osage-orange) or trees with large amounts of cull (rough and rotten trees). In fully stocked stands, trees are using all of the potential of the site to grow. As stands become overstocked, trees become overcrowded, growth begins to slow, and mortality increases. In poorly stocked stands, trees are widely spaced, or if only growing-stock trees are included in the stocking calculations, the stands can contain many trees with little or no commercial value. Poorly stocked stands can develop on abandoned agricultural land or result from wildfires or poor harvesting practices. Poorly stocked stands are not expected to grow into a fully stocked condition in a reasonable amount of time whereas moderately stocked stands will. Comparing stocking levels of all live trees with that of growing-stock trees shows us how much of the growing space is being used to grow trees of commercial importance and how much is occupied by trees of little or no commercial value.

### What we found

Trees have increased in size and number in Ohio. Of trees 5 inches and larger in d.b.h., the average diameter has increased from 9.3 to 9.7 inches since 1991. The average number of trees per acre of timberland has increased from 126 to 136 trees; 10 and 9 of these trees, respectively, are considered to be of noncommercial species (Fig. 22, 23). Numbers of noncommercial species have been declining, but because of changes in which species are considered noncommercial, estimates are not exact. In 1968, noncommercial trees averaged at least 23 trees per acre—one-fourth of the total trees per acre.

In Ohio, 3.2 million acres (42 percent) of forest are fully stocked or overstocked with live trees, and 1.0 million acres (13 percent) are either poorly stocked or nonstocked (Fig. 24). Since 1991, stocking levels have increased as acreage has shifted to the fully stocked and overstocked levels. Acreage in fully stocked and overstocked stands has increased by 1.5 million acres or 85 percent since 1991; still, more than half the stands are less than fully stocked with live trees. Considering only the commercially important growing-stock trees, the area with poor stocking is 2 million acres—double that when including all trees (Fig. 25). Of the 2 million acres that are poorly stocked with growing-stock trees, 37 percent are less than 20 years old. Poorly stocked stands are

Figure 22.—Mean diameter of live trees (5 inches and larger in d.b.h.) by inventory year, Ohio.

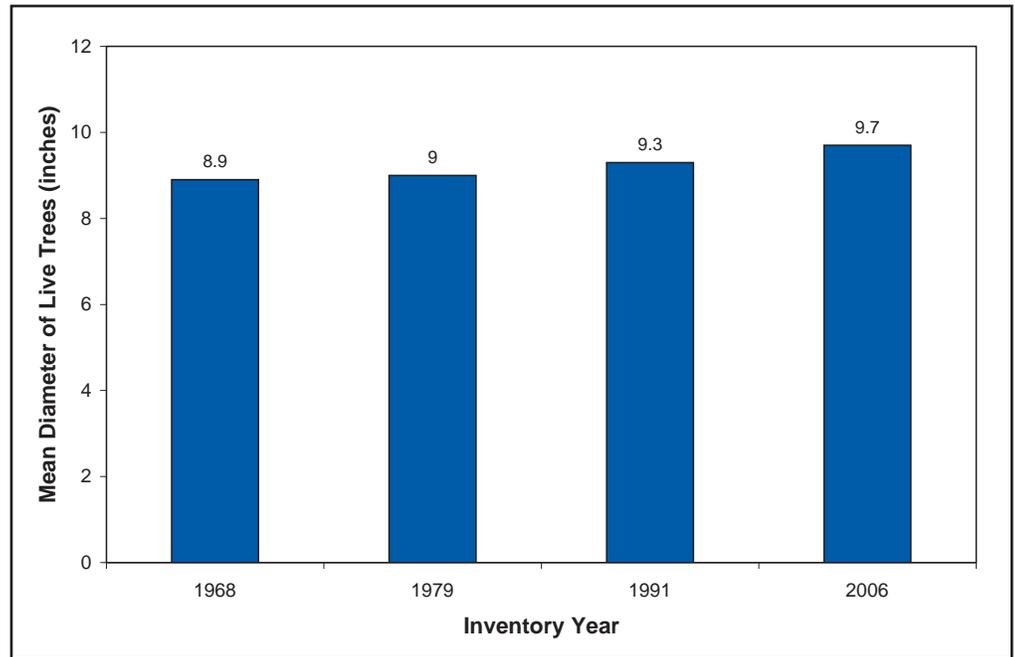
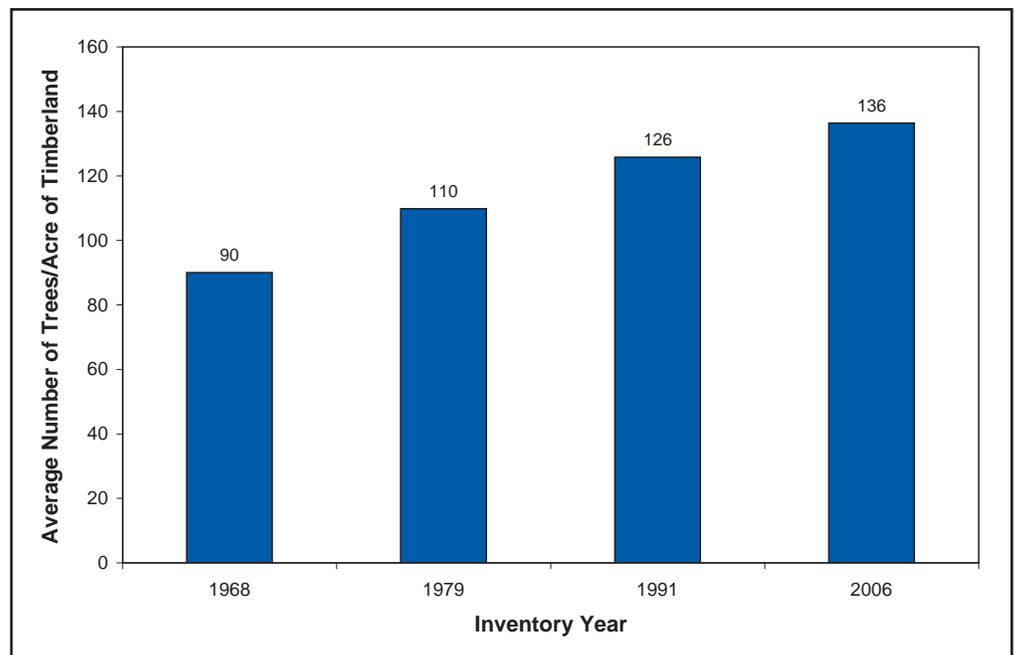


Figure 23.—Average number of trees per acre (5 inches and larger in d.b.h.) by inventory year, Ohio.



distributed across all stand age classes, although they make up a larger portion of young stands (Fig. 26). Ohio's forests are still fairly young—on 63 percent of the timberland the overstory trees average less than 60 years old.

### What this means

The recent increase in the average number of trees per acre and increase in average diameter have brought about an overall improvement in stocking levels in Ohio's forests. Most stands are well stocked with trees of commercial importance. These improvements have occurred while these same forests have contributed to Ohio's economy by supporting a vibrant timber products industry. The large area of well-stocked stands presents opportunities for forest management without diminishing forest growth. Managing these stands can keep them growing optimally by preventing them from becoming overstocked. The 2.0 million acres (27 percent) of timberland that is poorly stocked with commercially important species represents a loss of potential growth,

although these forests still contribute to diversity. These stands may have originated as pasture land that reverted to forest or from poor harvesting practices. They represent a challenge to forest managers because they contain little value to pay for improvement. Stands that are poorly stocked with trees are



Poorly stocked stand of bottom land hardwoods; photo by Richard Widmann, U.S. Forest Service

probably more susceptible to invasion by non-native species, such as multiflora rose and honeysuckle, than fully stocked stands because of their more open growing conditions.

The shift to denser levels of stocking indicates that growing conditions in Ohio are becoming more crowded and therefore more shaded. As competition for light, moisture, nutrients, and growing space increases, trees adapted to grow in more shaded conditions will tend to do better than trees adapted to the more open early successional conditions. This is reflected in the changes in the species composition discussed later in this report.

Figure 24.—Area of timberland by stocking class of live trees, Ohio, 1991 and 2006.

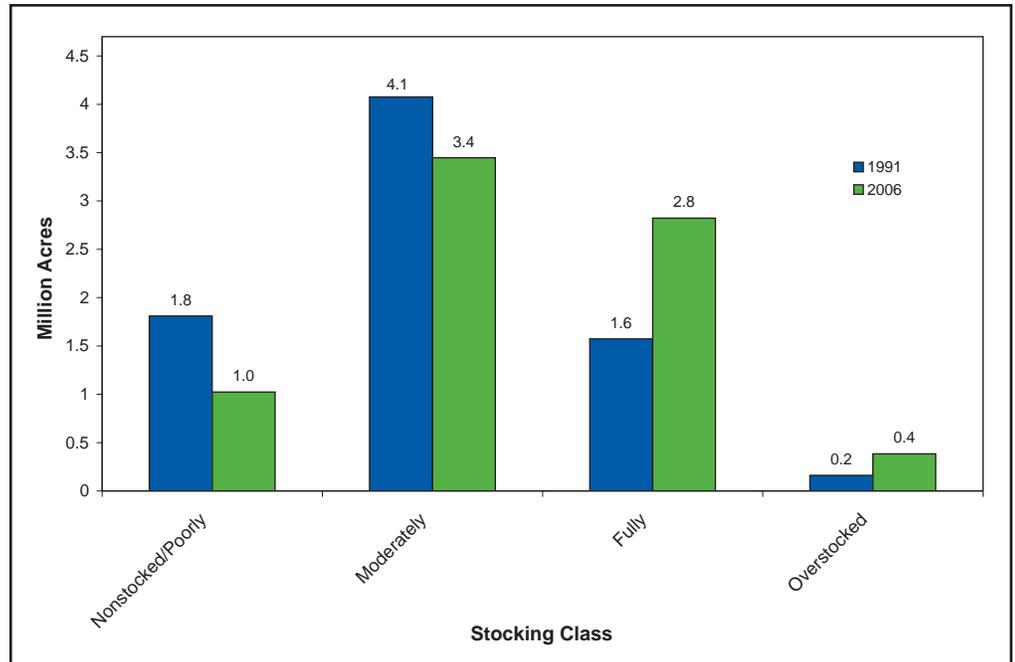


Figure 25.—Area of timberland by stocking class of growing-stock trees, Ohio, 1991 and 2006.

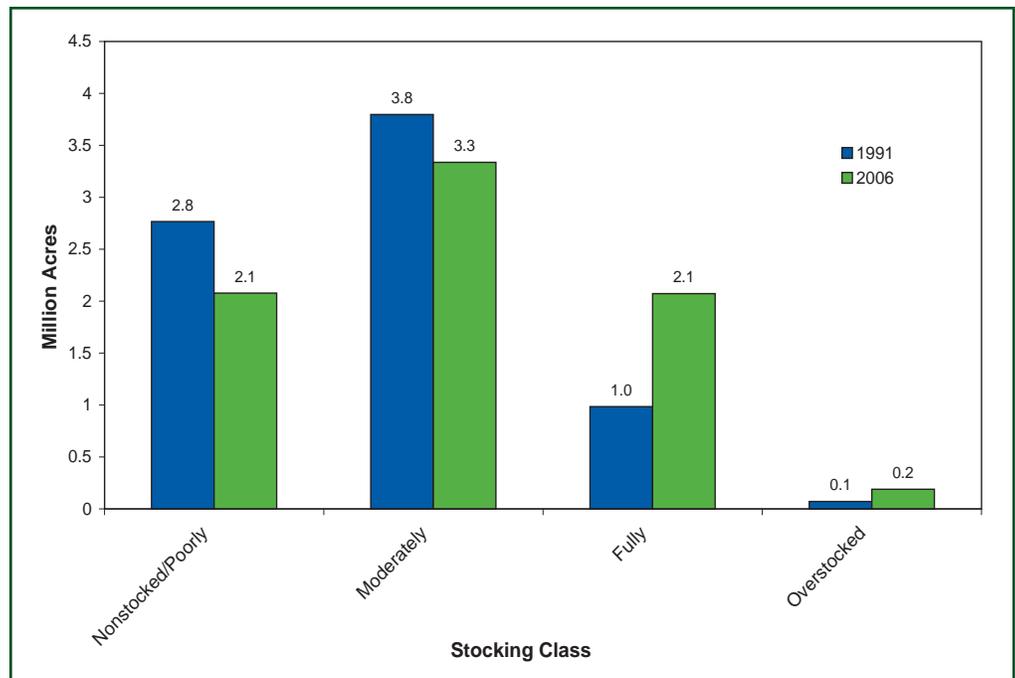
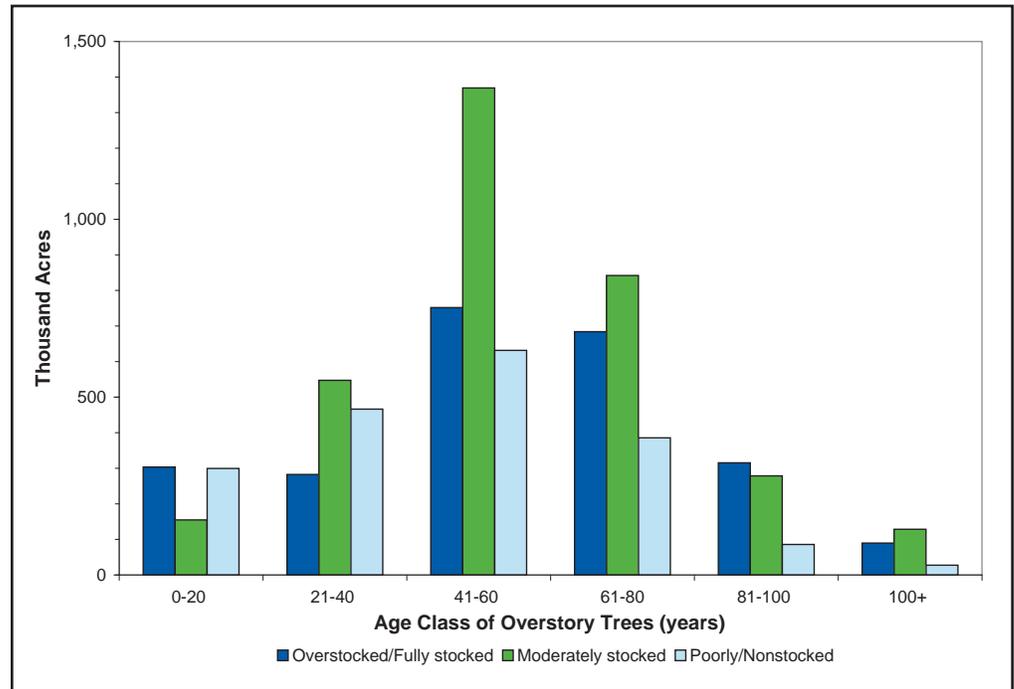


Figure 26.—Area of timberland by stocking of growing-stock trees and stand-age class, Ohio, 2006.



## Numbers of Trees by Diameter Class

### Background

The number of trees is a basic component of forest inventories. It is generally straightforward to estimate, reliable, objective, and comparable with past estimates. In spite of their simplicity, estimates of number of trees by size and species are valuable in showing the structure of Ohio forests and the changes that are occurring.

### What we found

Changes in the numbers of trees have not been distributed evenly across diameter classes (Fig. 27). Between 1968 and 1979, there were increases in the numbers of trees across all diameter classes with large increases in the numbers of trees in the 6- and 8-inch diameter classes. The 1991 inventory showed a continuation of this trend with increases across all diameter classes, although increases in the lower diameter classes were less than previously. Since 1991, the number of trees has decreased in the 6- and 8-inch classes and the numbers of trees in the larger diameter classes have continued to increase. The curves of numbers of trees by diameter class have shifted to the right. Generally, the larger the diameter class, the larger the percentage increase in numbers of trees (Fig. 28).

Of trees 5 inches and larger in diameter, red maple is the most numerous species, followed by sugar maple. Since 1979, numbers of these two species have increased by 109 and 92 percent, respectively. Between 1979 and 1991, white oak and aspen were the only species to decrease in number, decreasing by 10 and 2 percent, respectively. Since 1991, white oak has continued to decrease (-17 percent) and many more major species are now showing decreases; additionally, hickory, beech, northern red oak, elm, and chestnut oak have all decreased in numbers recently (Fig. 29). Major species to show increases in numbers during the most recent inventory period were white pine, yellow-poplar, aspen, and red and sugar maples.

Numbers of sapling-size trees (trees 1 to 4.9 inches in diameter) have decreased by 11 percent since 1991 in Ohio. Losses were spread among many major species with large decreases in white ash, black cherry, elm, and all the oak species groups (Fig. 30). There was also a large decrease in the numbers of noncommercial saplings. Beech is notable in having a large increase in the number of sapling-size trees and a decrease in the number of large beech trees. Of all the species, sugar maple saplings are most numerous followed closely by those of red maple.

Figure 27.—Number of growing-stock trees by diameter class and inventory year, Ohio.

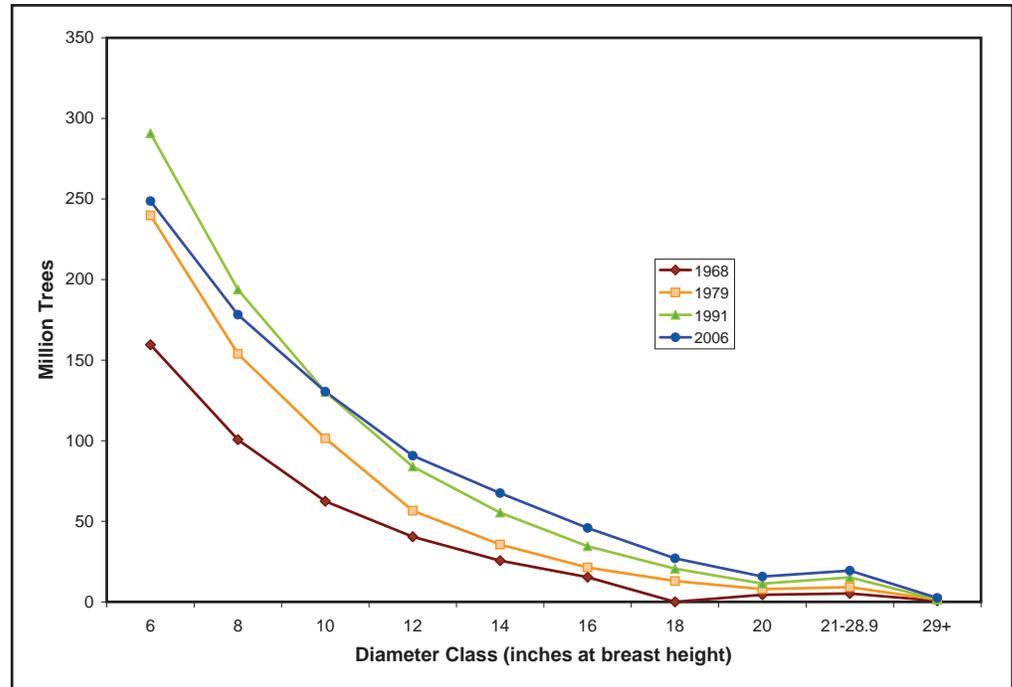


Figure 28.—Percent change in the numbers of trees by diameter class, Ohio, 1991-2006.

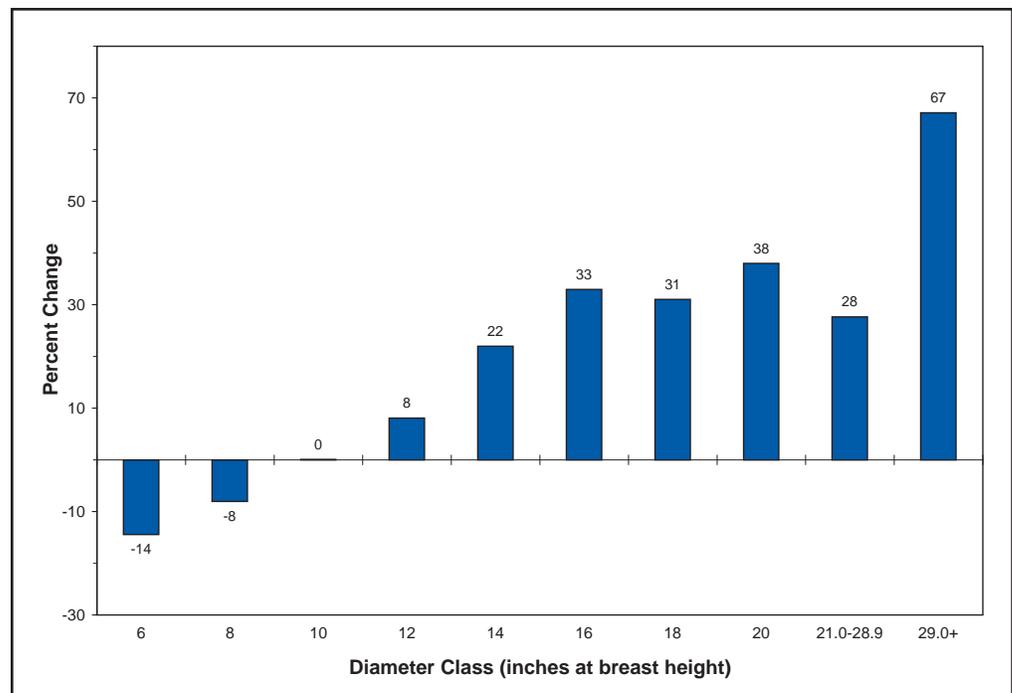


Figure 29.—Numbers of growing-stock trees 5 inches in d.b.h. and larger by species, Ohio, 1979, 1991, and 2006, and percent change 1991-2006.

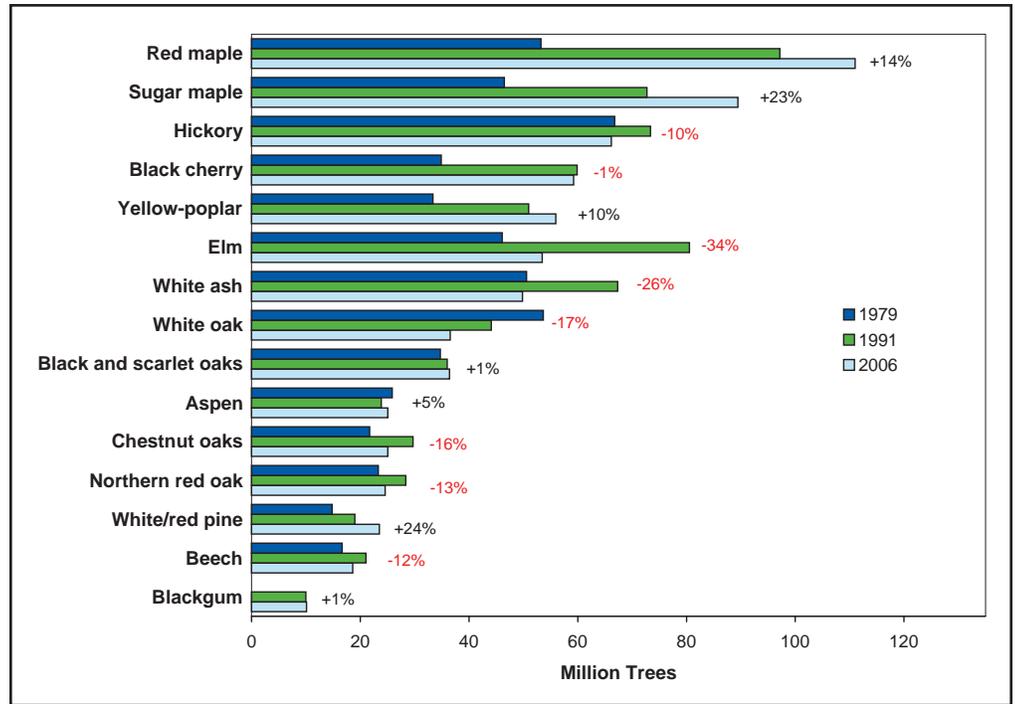
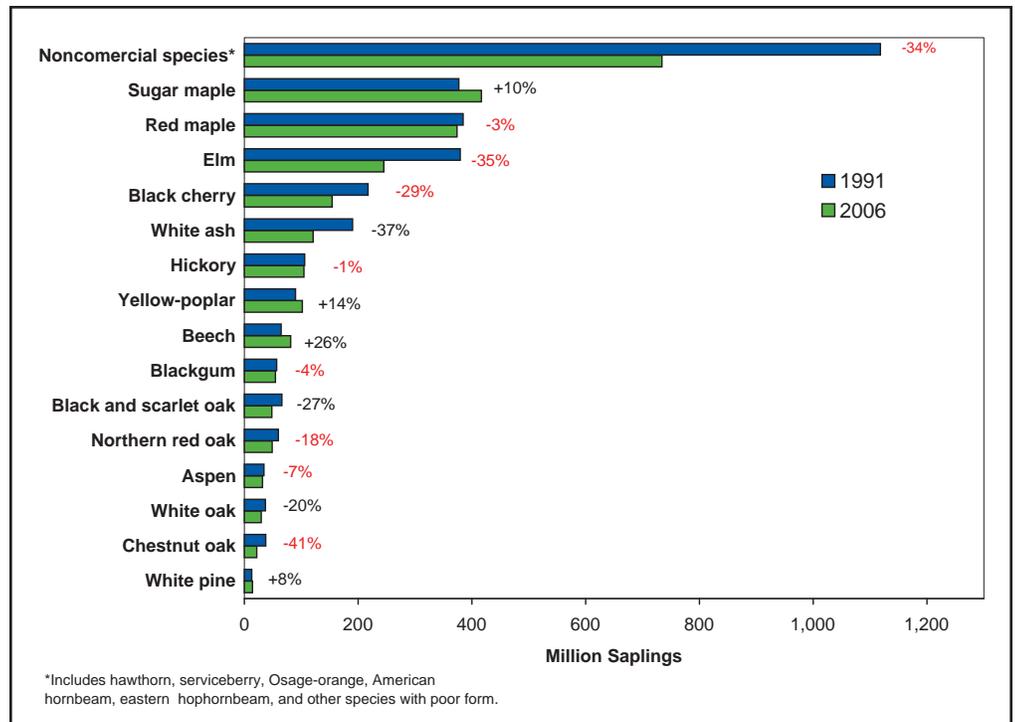


Figure 30.—Numbers of saplings (1 to 4.9 inches in d.b.h.) by species and percent change, Ohio, 1991 and 2006.





Fully stocked sapling-size stand; photo by Richard Widmann, U.S. Forest Service

### What this means

The numbers of large-diameter trees have increased steadily since 1968. The recent decrease in 6- and 8-inch trees indicates that as trees grow into larger size classes or succumb to competition they are not being completely replaced by smaller trees growing into the lower classes. At the landscape level, Ohio's forests have reached the point where the total number of trees has begun to decline because of crowding. Current trends indicate that the number of poletimber-size trees (5.0 to 10.9 inches d.b.h. for hardwood species) will continue to decline as the number of large sawtimber-size trees continues to increase.

Sapling-size trees represent the future forest. As large trees are harvested or succumb to insects and diseases, they will be replaced by saplings now growing in the understory. As this occurs the dominance of maple species in the understory will have an increasing influence on the species composition of large-diameter trees. The decrease in numbers of saplings is consistent with a maturing forest, which is especially true for the decrease in noncommercial species that has occurred. Many noncommercial species are pioneer species that need full sunlight to thrive.

## Tree Condition—Crown Position and Live Crown Ratio

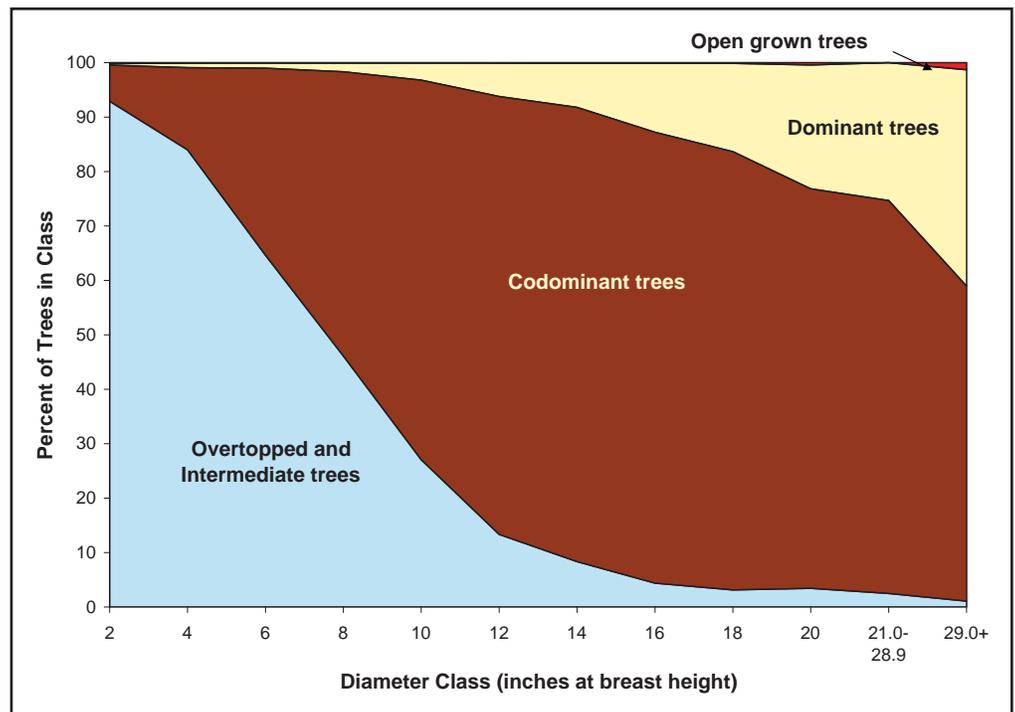
### Background

The crown position of a tree indicates how well it is competing with neighboring trees for light. A tree in an intermediate or overtopped crown position is below the general level of the canopy and is shaded by its dominant and codominant neighbors. Intermediate and overtopped trees generally can be expected to have slower growth and higher mortality rates than trees in more dominant positions. The live crown ratio or the percentage of a tree’s height in live crown is an indication of its vigor. Live crown ratios of less than 20 percent are typically assumed to be a sign of poor vigor. In the understory, trees with low live crown ratios have fallen behind in their struggle with surrounding trees for light and space and are unlikely to ever recover or grow into an overstory position.

### What we found

In Ohio, most trees in the 2-, 4-, 6-, and 8-inch diameter classes are in an overtopped or intermediate crown position—on average 86 percent (Fig. 31); conversely, 94 percent of trees with diameters 14 inches or larger are either dominant or codominant.

Figure 31.—Percentage of growing-stock trees by crown position and diameter, Ohio, 2006.

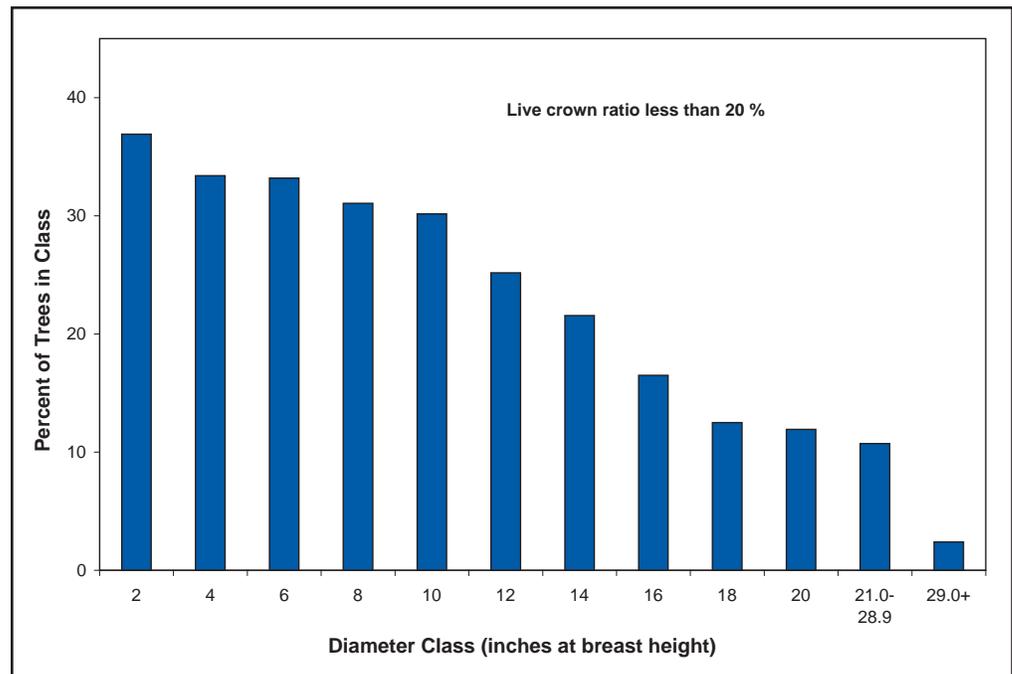


More than a third of trees in the 10-inch diameter class and below have live crown ratios of less than 20 percent. For the 6-inch class, 40 percent have live crown ratios below 20 percent (Fig. 32).

What this means

Shaded conditions created by overstory trees are stressing a large portion of trees below 10 inches in diameter. This finding is consistent with the maturing of Ohio’s forests and the likely cause for decreases in numbers of trees in the 6- and 8-inch diameter classes. Shaded conditions favor the growth of shade-tolerant species such as sugar maple over that of less shade-tolerant species such as American elm, white ash, and the oaks.

Figure 32.—Percentage of growing-stock trees with a live crown ratio of 20 percent or less by diameter, Ohio, 2006.



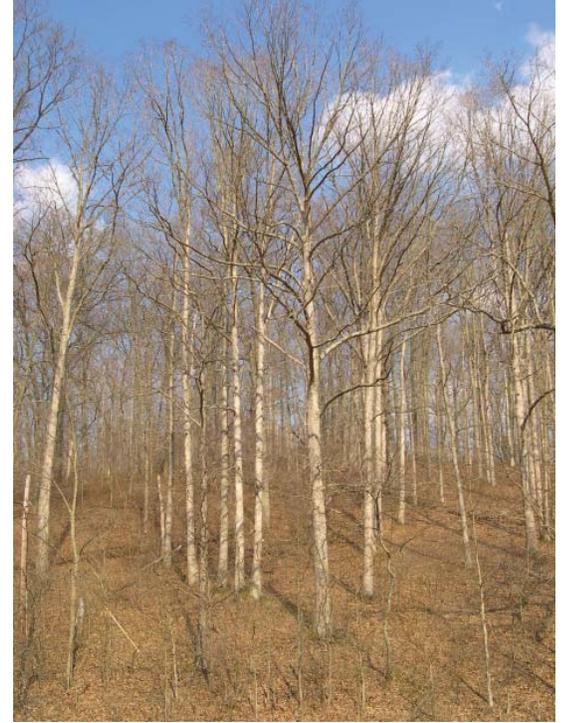
## Forest Composition

### Background

The species composition of a forest is the result of the interaction of climate, soils, disturbance, competition among trees species, and other factors over time.

Causes of forest disturbance in Ohio include wildfires, ice storms, logging, droughts, insects and diseases (e.g., Dutch elm disease), and land clearing followed by abandonment. Also, as forests mature, changes in growing conditions favor the growth of shade-tolerant species. Forest attributes that describe forest composition include forest type, forest-type group, numbers of trees by species and size, and changes in the species makeup of total volume.

Forest types describe groups of species that frequently grow in association with one another and dominate the stand. Similar forest types are combined into forest-type groups. While large trees represent today's forest, the composition of the lower diameter classes represents the future forest. Comparisons of species composition by size can provide insights into future overstory changes.



Sawtimber-size stand of white oak; photo by Richard Widmann, U.S. Forest Service

### What we found

The 2006 inventory of Ohio identified 109 tree species, 48 forest types, and 11 forest-type groups. The oak/hickory group covers more than half (4.1 million acres) of Ohio's forests, and the northern hardwood group covers another third (2.4 million acres) (Fig. 33). The oak/hickory group consists of white oak, northern red oak, hickory species, white ash, walnut, yellow-poplar, and red maple. Eighty-five percent of oak volume and 64 percent of red maple volume in the State grow in the oak/hickory group, while 78 percent of sugar maple volume and 60 percent of beech volume grow in the northern hardwood group. These broad species groups have changed little in area since 1991.

Sugar maple is the most numerous sapling (1 to 4.9 inches d.b.h.) followed by red maple (Fig. 34). Among trees between 5 and 10.9 inches d.b.h., red maple is most numerous followed by sugar maple. Together the oaks are most numerous in

Figure 33.—Area of timberland by forest-type group, Ohio, 2006 (error bars represent 67-percent confidence intervals around the estimates).

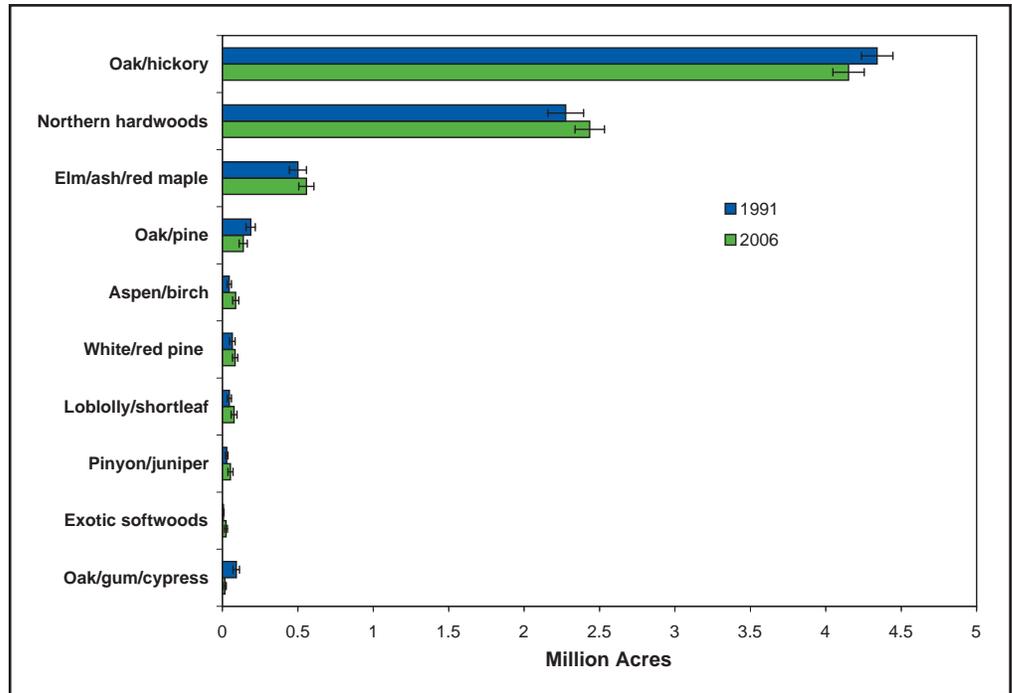
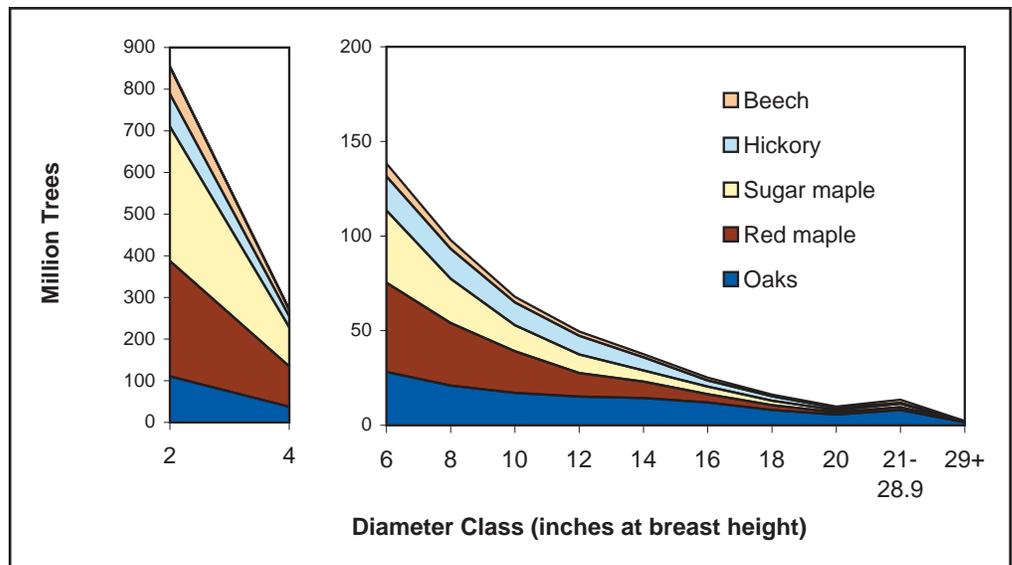


Figure 34.—Number of trees for selected species by diameter class, Ohio, 2006.



diameter classes 11 inches and larger. In the current inventory, oaks represent more than one-third of the trees 20 inches and larger in diameter, but only 5 percent of trees in the 2- and 4- inch diameter classes (Fig. 35). Conversely, maple species have a disproportionate share of trees in the 2- and 4-inch diameter classes—27 percent—compared to their presence in the larger diameter classes—14 percent of trees 20 inches d.b.h. and larger. Elm also has a disproportionately large share of trees in the 2- and 4- inch diameter classes—8 and 25 percent, respectively. Oaks have been decreasing as a percentage of total growing-stock volume since 1968, while maple species have had an increasing share of total volume since 1952 (Fig. 36).

#### What this means

The small shift in area from the oak/hickory forest-type group to other groups does not fully depict the underlying shifts going on in individual species. A lack of oaks in the small diameter classes means that as large oaks are harvested or die, they will likely be replaced by species such as red and sugar maples that dominate the lower diameter classes. Maples will play an increasing role in Ohio's future forest. The area occupied by the oak/hickory forest-type group is likely to undergo a long-term decline and be replaced by the northern hardwood group.

Decreases in the oak proportion of the resource have been attributed to inadequate oak regeneration and the subsequent lack of oak growing into larger diameter classes, and selective harvesting of oak over other species. Generally, current forest practices do not promote the regeneration of oaks, and silvicultural tools to promote oak are not being used. Contributing factors to poor oak regeneration are lack of fire, understory growing conditions that favor more shade-tolerant hardwoods, white-tailed deer preferentially browsing oak seedlings, and smaller openings from low intensity harvesting. Long-term changes in forest composition can alter wildlife habitats and affect the value of the forest for timber products.

Figure 35.—Species composition by diameter class, Ohio, 2006.

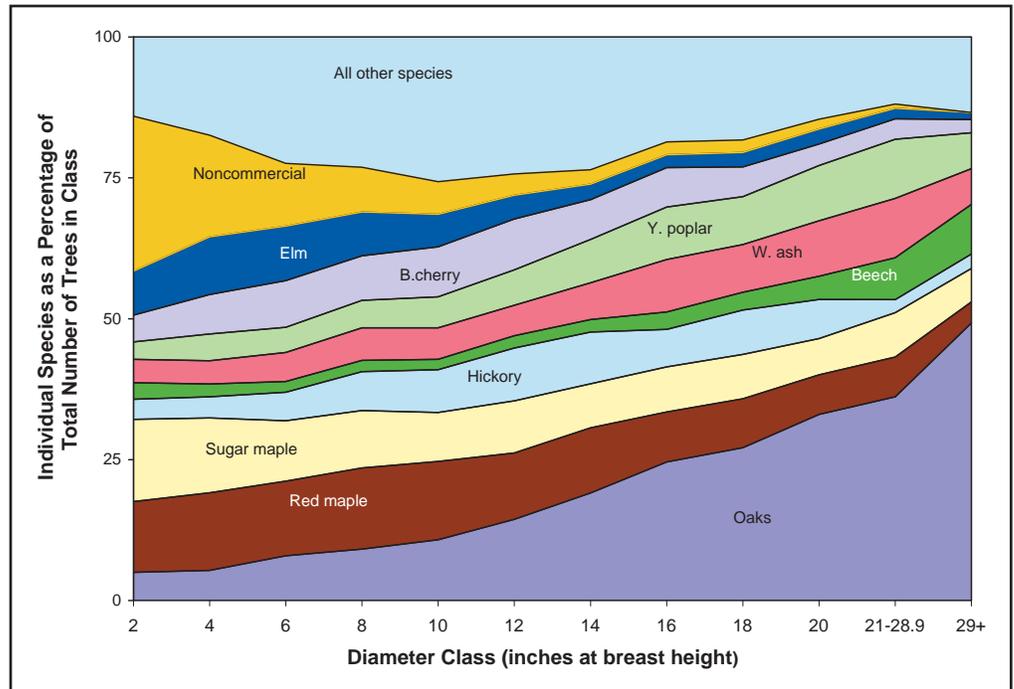
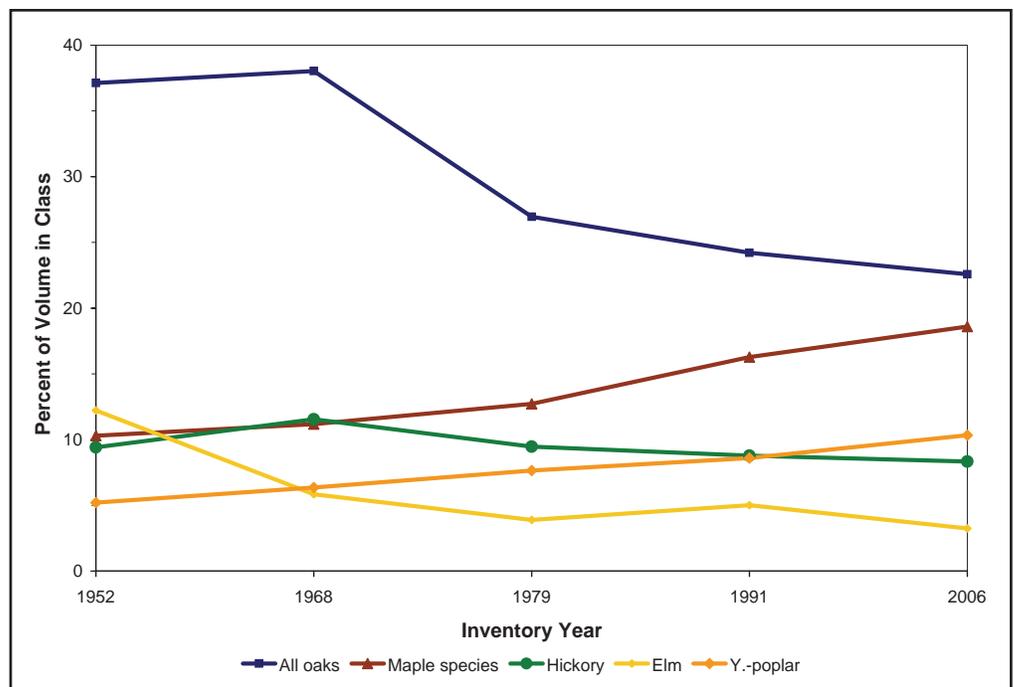


Figure 36.—Change in selected tree species as a percentage of total growing-stock volume, Ohio, 1952-2006.



## Distribution of Common Species

### Background

Displaying the distribution of individual species spatially shows where a species is concentrated and where it is sparse. Species are distributed by how well they are suited to particular site conditions and by the frequency of disturbances such as wildfire, timber harvesting, insect and disease outbreaks, and land clearing followed by reforestation. At the landscape scale, broad geophysical and biophysical features are apparent such as the extent of glaciers, and land use patterns.

FIA has mapped species distributions by taking the percentage of total basal area represented by each species on inventory plots and using it to make estimates of forest composition across the landscape. The highest category represents areas where a single species represents more than half the stocking of live trees. In the middle category, the mapped species represents a substantial portion (10 to 50 percent of stocking) of the stand. And in the lowest category, the mapped species is not present or is scattered.

### What we found

The major species of trees growing in Ohio are well distributed throughout the State. An example of this is red maple, a component of nearly every forest type in the State (Fig. 37). Red maple is concentrated mostly in the Northeastern Unit where soils tend to be poorly drained. Here red maple has seeded on abandoned farm land. Sugar maple also grows on a wide range of site conditions but typically does better on well-drained soils than on swampy or thin dry soils (Richard M. Godman et al. 1990). Sugar maple is commercially important chiefly in northeastern Ohio where it is associated with beech. Hickory grows throughout Ohio, but infrequently represents more than half the stand basal area. Yellow-poplar grows most abundantly on the west side of the Appalachian Mountains, where it grows well on lower slopes and sheltered coves. In Ohio it reaches its greatest abundance in the southeastern portion of the State. Black cherry is abundant in northeast Ohio but nearly absent from the southernmost part of the State. White ash is widely distributed. Its highest concentrations are in the center of the State where it frequently represents more than half the stocking. Together the oaks generally grow more abundantly in the unglaciated southeastern portion of the State. Here they are more tolerant to dry conditions in the thin upland soils than some of the other major species. This is especially true for chestnut oak, which grows mainly on dry ridges. Historically, wildfires have also promoted the growth of the oaks over other species in southern Ohio.

### What this means

Across the State, there are few areas where any one species represents more than half the stocking of live trees. Each of the 10 major species typically represents between 10 and 50 percent of stocking where it occurs. Ohio's diverse mix of species reduces the impact of insects and disease that target a single tree species.

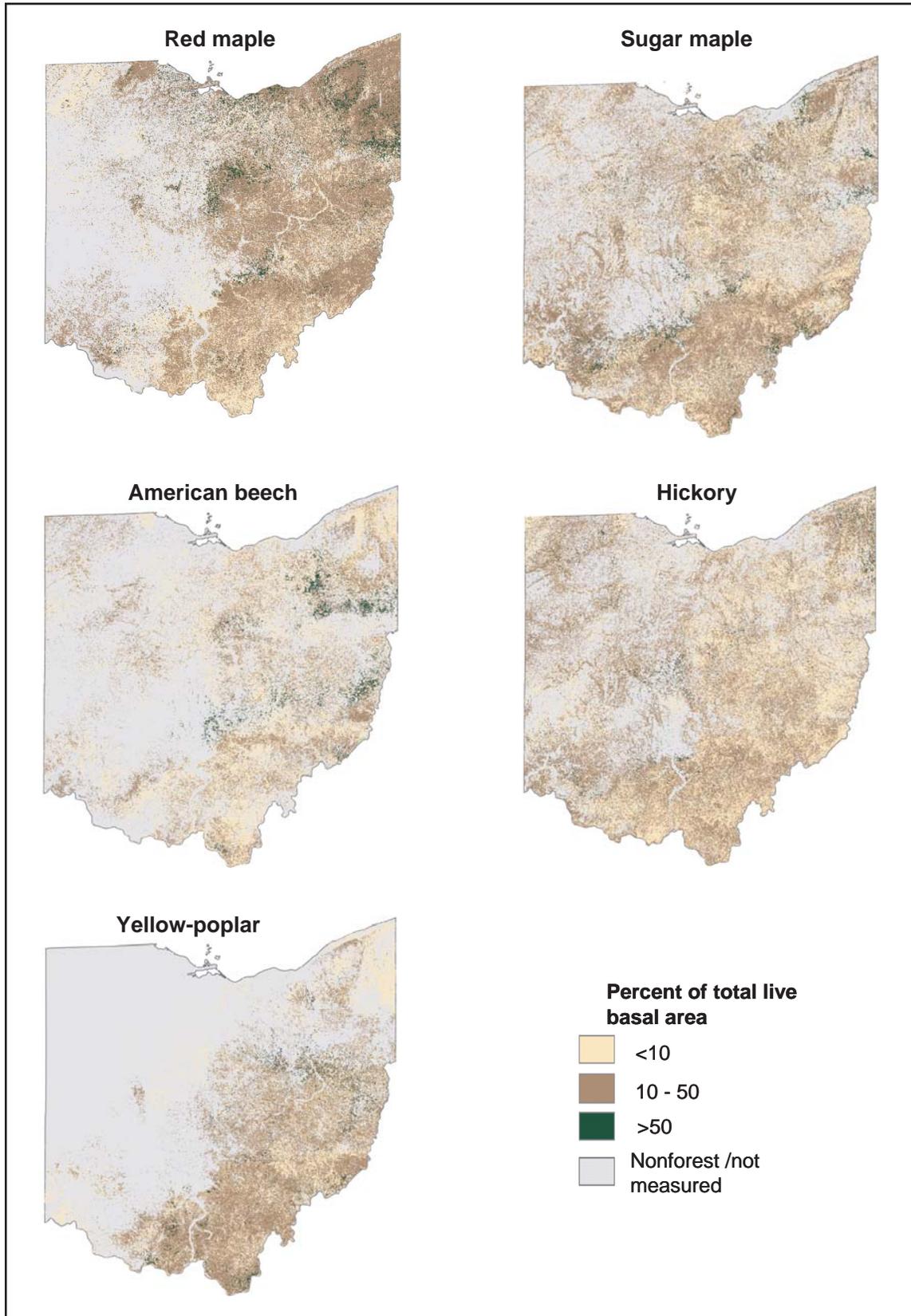


Figure 37.—Distribution of common tree species, Ohio, 2006.

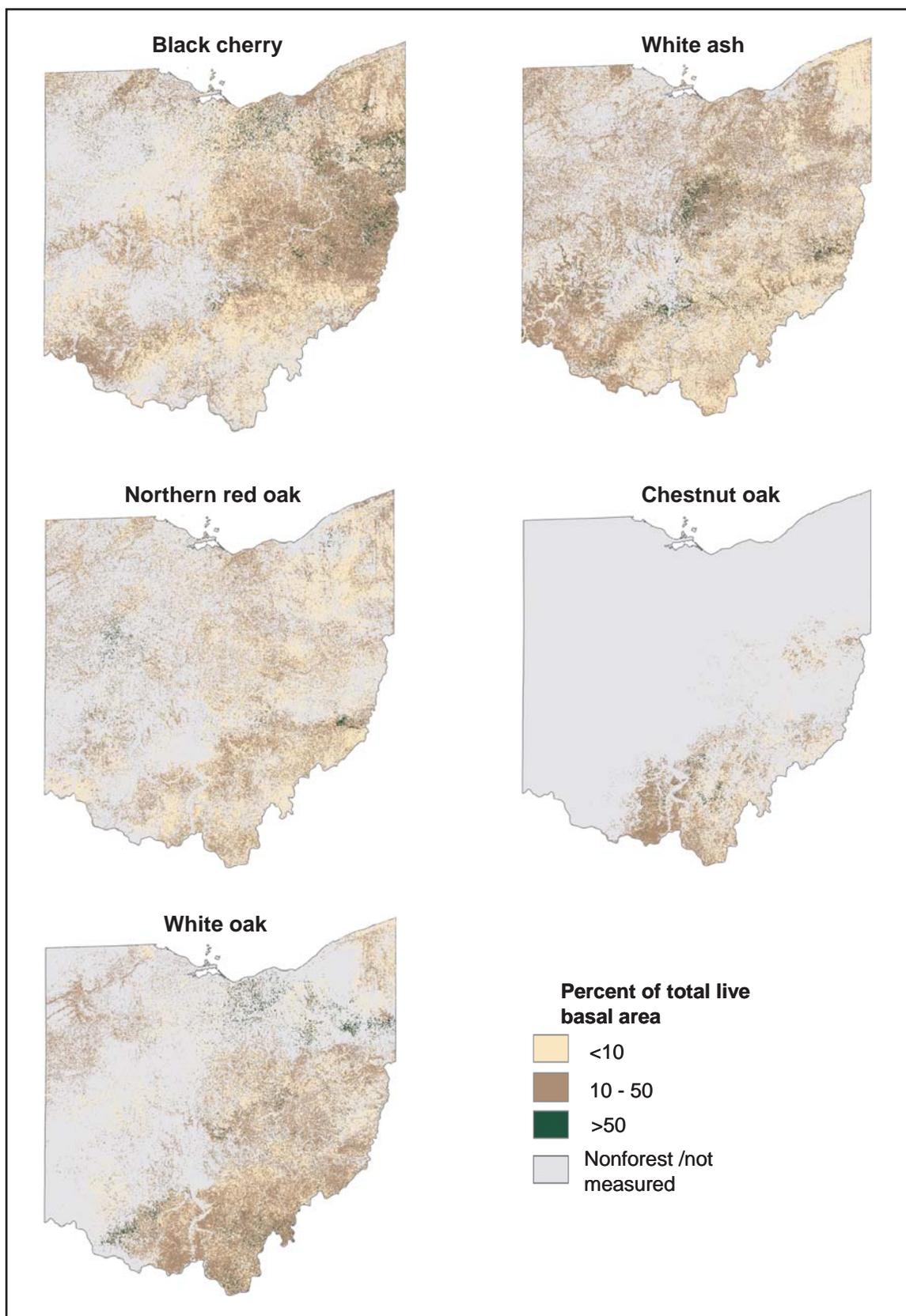


Figure 37.—continued.

## Volume of Growing-stock Trees

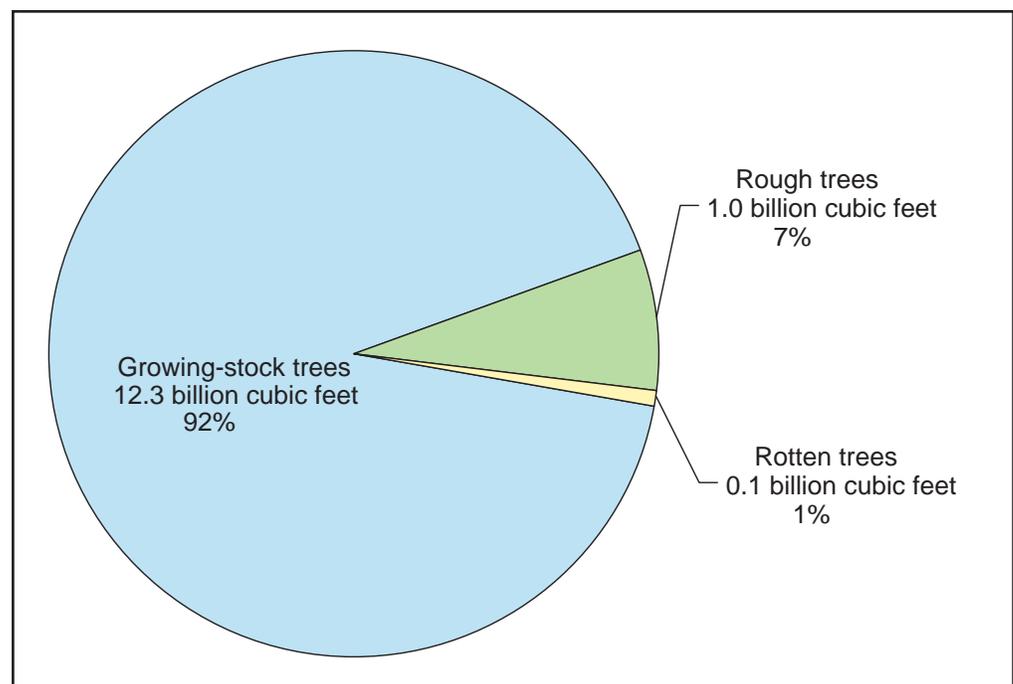
### Background

Measurement of growing-stock volume on timberland is important in assessing the volume of wood available for commercial products. Trees in this category meet minimum requirements for size and straightness, are within tolerances for rot, and are of commercial species. These trees are considered crop trees in silvicultural treatments where the goal is to maximize economic returns. Growing-stock volume is the resource base on which the forest products industry depends. Measures of growing-stock volume are useful in making comparisons to older inventories where only estimates of growing stock are available.

### What we found

Ninety-two percent of the sound wood volume in live trees is contained in growing-stock trees, which are commercially important species with good form. Rough and rotten trees account for 7 and 1 percent, respectively (Fig. 38). The total volume of growing stock on Ohio's timberland has steadily increased since 1968. The 2006 estimate of 12.3 billion cubic feet is 22 percent more than in 1991 and averages 1,603 cubic feet per acre (Fig. 39, 40). Forest inventories show a steady shift in timber volume toward larger trees (Fig. 41). During the most recent inventory period, volume increased in all classes greater than 8 inches, but the volume of trees decreased in the 6- and 8-inch diameter classes (Fig. 42). Most of the gains in volume were in trees large

Figure 38.—Components of total volume, Ohio, 2006.



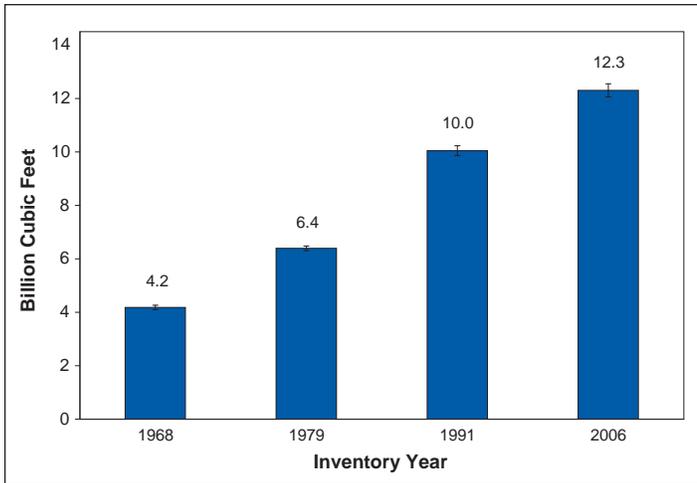


Figure 39.—Growing-stock volume by inventory year, Ohio, 1968, 1979, 1991, and 2006 (error bars represent 67-percent confidence intervals around the estimates).

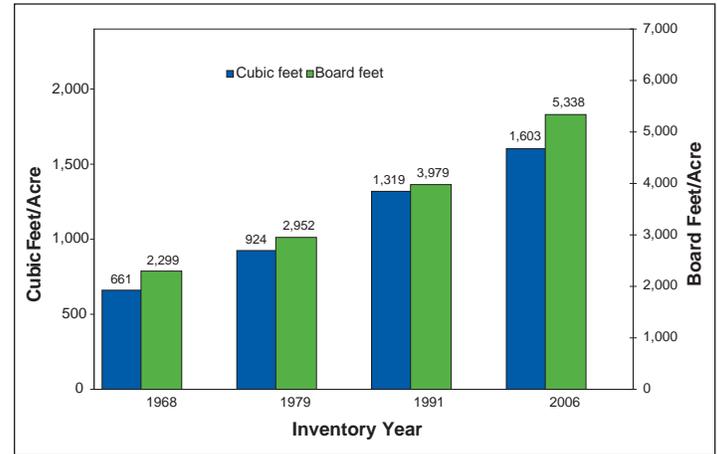


Figure 40.—Average growing-stock volume (board feet and cubic feet) per acre of timberland, Ohio, 1968, 1979, 1991, and 2006.

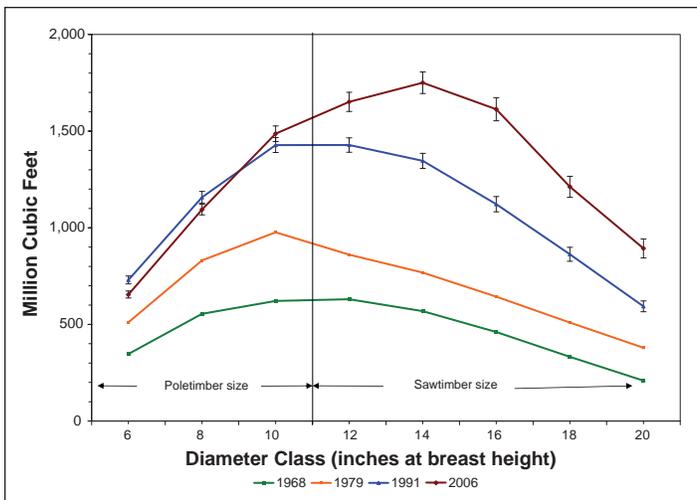


Figure 41.—Growing-stock volume by diameter class and inventory year, Ohio, 1961, 1975, 1989, and 2006 (error bars represent 67-percent confidence intervals around the estimates).

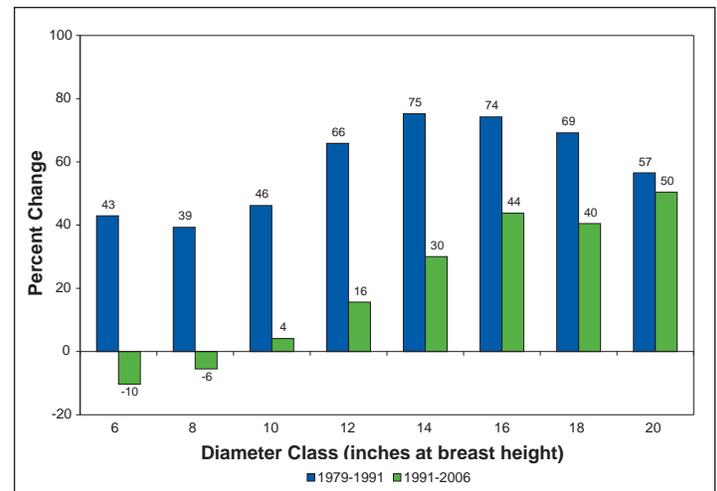


Figure 42.—Percent change in volume by diameter class on timberland, Ohio, 1979-1991 and 1991-2006.

enough to produce saw logs (11.0 inches in d.b.h. and greater for hardwood species), which reflects the changes in the numbers of trees discussed previously. The portion of volume large enough to produce saw logs increased by 35 percent to 41 billion board feet. Although recent gains are a continuation of increases that have been occurring over the last 40 years, the rate of increase is slowing. During the previous inventory period, 1979 to 1991, gains in growing-stock and sawtimber volumes were larger than in 1991 to 2006; 57 and 48 percent, respectively.

Yellow-poplar continues to lead in volume followed by red maple and sugar maple. These three species also had the largest volume gains since 1991 (Fig. 43). All of the oak species groups had increases in volume although these increases were generally less than many of the other major species. Together oak species increased in volume by 13 percent versus 22 percent for total volume. Of the major species, only white ash, elm, and American beech showed decreases in volume since the previous inventory.

In board-foot volume, the top ranked species differ little from those for all growing-stock volume (Fig. 44). Yellow-poplar remains the leading species, accounting for 12 percent of total board-foot volume followed by white oak and hickory. Together the oaks represent 27 percent of total board-foot volume and maples 15 percent. Ninety-six percent of Ohio's sawtimber volume is in hardwood species.

Average volumes per acre are highest in Ohio's Southeastern Unit (Fig. 45). This unit also has had a large increase in volume per acre since the previous inventory—37 percent. The Southeastern Unit includes much of the Wayne National Forest, which has high volumes per acre, averaging 1,935 cubic feet of growing stock per acre. The East-Central Unit has the lowest volumes per acre and the smallest percentage increase in volume per acre. In the Northwestern Unit, volumes per acre were comparable to the rest of the State, although this region had the lowest increase in total volume.

Yellow-poplar is the leading species in the three unglaciated units (East-Central, Southeastern, and South-Central) (Fig. 46). These units account for 89 percent of the State's yellow-poplar volume. White ash is the leading species in the Northwestern and Southwestern Units where it accounts for 15 percent of the total volume in each unit. Red maple, the leader in the Northeastern Unit, has nearly doubled in volume since the previous inventory and now makes up 20 percent of the volume in the unit.

Figure 43.—Growing-stock volume on timberland by species and percent change, Ohio, 1991 and 2006 (error bars represent 67-percent confidence intervals around the estimates).

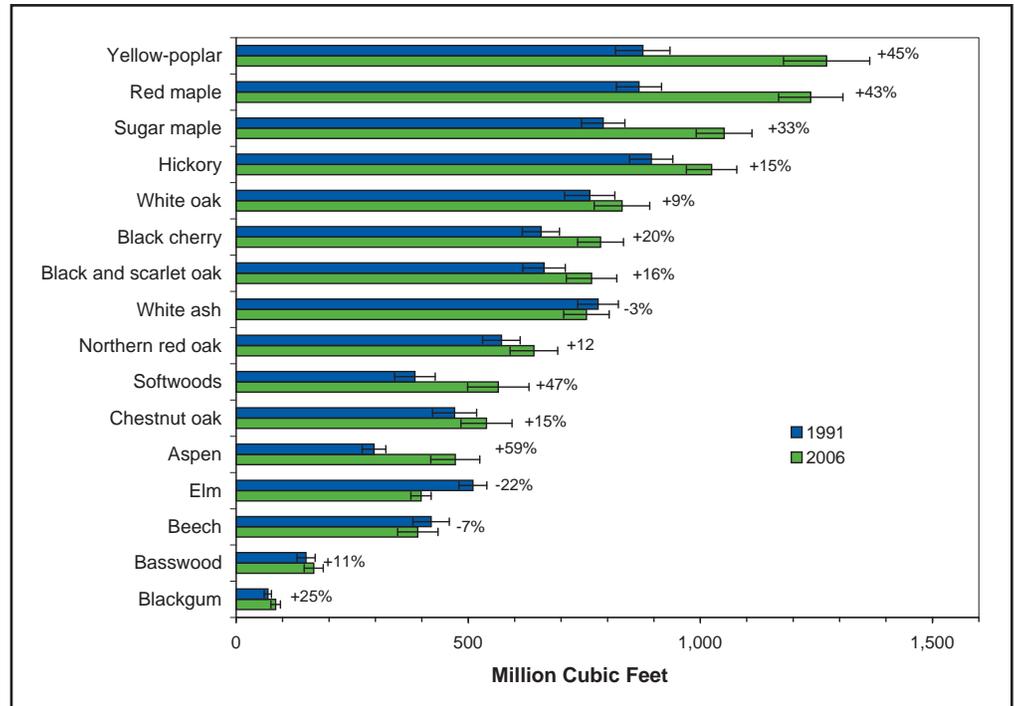


Figure 44.—Board-foot volume on timberland by species and percent change, Ohio, 1991 and 2006 (error bars represent 67-percent confidence intervals around the estimates).

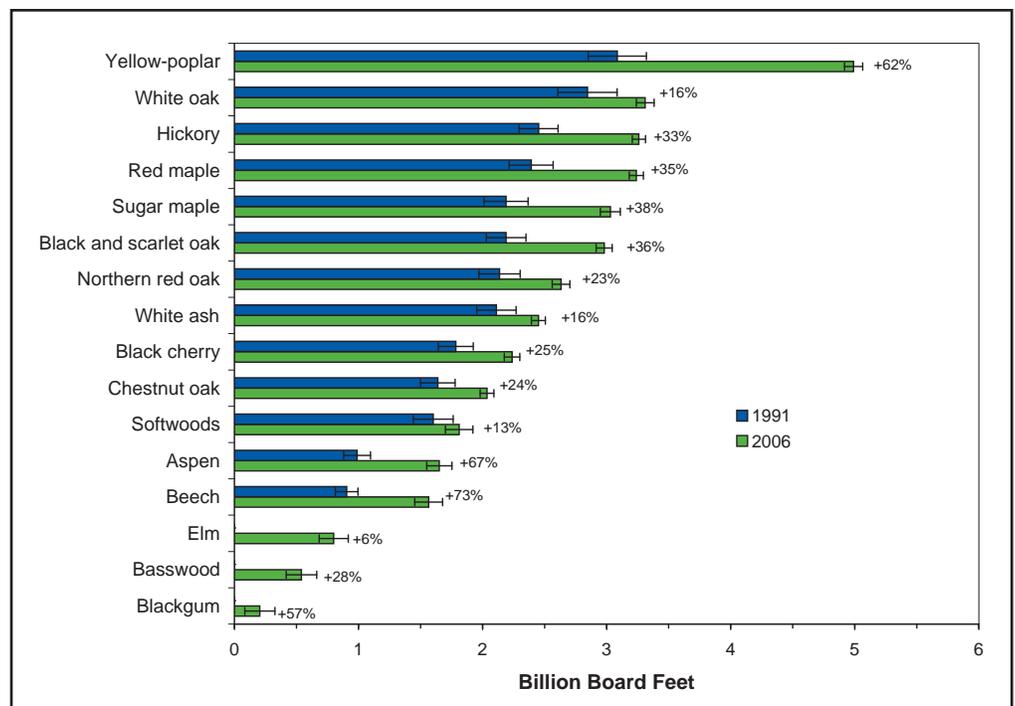


Figure 45.—Average cubic-foot and board-foot volumes per acre of timberland by unit, 2006, and percent change, Ohio, 1991-2006.

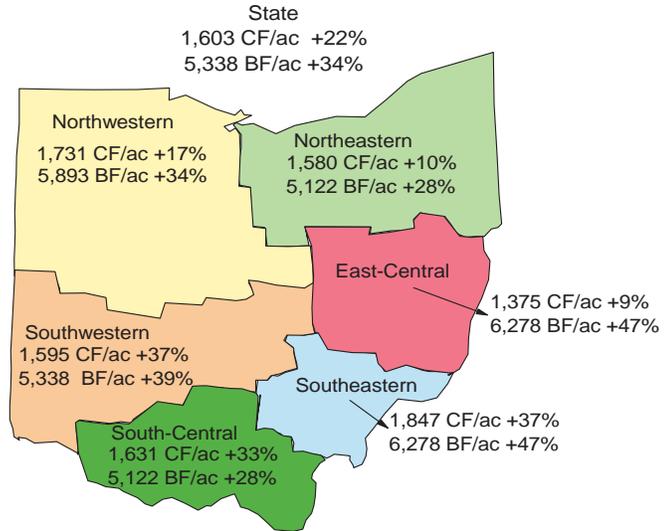
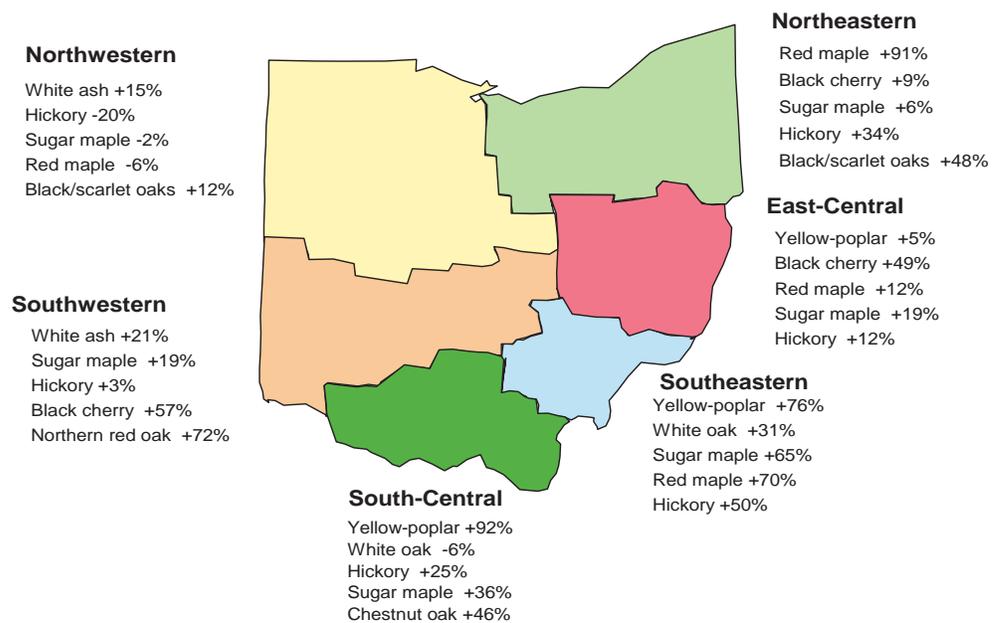


Figure 46.—Top five species by unit and percent change by volume, Ohio, 1991-2006.



## What this means

Continuous increases in volume have brought Ohio's timber resource to record levels in both total growing-stock volume and volumes per acre. And most trees meet minimum requirements to qualify as growing-stock trees. Timber growth is concentrated on sawtimber-size trees (more than 11 inches in d.b.h.), which explains why increases in board-foot volume (+35 percent) were more than those in cubic-foot volume (+22 percent). As trees grow in sawtimber size, their value for timber products jumps because they can now be used for higher value products. Because more growth is being put on higher value trees than previously, Ohio's forests are now adding value at an increasing rate, although rates of volume increase are slowing. This increase in value is good for landowners and the forest products industry. But, as the number of new trees growing into sawtimber size decreases, as shown by decreases in the numbers of 6- and 8-inch trees, harvesting practices become an increasing concern. Any mismanagement of sawtimber stands, if it occurs, will become more apparent in stands where most growth is occurring on residual sawtimber-size trees left after harvesting operations.

Changes in volume by species reflect changes that are occurring in species composition. Volume increases for the maples are larger than those for the oaks, although all oak species increased in volume. Oaks are doing better in Ohio than in the surrounding states of Pennsylvania, West Virginia, and Indiana, where many of the oak species have shown smaller increases or decreases in volume.

In the Northwestern Unit, increases in average volume per acre were comparable to the rest of the State, but total growing-stock volume increased by only 3 percent because of the loss of forest land. Decreases in volume of some of the leading species in this unit were also probably caused by loss of forest land. Because white ash is the leading species in the Northwestern and Southwestern Units, future mortality caused by the emerald ash borer will likely be significant in these areas. In the Northeastern Unit, red maple has proliferated on abandoned farm land. Because most red maple volume is in poletimber or small sawtimber-size trees, large increases in red maple volume are likely to continue there.

The East-Central Unit has lower volumes per acre and has had a smaller increase in volume since the previous inventory than the rest of the State. This finding is probably due to the region's land use history; large areas of forest in this unit are reclaimed strip mines with generally poor soils.

## Variation in Hardwood Quality by Species

### Background

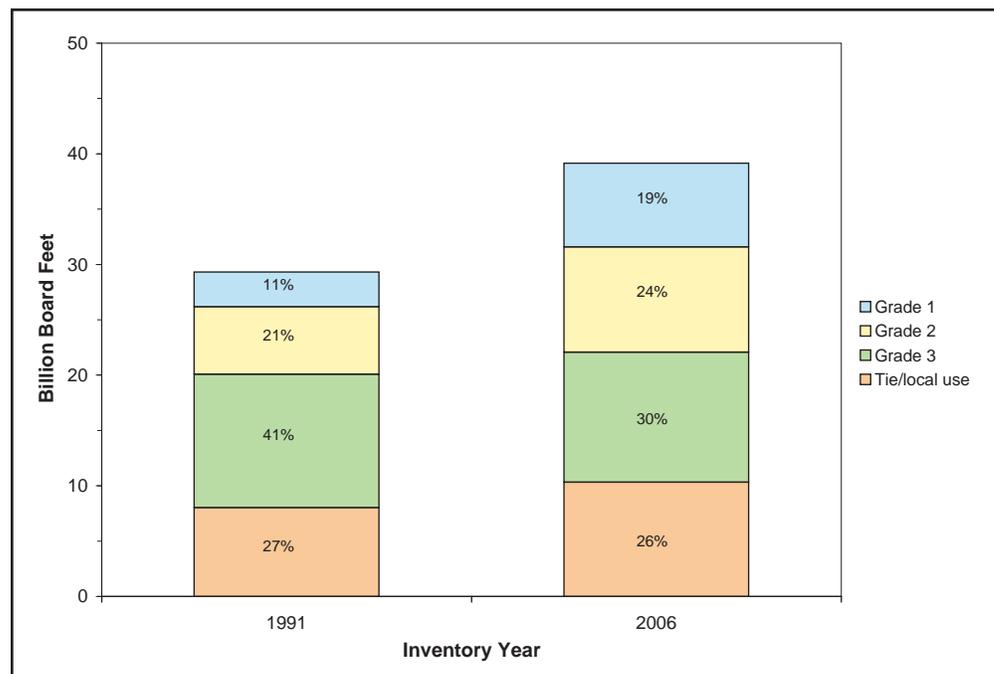
The use of the timber resource for sawn timber products is determined largely by tree quality and species. The best trees are used in the manufacture of furniture, cabinets, and other millwork that command high prices. Lower quality trees are used for pallets, pulpwood, and fuelwood. Quality varies by species due to differences in average diameter, growth characteristics, and past management practices. FIA assigns tree grades to sawtimber-size trees as a measure of quality. Tree grades are based on the amount of knot-free bole, amount of cull, and tree diameter. Trees need to be at least 13 inches d.b.h. to be considered for a grade 2, and 16 inches d.b.h. for a grade 1. Grade 1 yields the most high-grade lumber and tie/local use grades the least.

### What we found

The portion of sawtimber volume in tree grades 1 and 2 increased from 32 percent of total sawtimber volume in 1991 to 43 percent in 2006 (Fig. 47). In absolute terms the volume in grades 1 and 2 increased from 9.2 billion board feet in 1991 to 17.1 billion in 2006. Volume in the lowest grade (tie/local use) increased from 8.0 to 10.3 billion board feet, although it decreased as a portion of total volume to 26 percent.

In Ohio, yellow-poplar has the largest volume in tree grades 1 and 2, followed by white ash, northern red oak, basswood, and white oak (Fig. 48). These species, as well as chestnut oak and blackgum, have at least half of their sawtimber volume in tree grade 2 or better. Of the other major species in the State, beech had the lowest portion of volume in grades 1 and 2, followed by red maple, sugar maple, and black cherry. Many beech trees in Ohio are degraded because of large amounts of rotten wood. Red maple

Figure 47.—Hardwood board-foot volume by tree grade, Ohio, 1991 and 2006.



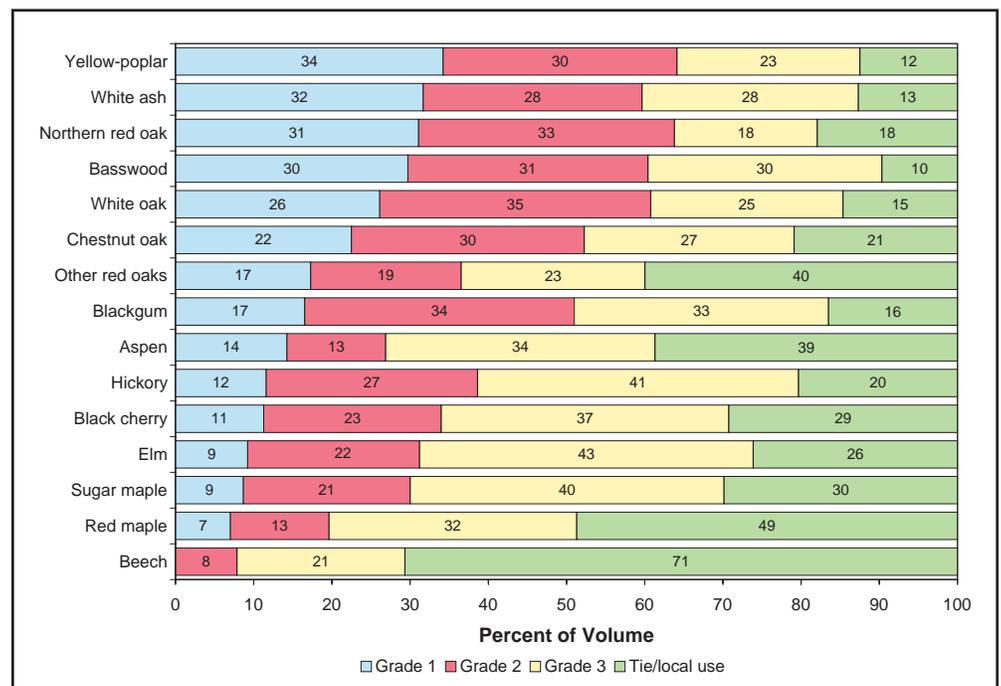
is graded lower than other species because it typically has more defects and smaller diameters. Beech, red maple, and sugar maple also do not self-prune as well as other species such as yellow-poplar and white ash.

What this means

Because small sawtimber-size trees are assigned a low grade on the basis of size alone, the increase in size of Ohio's trees has brought about an increase in saw log quality. Combined with increases in saw log volume, this represents a tremendous increase in the value of the forest resource for timber products. This increase is best shown by looking at yellow-poplar, which leads the State in board-foot volume; it had the largest increase in board-foot volume (62 percent) of all species between 1991 and 2006 and has the highest portion of its volume in grade 2 or better trees (64 percent). Countering the increase in quality because of tree size are changes in species composition. Red and sugar maples had some of the largest increases in volume but typically grade poorer than other major species. Future tree quality may be affected by changes in species composition.

In Ohio, about one-third of hardwood sawtimber volume is in trees less than 15 inches in d.b.h. These trees are too small to be rated grade 1. Forest land owners can receive high financial returns by practicing best management practices and favoring trees with the potential to grow into higher quality grade 1 and 2 trees. This rewards the landowner and greatly benefits the State's wood-using industries through value added in manufacturing.

Figure 48.—Percentage of saw log volume by tree grade for major species, Ohio, 2006.



## Biomass Volume of Live Trees

### Background

Trees play an important role in the world's carbon cycle. They act as a sink for carbon, removing it from the atmosphere in the form of carbon dioxide (a greenhouse gas) and storing it as cellulose. In this role, forests help mitigate the effect of burning fossil fuels and the resulting global climate change associated with increased levels of carbon dioxide in the atmosphere. Ohio's forests contribute greatly to the sequestration of carbon dioxide due to increases in tree volume.

Tree biomass, a measure of how much carbon is being stored on forest land, is the total weight of both live and dead trees, including branches, roots, and stumps.

### What we found

Biomass of all trees standing in Ohio's forests equals 635.2 million dry tons—an average of 80 tons per acre. The greatest portion (54 percent) is in the merchantable boles of commercially important trees (Fig. 49). It is this component that can be converted to high-value wood products. Other portions of biomass are underutilized and can be considered as a potential source of fuel for commercial power generation. Biomass in trees 5 inches and larger in diameter has increased by 20 percent since 1991. The greatest concentrations of biomass in Ohio are in the Southeastern and South-Central Units (Fig. 50).



Understory shrubs benefit wildlife; photo by Richard Widmann, U.S. Forest Service

Figure 49.—Components of tree biomass on forest land in Ohio, 2006.

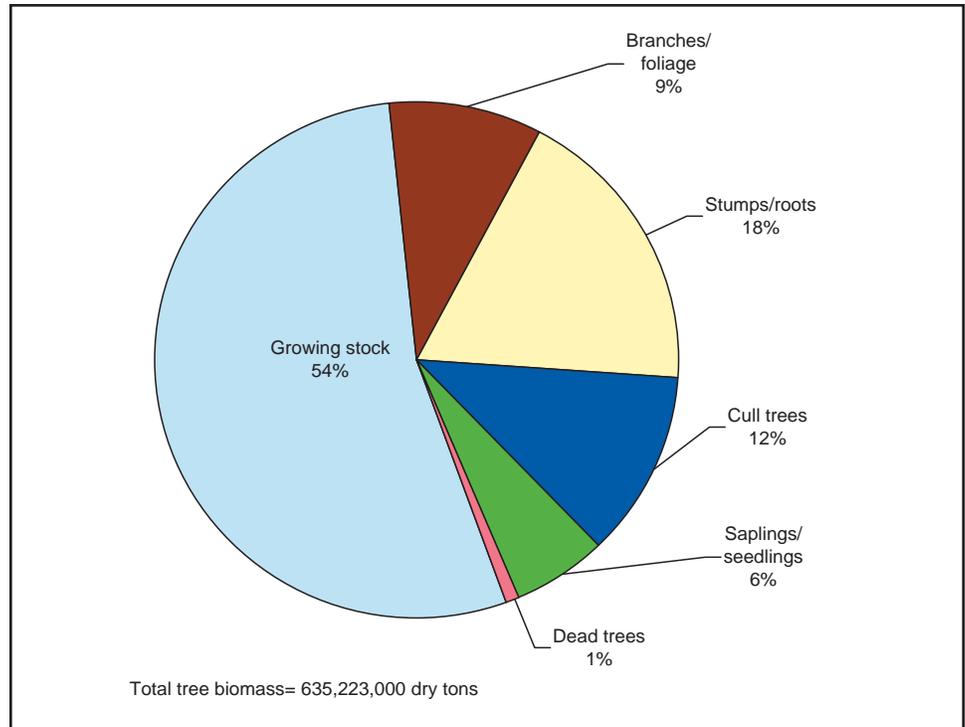
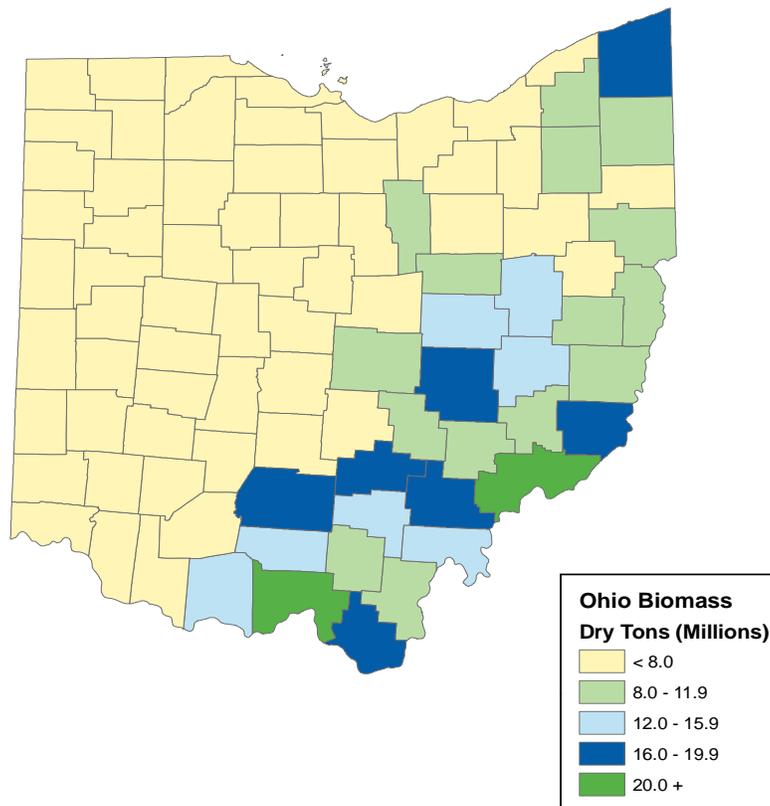


Figure 50.—Biomass of standing trees by county, Ohio, 2006.





Debris left after harvesting is a potential source for biomass fuel; photo by Richard Widmann, U.S. Forest Service

### What this means

Ohio's forests are accumulating substantial amounts of biomass. These stores of carbon will receive increasing attention as the Nation seeks sources for renewable energy and ways to offset carbon dioxide emissions. Because biomass is a renewable source of energy, it can help reduce the Nation's dependence on fossil fuels and provide markets for low-grade wood. Any new plant that turns woody biomass to energy would need a large local source of biomass to keep transportation costs low. The higher concentrations of biomass in southeastern Ohio would make the region the most likely location for such a plant.

Forest landowners are not financially compensated for contributions their trees make in absorbing carbon dioxide and storing carbon. However, this may change if recent proposals to pay landowners for storing carbon in their forests become a widespread reality. The Chicago Climate Exchange has recently developed a financial instrument to trade carbon contracts for forest carbon sequestration to offset emissions of greenhouse gases. Improvements in how biomass is measured and accounted for would likely help promote this new income source for landowners.

## Components of Annual Volume Change

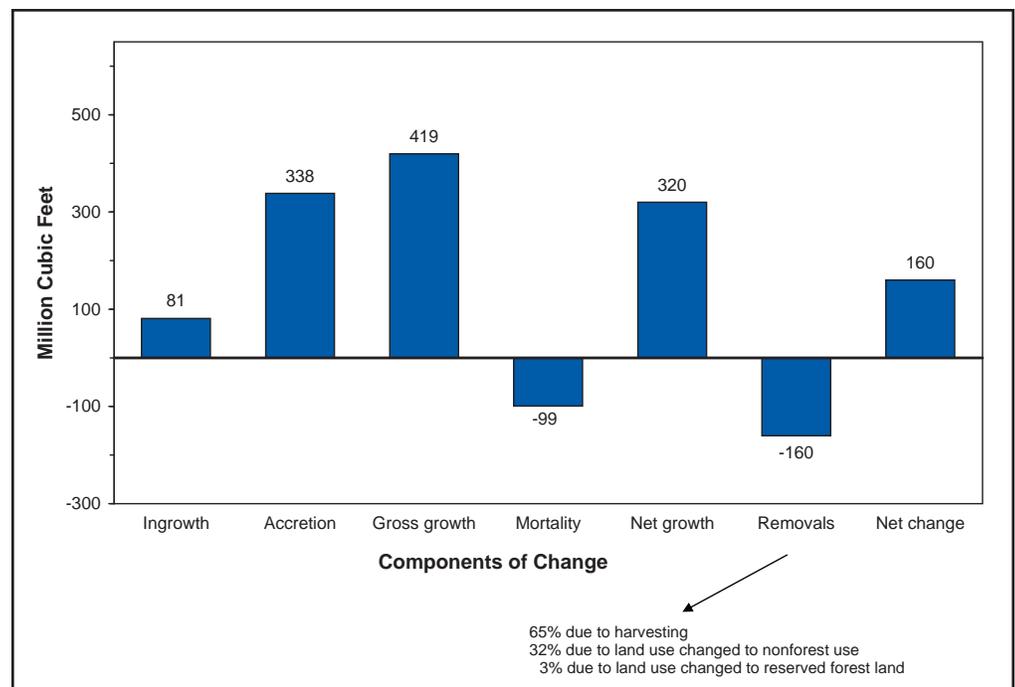
### Background

Well-tended forests supply a continuous flow of products without impairing long-term productivity. Unlike coal and oil, forests are alive and renewable. One way to judge the sustainability of a forest is to look at the components of annual change in inventory volume—growth, removals, and mortality. Removals include trees harvested on land that remains in timberland, trees on timberland that has been reclassified to reserved forest land, and trees lost because the forest was developed for a nonforest use. Analysis of these individual components can help us better understand what is influencing net change.

### What we found

During the last 50 years in Ohio, the growth of trees has greatly outpaced mortality and removals. The most recent inventory revealed that since 1991, on an annual basis, gross growth has totaled 419 million cubic feet (Fig. 51). Eighty-one percent of this growth was accretion (growth on trees that were at least 5 inches in diameter at the time of the previous inventory) and 19 percent was ingrowth (trees less than 5 inches in diameter that grew to at least 5 inches in diameter). Annual mortality averages 99 million cubic feet, resulting in a net growth of 320 million cubic feet. The removals of trees due to both harvesting and land use change averaged 160 million cubic feet, leaving an annual surplus or net change of 160 million cubic feet on Ohio’s timberland. About two-thirds of the removals was due to the harvesting of trees and

Figure 51.—Annual components of change in growing-stock volume, Ohio, 1991-2006.



the remainder was due to changes in land use. As a percentage of the inventory, gross growth was 3.8 percent, mortality—0.9 percent, net growth—2.9 percent, removals—1.4 percent, and net change—1.4 percent.

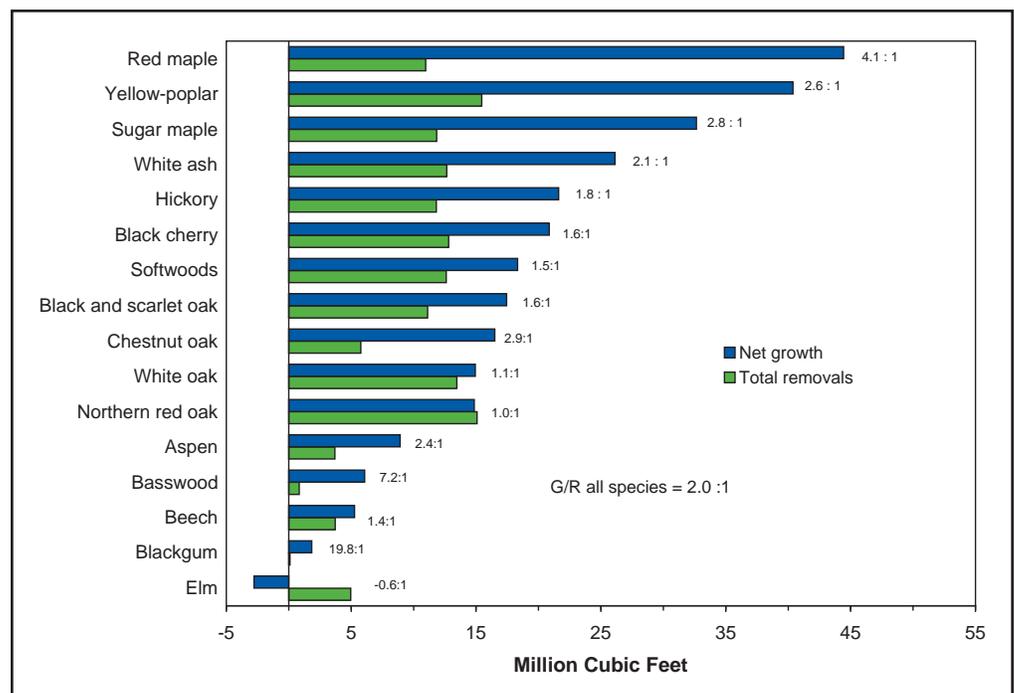
The net change of 160 million cubic feet was nearly the same as during the 1979-1991 inventory period, although all the components were greater. Greater growth was offset by increases in both mortality and removals.

The ratio of growth-to-removals (G/R) averaged 2.0:1 for 1991-2006, but varied considerably between species (Fig. 52). Net growth exceeded removals for all major species except elm, which had negative growth due to high mortality. Yellow-poplar had the largest amount of removals, but its growth still exceeded removals by 2.6 to 1. Northern red oak and white oak ranked second and third in removals, respectively. Their removals nearly matched their growth with growth-to-removals ratios of 1.0:1 and 1.1:1, respectively. Red maple had the largest amount of growth, with growth exceeding removals by 4.1:1.

What this means

Today’s well-stocked forests are a product of growth consistently outpacing removals during the last half century and the surplus accumulating in the forest. Since 1991 net growth has been twice that of removals; the net change has amounted to an annual increase of 1.4 percent in inventory volume. This finding implies that the current level

Figure 52.—Average annual net growth, removals, and growth-to-removals (G/R) ratio for major species, Ohio, 1991-2006.





Large sapling stand; photo by Richard Widmann, U.S. Forest Service

of removals is sustainable and that increases in timber volumes will continue. For the most part, this is true: nearly two-thirds of removals are due to harvesting and trees regenerate and thrive after harvesting as long as the land remains in forest. And the small portion of removals due to timberland being reclassified to reserved forest land will continue to provide benefits other than timber products. But, the nearly third of removals due to conversion of timberland to nonforest uses threatens sustainability because such changes usually are permanent. As a result, future timber growth from these lands is lost, as are related benefits, such as the recharge of groundwater aquifers and forest habitats.

A characteristic of a maturing forest is the growth shift from ingrowth to accretion. In 2006, four-fifths of growth in Ohio was accretion on trees larger than 5 inches d.b.h. and the remaining fifth was from trees growing into 5-inch or larger diameter classes. This means that small trees will have a diminishing effect on changes in species composition, because it is more likely that existing trees will fill in gaps created by mortality and harvesting rather than ingrowth of small trees.

Comparing the growth-to-removals ratios of individual species to the average ratio for all species (2.0:1) reveals which species are increasing in importance and which are decreasing. The high growth-to-removals ratios for red maple, sugar maple, and yellow-poplar show these species will increase in importance in Ohio's forests. These ratios help us better understand shifts in species composition, particularly when comparing species with high ratios such as the maples to those with relatively low ratios such as many of the oaks.

## Mortality

### Background

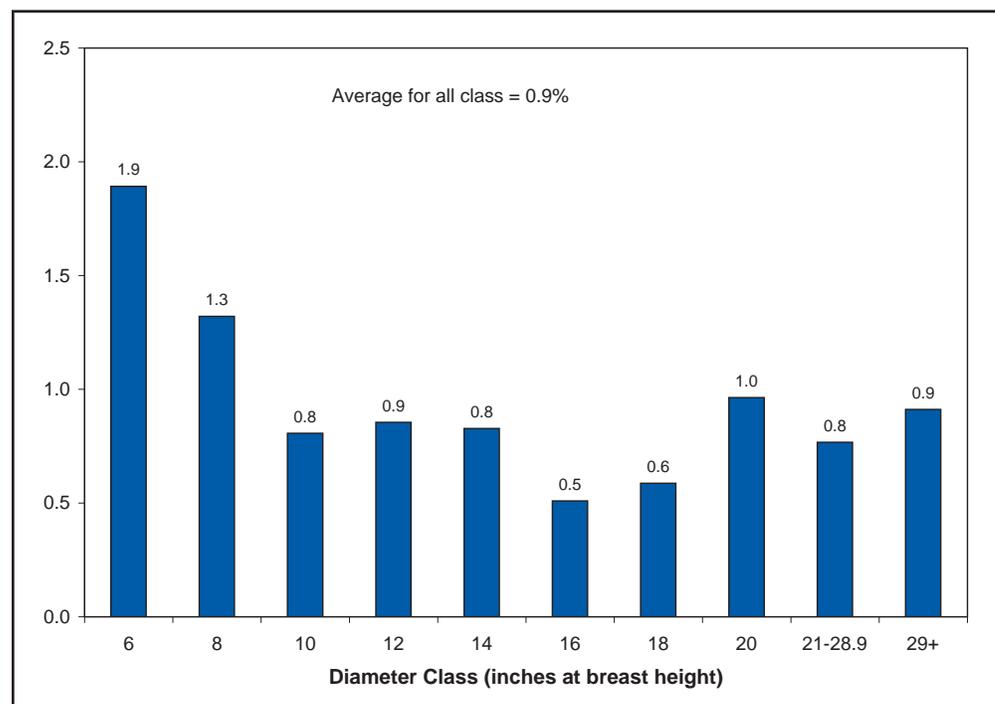
The volume of trees that die from natural causes such as insects, diseases, fire, wind, and suppression from other trees is reported as mortality; harvested trees are not included. Tree mortality is a natural process that occurs in a functioning ecosystem although dramatic increases in mortality can indicate problems in forest health.

### What we found

In Ohio, average annual mortality was 99 million cubic feet, a rate of 0.9 percent of inventory volume. This is an increase from the previous inventory (1979-1991) when annual mortality averaged 57 million cubic feet or 0.6 percent. Despite this increase, Ohio's mortality rate is similar to neighboring states and is considered normal: Michigan 0.8, West Virginia 0.9, Pennsylvania 0.9, and Indiana 0.9. Mortality rates were higher for smaller diameter trees than for larger ones (Fig. 53). The mortality rate in the 6-inch class was 1.9 percent per year, which is more than twice the average rate across all diameter classes. The 16-inch class had the lowest mortality rate—0.5 percent. Trees less than 11 inches in diameter accounted for 40 percent of total mortality, even though most mortality occurred in sawtimber-size stands (76 percent).

Species groups with high annual mortality rates were elm, aspen, and softwoods—4.1, 1.6, and 1.4 percent, respectively (Fig. 54). Five of the major species groups account for more than half the total mortality: elm (19 percent), white ash (10), hickory (8), black cherry (8), and softwoods (7).

Figure 53.—Average annual mortality rate (in percent) of growing-stock volume on timberland by diameter class, Ohio, 1991-2006.

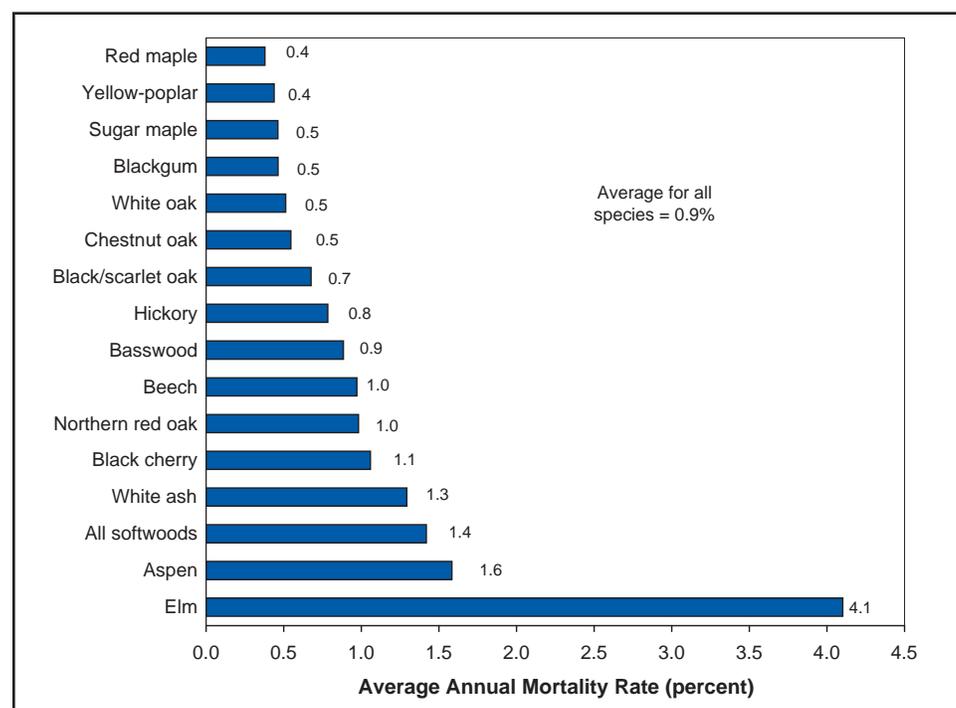


What this means

Tree mortality rates in Ohio have increased since previous inventories, although they are still comparable to those in surrounding states. Much of the mortality can be explained by stand dynamics and insects and diseases that target specific species. The maturing of Ohio’s forests has resulted in more crowded growing conditions. As trees compete for light and growing space, some fall behind their neighbors, lose vigor, and eventually succumb to insects and diseases. This is evident in the condition of small trees. As discussed earlier, most trees less than 8 inches in diameter grow in the understory (Fig. 31), and a third of trees less than 10 inches in diameter have live crowns less than 20 percent of their height—a sign of poor vigor in the lower diameter classes (Fig. 32).

Even though most species have low mortality rates, some are not so fortunate. These species have increased the overall mortality rate for the State. The high rate of mortality for elm can be attributed to Dutch elm disease. Some of the ash mortality can probably be attributed to the emerald ash borer that has been found in northwestern Ohio, although other diseases also attack ash. Ash decline and ash yellows have been ongoing problems for ash. Other species groups with high mortality rates are aspen, all softwoods, and black cherry, which are mostly early succession species that are intolerant to shade. Pitch and Virginia pine are responsible for most of the mortality in the softwood group. These two species likely became established when wildfires were much more prevalent than they are today and are slowly being replaced by hardwood species in Ohio, as well as in many neighboring states, as natural succession progresses.

Figure 54.—Average annual mortality rate (in percent) for major species, Ohio, 1991-2006.



## Status of Oaks

### Background

Concern is growing about the sustainability of oaks across the oak/hickory forests of the Northern States. Oak species serve as keystone species in the forest ecosystem in that they create a community structure and environment that maintains critical ecosystem processes (Fralish 2004). The hard mast oaks provide is especially important because of the demise of American chestnut (*Castanea dentate*) and reduced numbers of large American beech (*Fagus grandifolia*) in many areas because of beech bark disease. Oaks are also important to the forest products industry.

Analysis of inventory data typically looks at changes in growing-stock volume. In Ohio the cubic-foot volume of oaks increased by 13 percent and board-foot volume increased by 21 percent between the 1991 and 2006 inventories. Because volume estimates are heavily influenced by changes in large trees, further examination of the numbers of trees, especially in the lower diameter classes, can give us insight into future changes in oaks.

### What we found

Ohio has had an overall decrease in the numbers of small trees. Decreases in small trees are more pronounced in oaks than in non-oak species (Figs. 55, 56). By 2-inch diameter class, numbers of oaks have decreased in the 2-, 4-, 6-, 8-, 10-, and 12-inch classes since 1991, whereas all non-oak species decreased in only the 2- and 4-inch classes. The oak portion of trees declined in most diameter classes between the 1991 and 2006 inventories, with large decreases in diameter classes 8 through 12 inches (Fig. 57). Only in the 29-inch and larger diameter class did the portion of oaks increase. Oaks are well represented in the large diameter classes but are poorly represented in

Figure 55.—Number of oak trees by diameter class, Ohio, 1991 and 2006.

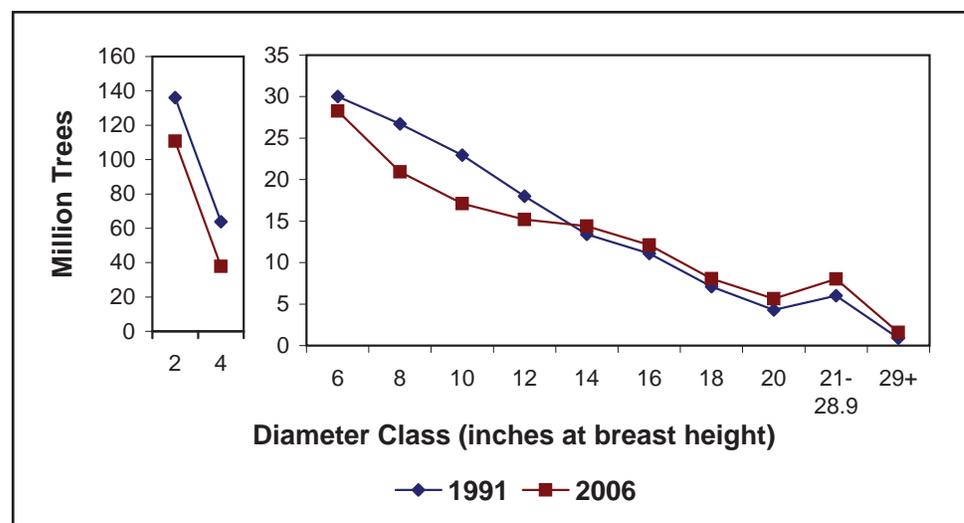


Figure 56.—Comparison of oaks and all other non-oak species as a percentage of total trees by diameter in class, Ohio, 2006.

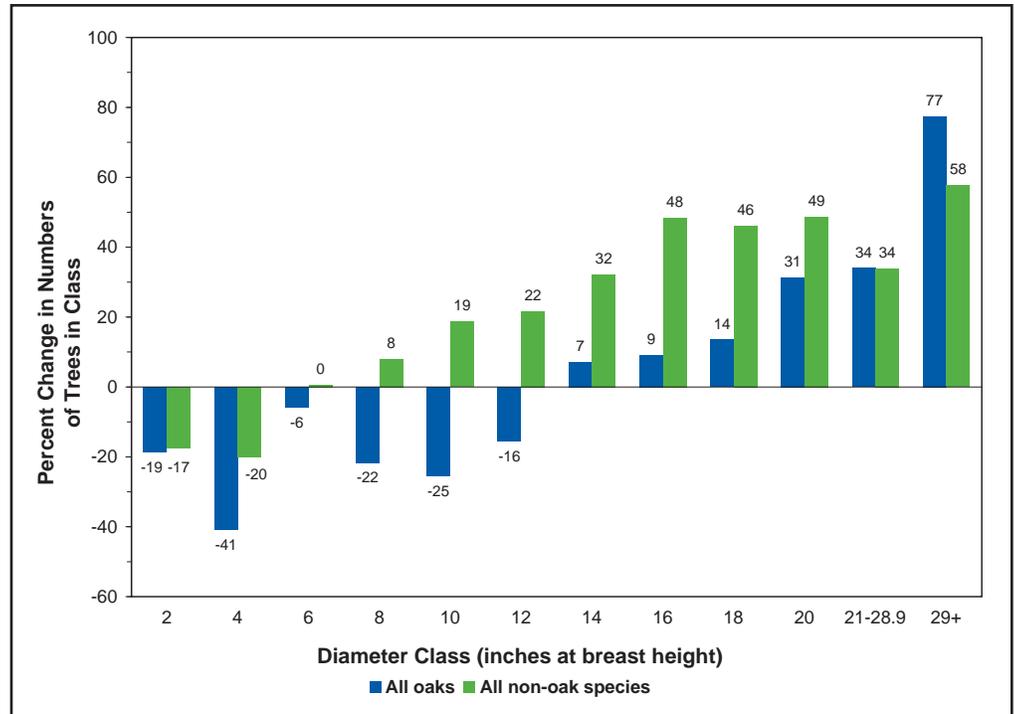
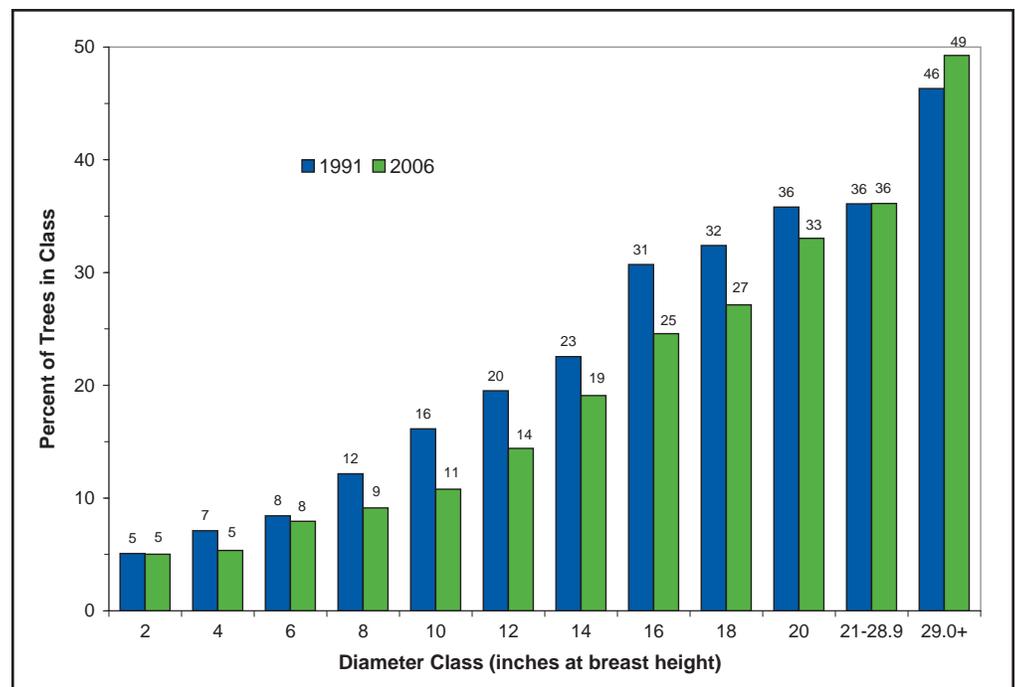


Figure 57.—Oaks as a percentage of total number of trees in class, 1991 and 2006.

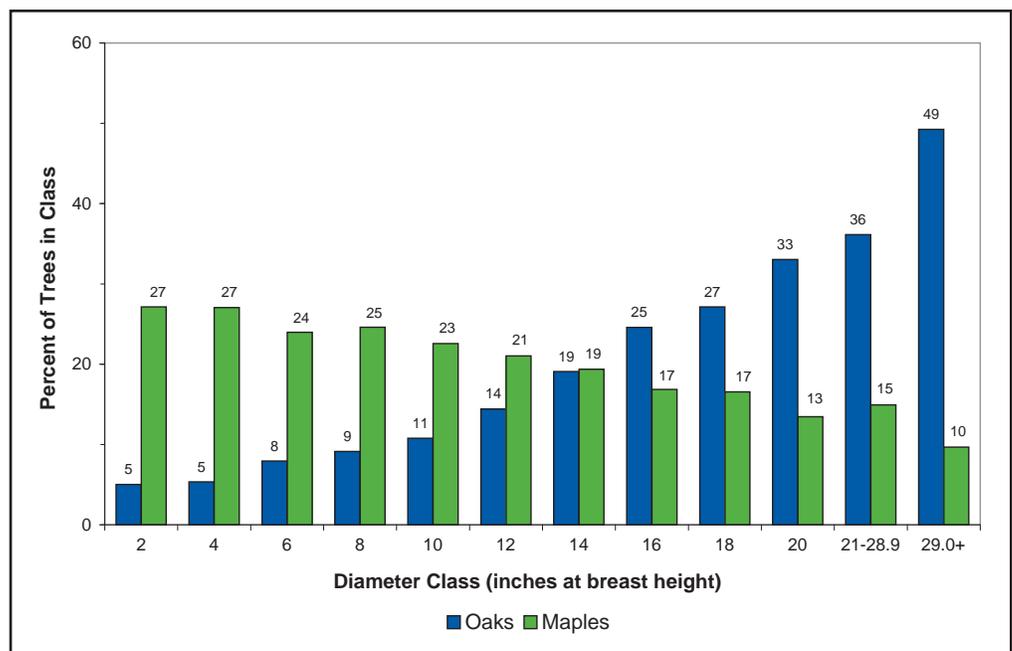


the smaller ones. Currently, oaks make up 32 percent of the trees in diameter classes 18 inches and larger versus 6 percent of the trees less than 10 inches in diameter. By contrast, maple species represent a fourth of the trees less than 10 inches in diameter and their share decreases as diameter increases (Fig. 58).

What this means

The current predominance of oak in the large diameter classes is not sustainable. The decline in numbers of small-diameter oaks means fewer trees are available for recruitment into the larger diameter classes. And while growing conditions in Ohio do not favor small-diameter trees of any species, the declining portion of oaks in the lower diameter classes will significantly impact the future oak resource. Other factors acting against oaks are that oaks have lower growth-to-removals ratios and higher mortality rates than the maples and yellow-poplar, as seen in earlier charts. Also, current forest practices do not favor the regeneration of oaks; few forest land owners follow silvicultural guidelines that are recommended for oak regeneration. The loss of oaks will affect wildlife populations and wood-using industries that now depend on oak. Historically, a large portion of Ohio’s lumber production has been from oak species. The composition of timber harvests will need to be adjusted to better reflect the composition of the changing resource. Declines in the oak component of forests have also been observed in Pennsylvania, West Virginia, and Maryland, as well as other states in the Northeast (Widmann and McWilliams 2006).

Figure 58.—Comparison of oaks and maples as a percentage of total number of trees in diameter class, Ohio, 2006.



## Important Habitat Features

### Background

Wildlife populations depend on the quality of their habitat. Habitat characteristics that change as stands mature include stand size, numbers of standing dead and cull trees, and size of mast-producing trees. These factors contribute to changes in wildlife habitat and influence the suite of wildlife species that inhabit a forest.

The seedling-sapling stage follows major disturbances such as clearcutting, strip mine reclamation, and reversion of farm land to forest. In this stage many wildlife species use low-growing herbaceous and shrub vegetation. Typically found in such stands are early successional, pioneer tree species, such as aspen, black cherry, and white ash, and a variety of herb and shrub plants that thrive in full sunlight. These stands provide unique nesting and feeding habitat for wildlife. As stands grow into the pole-timber- and sawtimber-size classes, much of the low-growing vegetation is shaded out and species that depend on early successional vegetation decline in number as species that use the boles of trees increase. Bole characteristics that develop as a stand matures include bark flaps and cavities.

Standing dead trees are important feeding and nesting sites for wildlife. These trees have a higher probability of use by primary cavity nesters such as woodpeckers than other trees because their wood is excavated more easily. These cavities and natural ones caused by disease or injury are used as resting or nesting sites by various bird species and small mammals. Cull trees, also important to wildlife, exceed maximum allowances for defects for use as timber products. Some of the same characteristics that make these trees undesirable for timber products benefit wildlife. Examples include cavities, broken tops, pockets of rot, and boles with numerous forks and limbs.

As stands mature, overstory trees produce hard mast such as nuts and hard seeds that are an important forage resource for wildlife. Nut production increases as tree diameters increase and crowns become larger. Species that feed on acorns and other hard mast include wild turkey, red-headed woodpecker, blue jay, squirrel and chipmunk, gray fox, striped skunk, and white-tailed deer.



Acorns are an important forage resource for wildlife; photo by Richard Widmann, U.S. Forest Service

What we found

Across the State, forests have continued to mature as large amounts of timberland have grown to sawtimber size. Simultaneously, the area in sapling/seedling and nonstocked stands has decreased substantially (Fig. 59). Since 1968, sawtimber-size stands have more than doubled in area and now represent 63 percent of the timberland—4.8 million acres—and sapling/seedling and nonstocked stands have decreased from representing more than half the timber land to 13 percent—1.0 million acres. Ohio has a higher percentage of timberland in the sapling/seedling class than the surrounding states: Pennsylvania (12 percent), West Virginia (7), Kentucky (11), and Indiana (8).

Important hard mast-producing species in Ohio include the oaks, hickory, and beech. Since 1991, the number of these trees that are 11 inches and larger in diameter has increased (Fig. 60). White oak, chestnut oak, black and scarlet oak, and hickory increased by 4, 7, 18, and 19 percent, respectively. These gains more than offset a 6-percent decline in beech trees and a 1-percent decline in northern red oak.

In Ohio’s forest, 9 percent of all standing trees more than 5 inches in diameter are dead (Fig. 61). Dead trees average 13 per acre and most are in the 5.0- to 10.9-inch diameter class. On average, there were 0.6 dead trees 15 inches and larger in diameter per acre. Since 1991, there has been a 15-percent increase in dead trees 11 inches and

Figure 59.—Percentage of timberland by stand-size class, Ohio, 1968, 1979, 1991, and 2006.

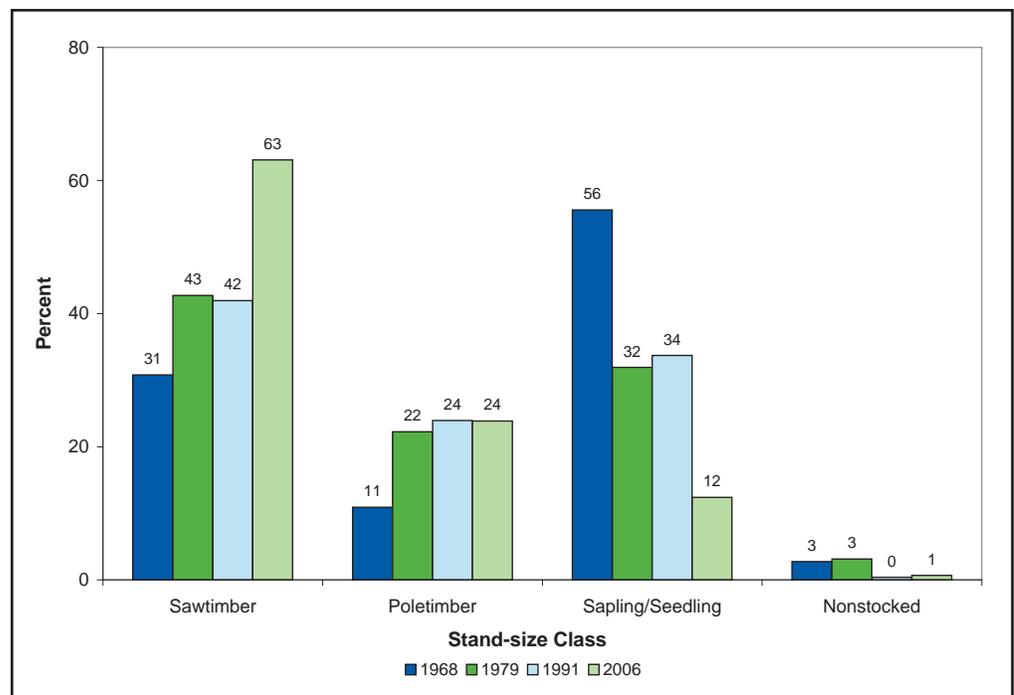


Figure 60.—Change in numbers of hard mast producing trees 11 inches and larger in diameter, 1991-2006.

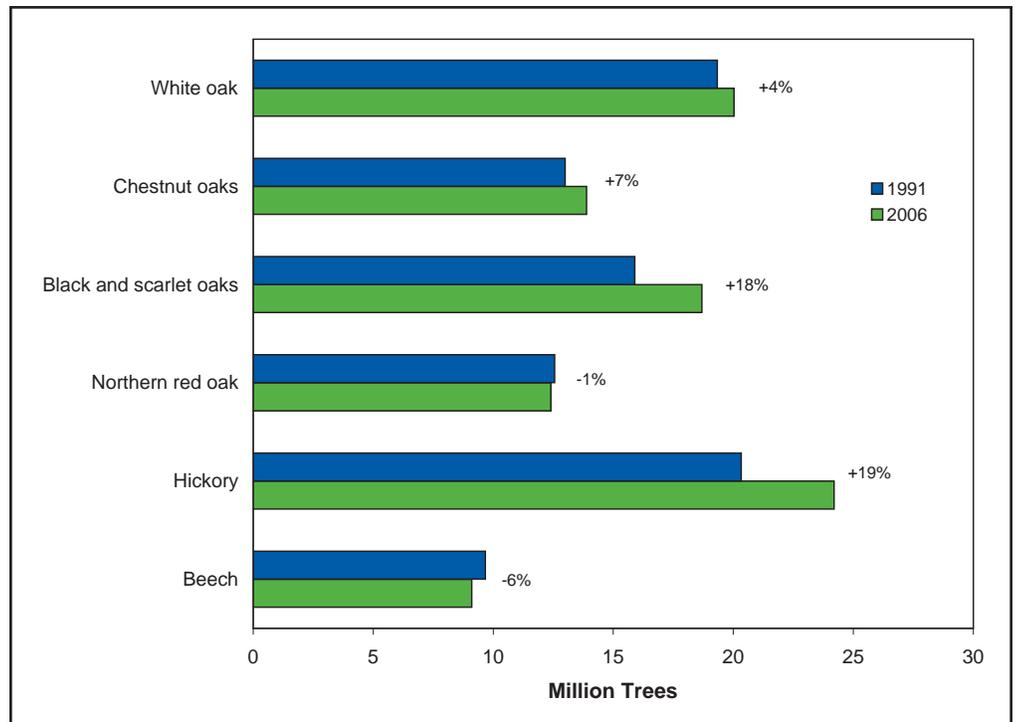
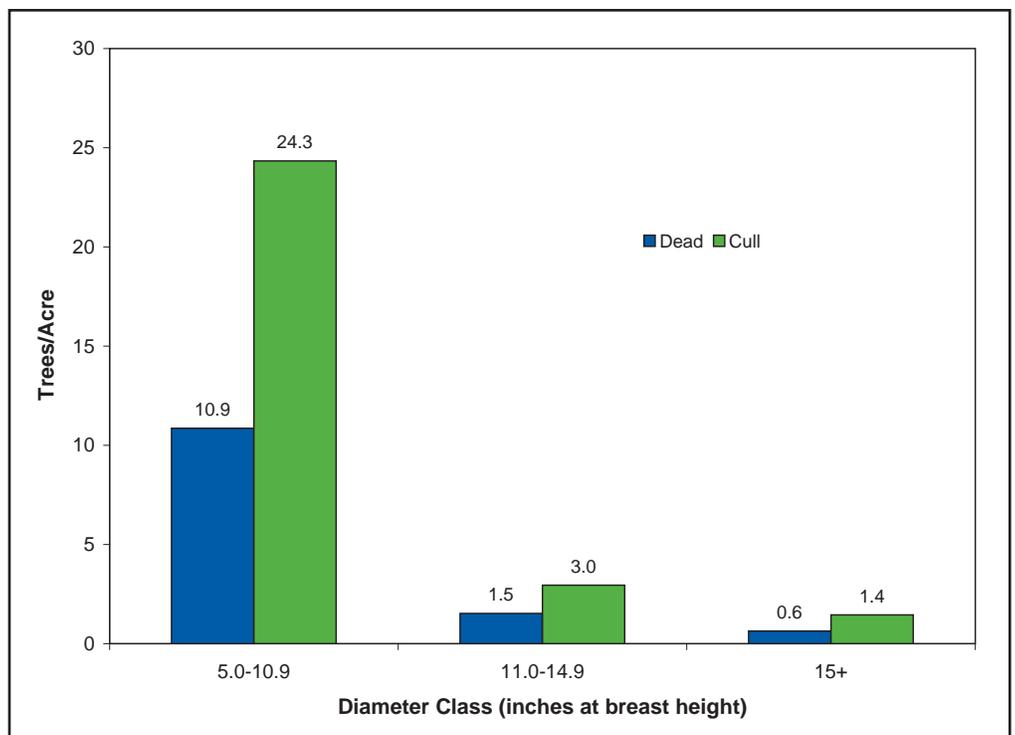


Figure 61.—Average number of dead and cull trees per acre of timberland, Ohio, 2006.



larger. Twenty percent of the dead trees are species of elm and 9 percent are species of oak. Additionally, there are 29 cull trees per acre—1.4 of these are 15 inches or larger in diameter (Fig. 61).

### What this means

Ohio's forests have a variety of stand-size classes that provide diverse habitats for wildlife. The shift in stand size to more sawtimber-size trees is further evidence that Ohio's forests are maturing. Accompanying this shift, habitats have changed to accommodate more woodland species over the last half century. Many woodland bird species such as oven bird, red-eyed vireos, wild turkey, and pileated woodpecker



Controlled burn to improve wildlife habitat on the Wayne National Forest; photo by Cheryl Coon, U.S. Forest Service

have prospered. Declines in sapling/seedling area are likely to continue as more stands mature into larger size classes and decreasing amounts of farm land are allowed to revert to forest land. Continued losses of sapling/seedling stands are problematic for species such as ruffed grouse that prefer dense patches of young trees for at least part of their life cycle. But, the maturing of Ohio's forest may also set the stage for the return of other woodland species such as black bear. Besides offering diverse

habitats and providing a steady flow of wood products, forests that contain all stand sizes might be more resistant to devastating outbreaks of insects and diseases.

Because hard mast production increases as trees become larger, we can assume that hard mast production has increased in Ohio because of increases in the number of large-diameter oak and hickory trees. This benefits scores of wildlife species that use the nuts. Before the 1920s, American chestnut provided large amounts of mast. With the decline of American chestnut, wildlife became dependent on nuts produced by oaks, hickory, and beech. A decline in the numbers of large beech trees indicates that wildlife is depending ever more on oak and hickory mast.

The increase in numbers of large dead trees corresponds with the maturing of Ohio's forests and indicates improving habitats for species that use the boles of dead trees.

## FOREST HEALTH INDICATORS



Hocking Hills State Park; photo by Richard Widmann, U.S. Forest Service.  
Inset: Wild ginseng; photo by Deborah Veen, U.S. Forest Service.

## Down Woody Material

### Background

Down woody materials, in the form of fallen trees and branches, fill a critical ecological niche in Ohio’s forests. Down woody materials provide both valuable wildlife habitat in the form of coarse woody debris and contribute toward forest fire hazards via surface woody fuels. Woody fuels are classified into time-lag classes that predict the time it takes for wet fuels of various sizes to dry.

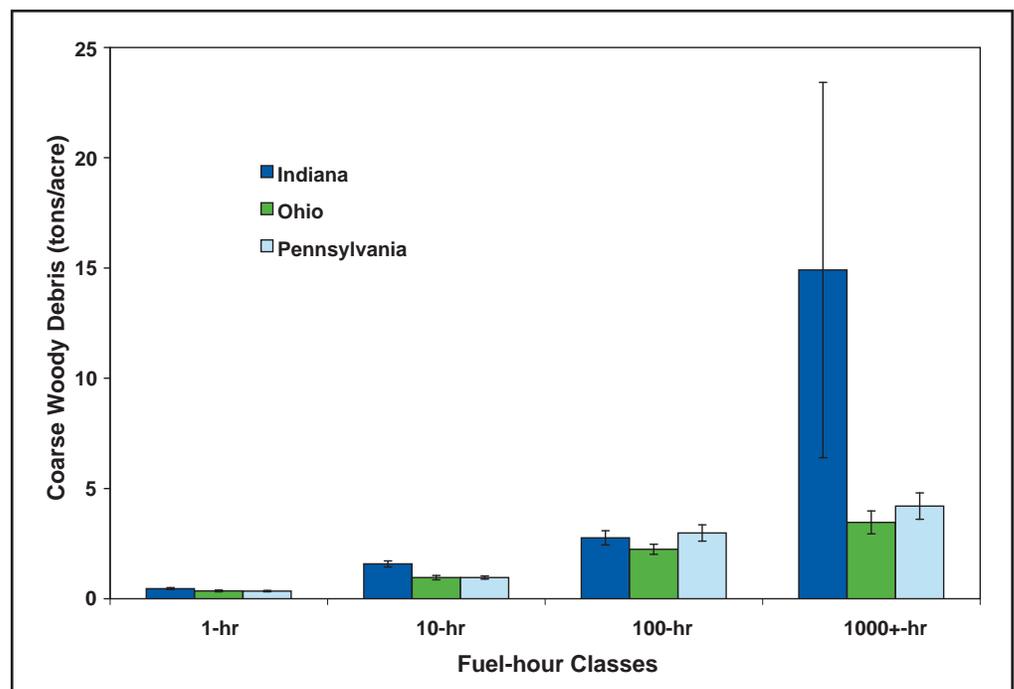


Down woody debris; photo by Richard Widmann, U.S. Forest Service

### What we found

The fuel loadings of down woody materials (time-lag fuel classes) are not exceedingly high for most classes in Ohio (Fig. 62). When compared to those of the neighboring states of Indiana and Pennsylvania, Ohio’s fuel loadings of smaller time-lag fuel classes are not significantly different (for time-lag definitions, see Woodall and Williams 2005). One exception is the amount of 1,000+-hr fuels in Indiana, which is most likely

Figure 62.—Means and associated standard errors of fuel loadings (tons/acre, time-lag fuel classes) on forest land in Ohio and neighboring states, 2001-2005 (error bars represent 67-percent confidence intervals around the estimates).



the result of localized disturbance events. In Ohio, coarse woody debris averages 7 tons per acre of forest land, whereas standing trees average 76 tons per acre. The size class distribution of coarse woody debris appears to be heavily skewed (90 percent) toward pieces less than 8 inches in diameter at the point of intersection with plot sampling transects (Fig. 63A). In decay class distribution, coarse woody debris pieces in moderate stages of decay appear to dominate (decay class three, 40 percent) (Fig. 63B). Decay class three coarse woody pieces are typified by moderately decayed logs that are still structurally sound but missing most of their bark with extensive sapwood decay. There is no strong trend in coarse woody debris volumes/acre among classes of live tree density (basal area/acre) (Fig. 64).

Figure 63.—Mean proportions of coarse woody debris by (A) diameter (inches) and (B) decay classes, on forest land in Ohio, 2001-2005.

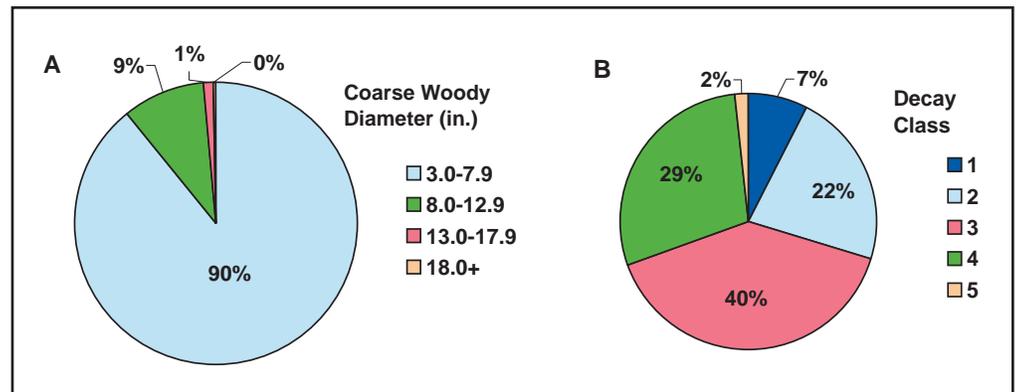
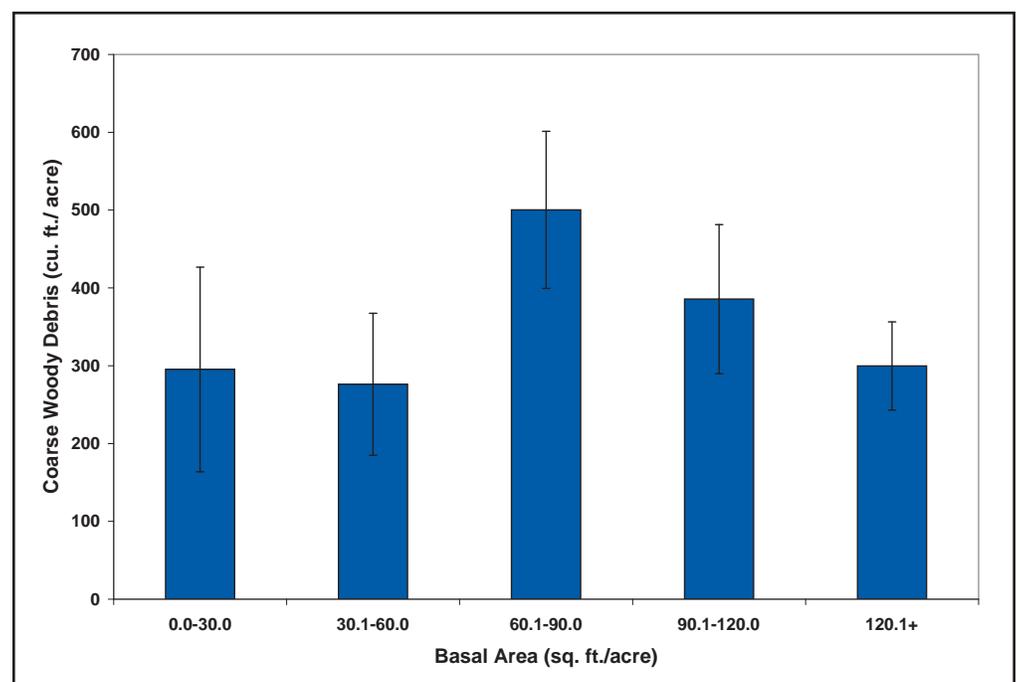


Figure 64.—Means and associated standard errors of coarse woody debris volumes (cubic feet/acre) on forest land in Ohio, 2001-2005 (error bars represent 67-percent confidence intervals around the estimates).



### What this means

The down woody fuel loadings in Ohio's forests are neither exceedingly high nor different from those found in neighboring states. Therefore, only in times of extreme drought would these low amounts of fuels pose a hazard across the State. Of all down woody components, 1,000+-hr fuels make up the largest amounts. However, coarse woody debris volumes are still relatively low and were represented by small, moderately decayed pieces. Overall, because fuel loadings are not exceedingly high across Ohio, possible fire dangers are outweighed by the benefits of down woody material as wildlife habitat and carbon sinks.



Northern hardwoods, snag and large downed woody debris;  
photo by Steven Katovich, U.S. Forest Service, [www.forestryimages.org](http://www.forestryimages.org).

## Lichens

### Background

Lichens are composite, symbiotic organisms made up from members of as many as three kingdoms. The dominant partner is a fungus. Fungi are incapable of producing their own food, instead providing for themselves as parasites or decomposers. The lichen fungi (kingdom Fungi) cultivate partners that manufacture food by photosynthesis. Sometimes the partners are algae (kingdom Protista), other times cyanobacteria (kingdom Monera), formerly called blue-green algae. Some enterprising fungi exploit both at once (Brodo et al. 2001).

Lichen community monitoring is included in Forest Health Monitoring to address issues such as the impact of air pollution on forest resources, or spatial and temporal trends in biodiversity. This long-term lichen monitoring program in the U.S. dates back to 1994 and is currently ongoing in 32 states. The objectives of the lichen indicator are to determine the presence and abundance of lichen species on woody plants and to collect samples. Lichens occur on many different substrates (e.g., rocks), but all sampling was restricted to standing trees or branches/twigs that have recently fallen to the ground. The samples were sent to lichen experts for species identification.

A close relationship exists between lichen communities and air pollution, especially acidifying or fertilizing nitrogen- and sulfur-based pollutants. A major reason lichens are so sensitive to air quality is their total reliance on atmospheric sources of nutrition. In contrast, it is difficult to separate tree-growth responses specific to air pollution (McCune 2000).

### What we found

A total of 81 lichen species (gamma diversity) in 29 genera were sampled on the 66 lichen plots (Table 1). The most common lichen genera, *Phaeophyscia* and *Physcia*, were present on 16 and 15 percent of the plots, respectively (Table 2). The genus with the most species sampled was *Cladonia* (10 species).

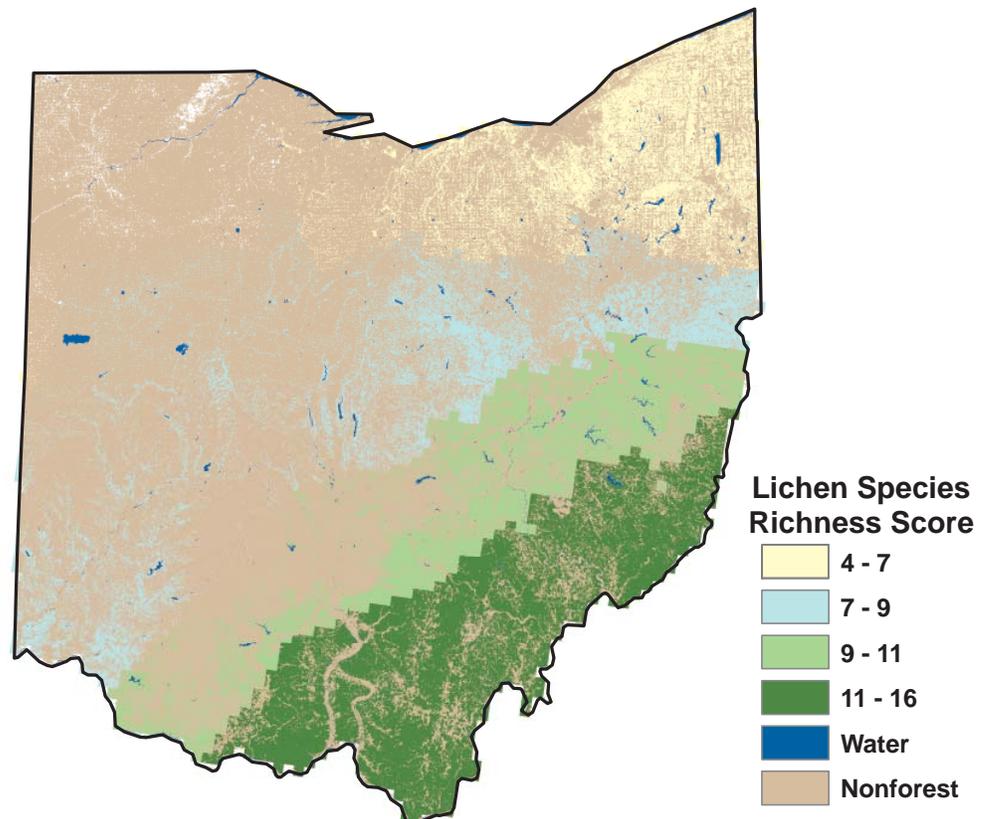
The easiest way to measure species diversity is to count the number of species at a site; this measure is termed species richness. However, species richness does not provide a complete picture of diversity in an ecosystem because abundance is excluded. Species diversity is a concept used to describe the number of different species present in an area and the distribution of individuals among species. Richness values fell into the low and medium categories across the State (Table 1). The mean species richness of the lichen plots was similar across forest-type groups (Table 3). Lichen species richness was lowest on seedling-sapling plots, which reflect the lag time for lichen recolonization after harvest or disturbance (Table 4). The spatial distribution of lichen species richness scores is shown in Figure 65. In general, species richness scores were higher in southern Ohio. The lichen species richness and diversity scores reported here will serve as baseline estimates for future monitoring at the State and regional levels.

**Table 1.—Lichen communities summary table for Ohio, 2001-2005**

Parameter	Ohio, 2001-2005
Number of plots surveyed	66
Number of plots by species richness category	
0-6 species (low)	17
7-15 species (medium)	46
16-25 species (high)	3
Median species richness score	8.5
range of species richness score per plot (low-high)	1-17
Average species richness score per plot (alpha diversity)	8.7
Standard deviation of species richness score per plot	3.4
Species turnover rate (beta diversity) <sup>1</sup>	9.3
Total number of species per area (gamma diversity)	81

<sup>1</sup>Beta diversity is calculated as gamma diversity divided by alpha diversity

Figure 65.—Estimated lichen species richness, Ohio, 2000-2003.



**Table 2.—Percentage of specimens and number of species for lichen genera sampled, Ohio, 2001-2005**

Genus	All specimens	All species
Phaeophyscia	16.0	6
Physcia	15.4	5
Punctelia	15.0	7
Flavoparmelia	9.1	3
Myelochroa	8.2	3
Parmotrema	7.1	8
Parmelia	5.3	3
Cladonia	4.7	10
Canoparmelia	4.2	3
Pyxine	4.1	2
Candelaria	3.9	1
Heterodermia	1.4	2
Parmelinopsis	1.0	2
Hypotrachyna	0.9	5
Imshaugia	0.5	2
Physciella	0.5	1
Usnea	0.5	3
Cetraria	0.4	1
Physconia	0.4	3
Flavopunctelia	0.2	2
Melanelia	0.2	1
Anaptychia	0.1	1
Bryoria	0.1	1
Leptogium	0.1	1
Parmeliopsis	0.1	1
Ramalina	0.1	1
Rimelia	0.1	1
Xanthoria	0.1	1
unknown	0.1	1
<b>Total</b>	<b>100.0</b>	<b>81</b>

**Table 3.—Number of FIA Phase 3 plots and richness, diversity, and summation of lichen species by forest-type groups, with associated sampling errors at the 67-percent confidence level, Ohio, 2001-2005**

Forest-type group	N	Species richness	SE	Diversity	SE	Summation	SE
Maple/beech/birch	12	8.8	0.9	2.06	0.15	23.3	2.8
Oak/hickory	50	8.7	0.5	2.03	0.07	23.2	1.4
Other	4	8.3	1.8	1.97	0.30	22.0	4.9
All	66	8.7	0.4	2.00	0.06	23.2	1.2

**Table 4.—Number of FIA Phase 3 plots and richness, diversity, and summation of lichen species by stand-size categories, with associated sampling errors at the 67-percent confidence level, Ohio, 2001-2005**

Stand size	N	Species richness	SE	Diversity	SE	Summation	SE
Seedling/sapling	6	7.7	1.7	1.79	0.37	21.7	5.0
Poletimber	25	9.1	0.8	2.04	0.12	24.4	2.4
Sawtimber	35	8.5	0.4	2.06	0.05	22.5	1.1
All	66	8.7	0.4	2.00	0.06	23.2	1.2

### What this means

Due to the sensitivity of many lichen species to airborne pollution, it is useful to look at acid deposition levels. Showman and Long (1992) reported that mean lichen species richness was significantly lower in areas of high sulfate deposition than in low deposition areas in north-central Ohio. Sulfate deposition levels have been relatively high in Ohio and surrounding states in recent years (Fig. 66). A general pattern of lower lichen species richness scores in high deposition areas and vice versa is evident (Fig. 67), but many other factors affect the distribution of lichen species including intrinsic forest characteristics and long-term changes in climate.

Figure 66—Mean sulfate ion wet deposition, 1994-2002. Data source: National Atmospheric Deposition Program.

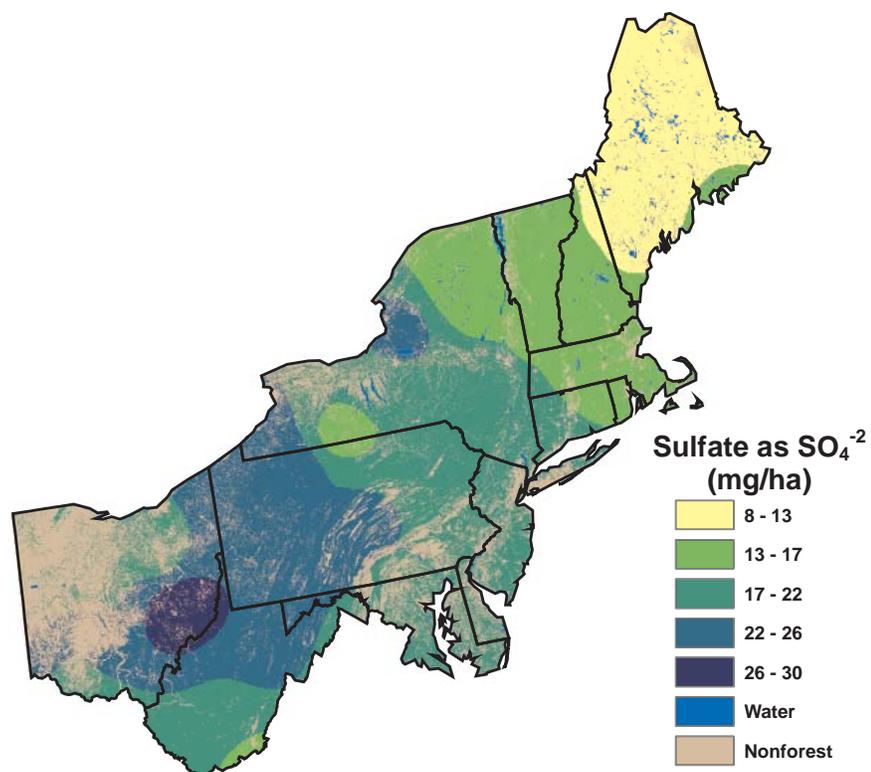
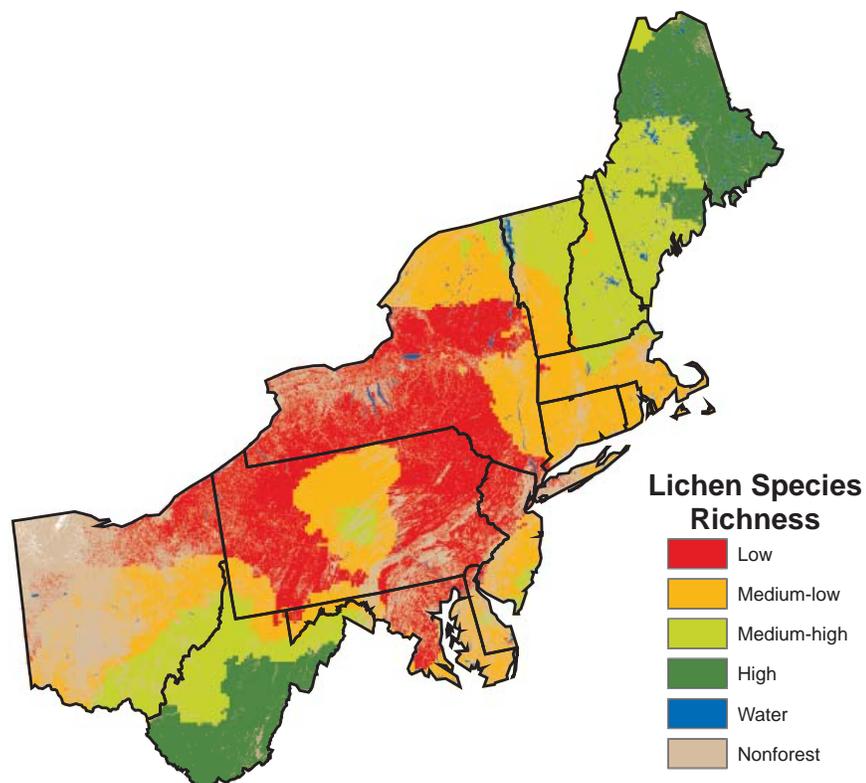


Figure 67.—Estimated lichen species richness, Northeastern U.S., 2000-2003.



## Forest Soils

### Background

Rich soils are the foundation of productive forest land, and they are also one of the major carbon banks. Soils develop in response to several factors (climate, local vegetation, topography, parent material, and time), and these factors can be used to identify soil regions related to particular native forests. Today, the forest soil inventory illustrates the unique niches that different forests now occupy to maximize their competitive advantage. By identifying the soil properties associated with various forest types, the data collected by FIA provide critical baseline information to document changes in forest health resulting from natural or human influences.

The study of soil carbon is in its infancy. We need more measurements quantifying the soil carbon pool across different land types, and we need more information on soil carbon flux over time. Annual inventories of FIA soil plots will provide this type of information. The results presented here are based upon observations at 84 plots throughout Ohio and 96 plots in the similar forests of Pennsylvania and West Virginia.

### What we found

Substantial variability exists within the soil regions of Ohio, Pennsylvania, and West Virginia as forest trees compete for and create specialized niches. Oak/hickory and the northern hardwood (maple/beech/birch) stands, for example, accumulated more forest floor material than elm/ash/red maple stands, but these forests in Ohio tended to accumulate less forest floor material than forests in the two neighboring states (Fig. 68). As a result, the carbon content of the forest floor in Ohio is less than that of Pennsylvania in similar forest types (Fig. 69). The differences were less consistent in the mineral soil carbon stocks (Fig. 70). The oak/hickory forest in Ohio stored less carbon than similar forests in West Virginia, but the northern hardwood forest was similar to that in neighboring states. In Ohio, forest floor carbon averages 2 tons per acre, carbon in the top 20 cm (7.9 inches) of mineral soil averages 22 tons per acre, and carbon in trees averages 39 tons per acre.

The Soil Quality Index (SQI) is designed to combine the distinct physical and chemical properties of the soil into a single, integrative assessment (Amacher et al. 2007). Overall soil quality in Ohio is superior to that observed in Pennsylvania and West Virginia (Fig. 71). This finding can be broken down into two important components. The northern hardwood forests of Ohio occurred in landscapes with greater effective cation exchange capacities (more mineral nutrients) (Fig. 72). Even more importantly, the calcium:aluminum ratio of mineral soils underlying Ohio's forests was generally greater than 0.5; that ratio in Pennsylvania, by contrast, was largely less than 0.5 (Fig. 73).

Figure 68.—Mean forest floor thickness by forest-type group (error bars represent 67-percent confidence intervals around estimates).

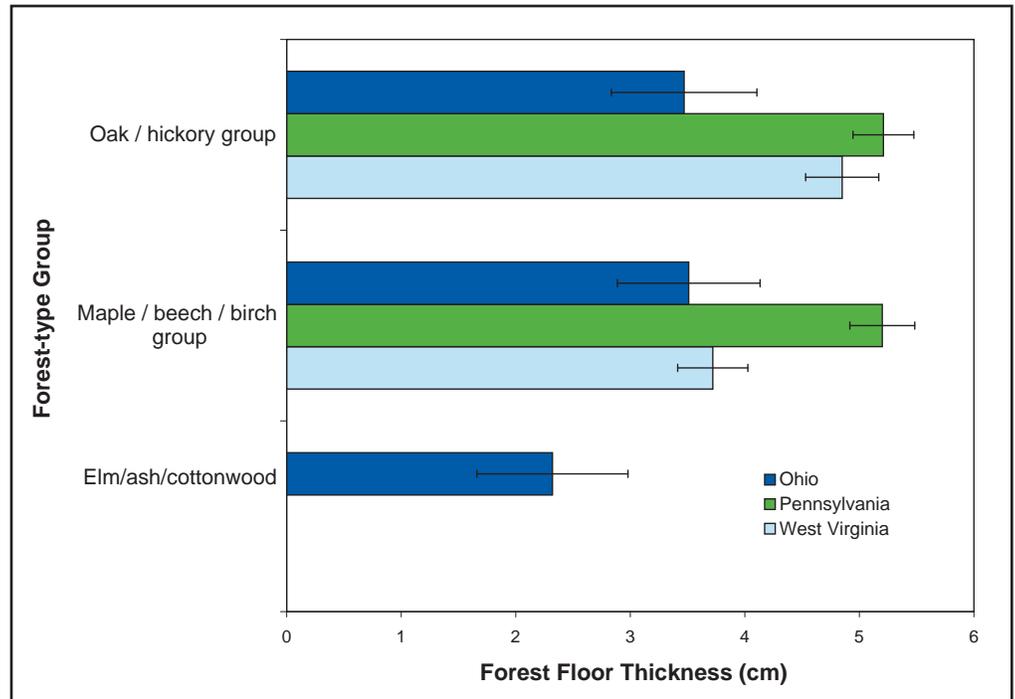


Figure 69.—Mean forest floor carbon by forest-type group (error bars represent 67-percent confidence intervals around estimates).

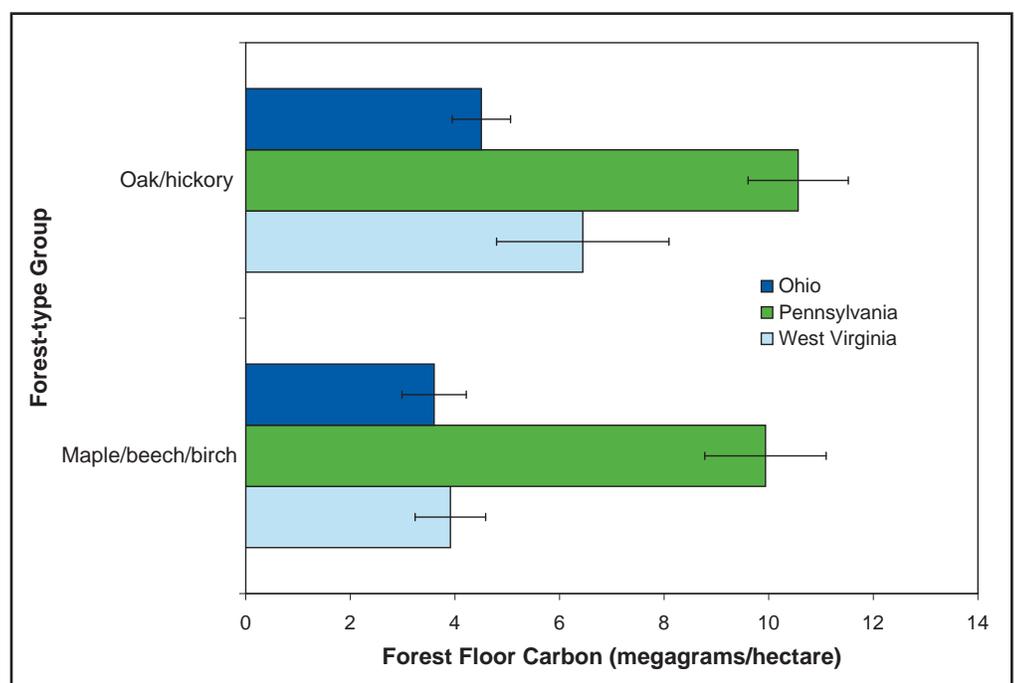


Figure 70.—Mean carbon content of forest soils by forest-type group (error bars represent 67-percent confidence intervals around estimates).

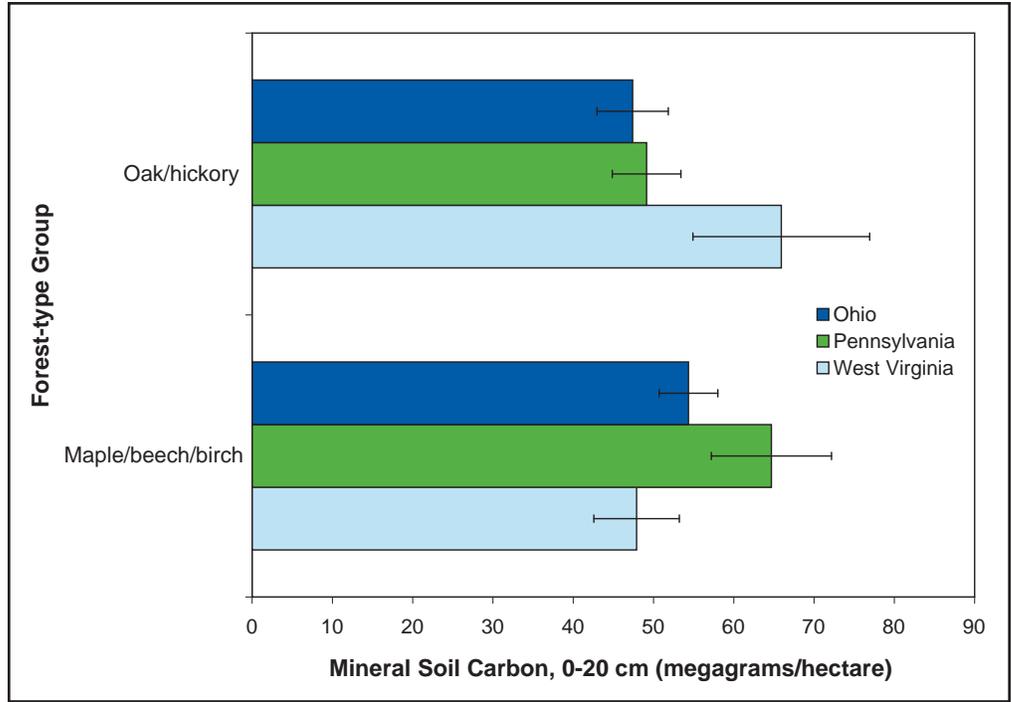


Figure 71.—Soil Quality Index by forest type (error bars represent 67-percent confidence intervals around estimates).

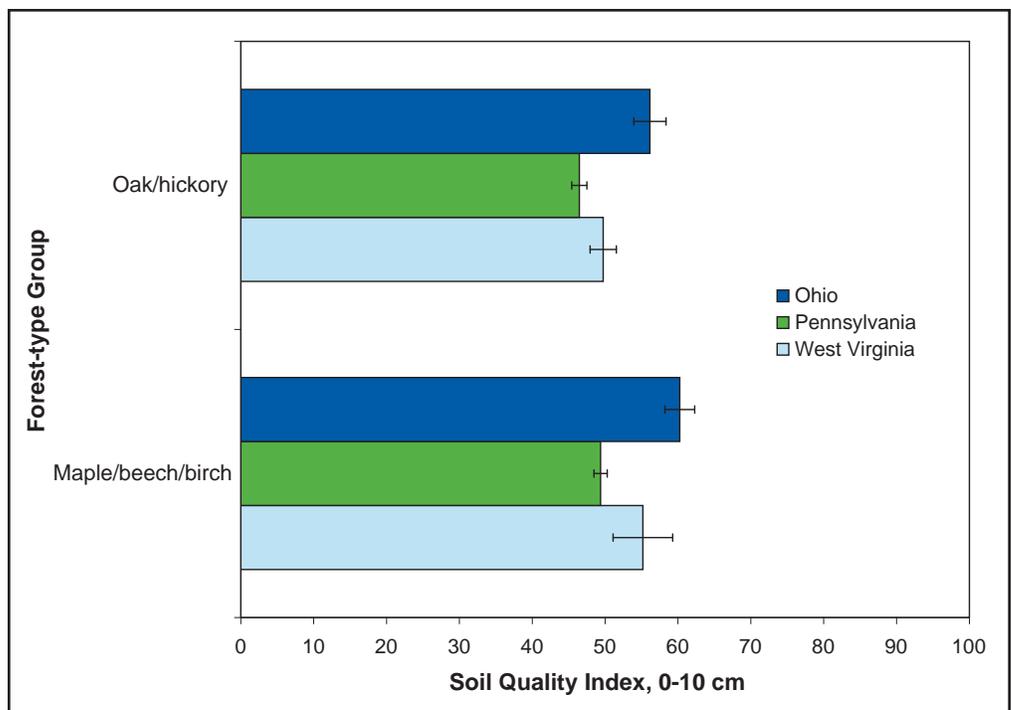


Figure 72.—Mean effective cation exchange by forest type (error bars represent 67-percent confidence intervals around estimates).

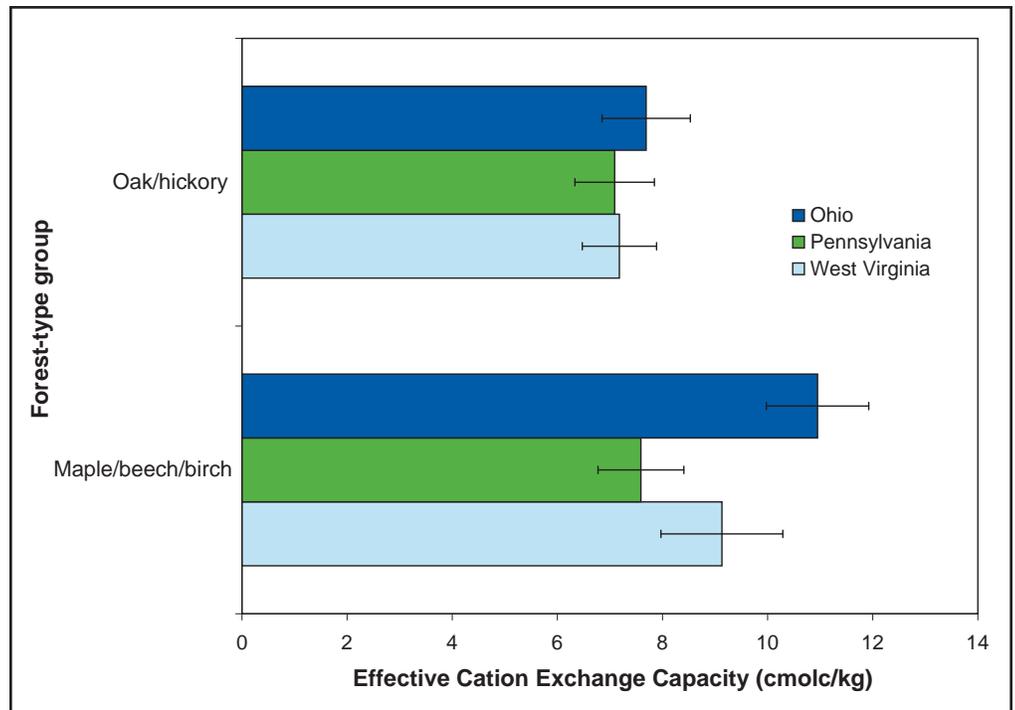
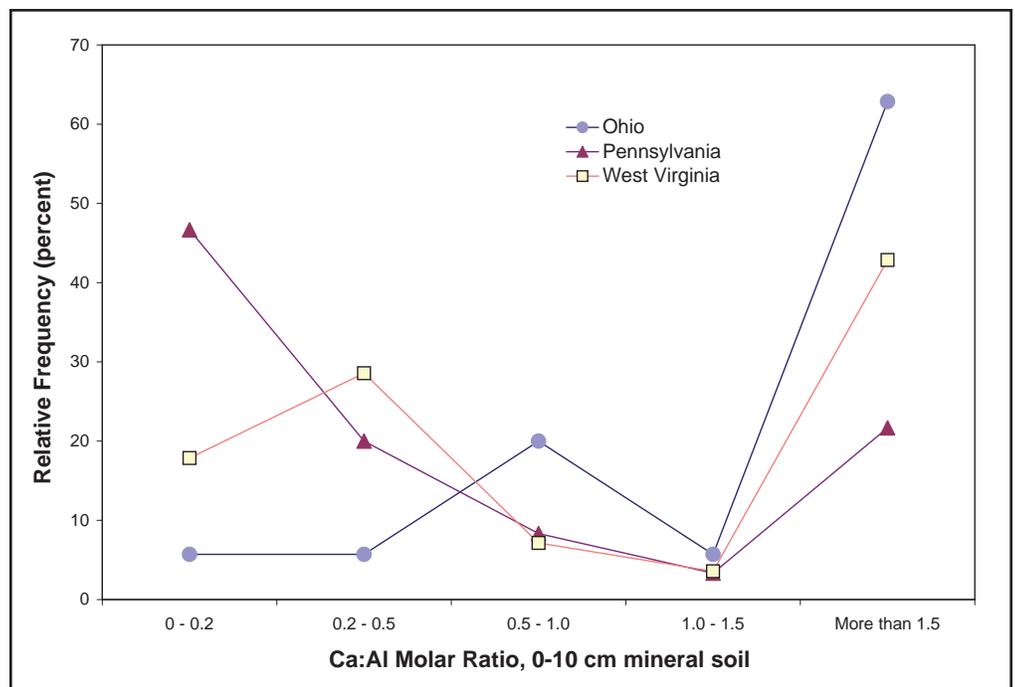


Figure 73.—Mean ratio of calcium to aluminum by state.



## What this means

The forest floor develops from the slow accumulation of organic matter. Carbon is the primary component of soil organic matter, which has a number of important functions. These include increasing water holding capacity, retaining some nutrients by cation exchange (e.g.,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{K}^{+}$ ), releasing other nutrients as it decays (e.g., nitrogen, phosphorus, and sulfur), and capturing potential toxic agents (e.g., mercury) (McBride 1994). Carbon is also inventoried to track the sequestration of certain greenhouse gases. It traps nutrients and improves water holding capacity. Thicker forest floors contribute toward greater carbon storage. Direct measurements of carbon and the functions it provides are essential in improving our understanding of the carbon cycle. Given the similarities between carbon stocks in Ohio's two major forest types, there is no incentive to convert forests as a means of increasing carbon sequestration.

Atmospheric deposition of nitrogen and sulfur alters the soil by leaching essential minerals from it (Driscoll et al. 2001). Historically, the problem of acid deposition was particularly severe in the upper Ohio River basin (see National Atmospheric Deposition Program, <http://nadp.sws.uiuc.edu/amaps2/>), but while the emissions that lead to acid deposition have declined, the effects persist (Driscoll et al. 2001). Effective cation exchange capacity (ECEC) is calculated as the sum of five key mineral elements: sodium, potassium, calcium, magnesium, and aluminum. High ECEC values are associated with higher fertility. The molar ratio of Ca to Al is a useful indicator of stress in forest ecosystems, particularly that caused by acid deposition (Cronan and Grigal 1995), and low Ca:Al ratios (less than 0.5) indicate an increased likelihood of negative impacts on tree growth. Additionally, deposition of nitrogen increases litter decay rates (Kuperman 1999) with the potential to negatively affect the forest through nitrogen saturation (Aber 1992).

## Vascular Plants in Ohio's Forest

### Background

Understory vegetation is an important component of most forested ecosystems. The total number of species and their relative proportions are the results of past stand history, including natural disturbances and human influences. By looking at diversity and abundance of vascular plant species, we may see indications of stresses such as pollution or forest site degradation. Another indicator of disturbance is an increase in the number of exotic plants, many of which are early colonizers. FIA assessed understory vegetation by examining all vascular plants on the forested portion Phase 3 plots during the growing seasons in 2001-2005, about one-sixteenth of the total forested plots in the State.

### What we found

On a total of 75 Phase 3 plots in Ohio in this inventory, FIA found 609 different species and undifferentiated genera of vascular plants. Of this total, 228 were forbs or herbs, based on their categorization by the PLANTS database of the USDA Natural Resources Conservation Service (Table 5). Seventy-two were grass or grass-like plants (graminoids), including grasses, sedges, rushes, arrow-grasses, and quillworts, while 95

**Table 5.—Number of species in Ohio, 2005, by growth habit (per PLANTS database, USDA Natural Resources Conservation Service)**

Growth habit	Number of species or undifferentiated genres
Forb/herb	228
Graminoid	72
Shrub	25
Shrub, Subshrub, Vine	2
Subshrub, Forb/herb	3
Subshrub, Shrub	10
Subshrub, Shrub, Forb/herb	11
Tree	57
Tree, Shrub	37
Tree, Shrub, Subshrub	1
Vine	7
Vine, Forb/herb	13
Vine, Forb/herb, Subshrub	1
Vine, Shrub	2
Vine, Subshrub	3
Vine, Subshrub, Forb/herb	2
Vine, Subshrub, Shrub	2
Unclassified	133
<b>Total</b>	<b>609</b>

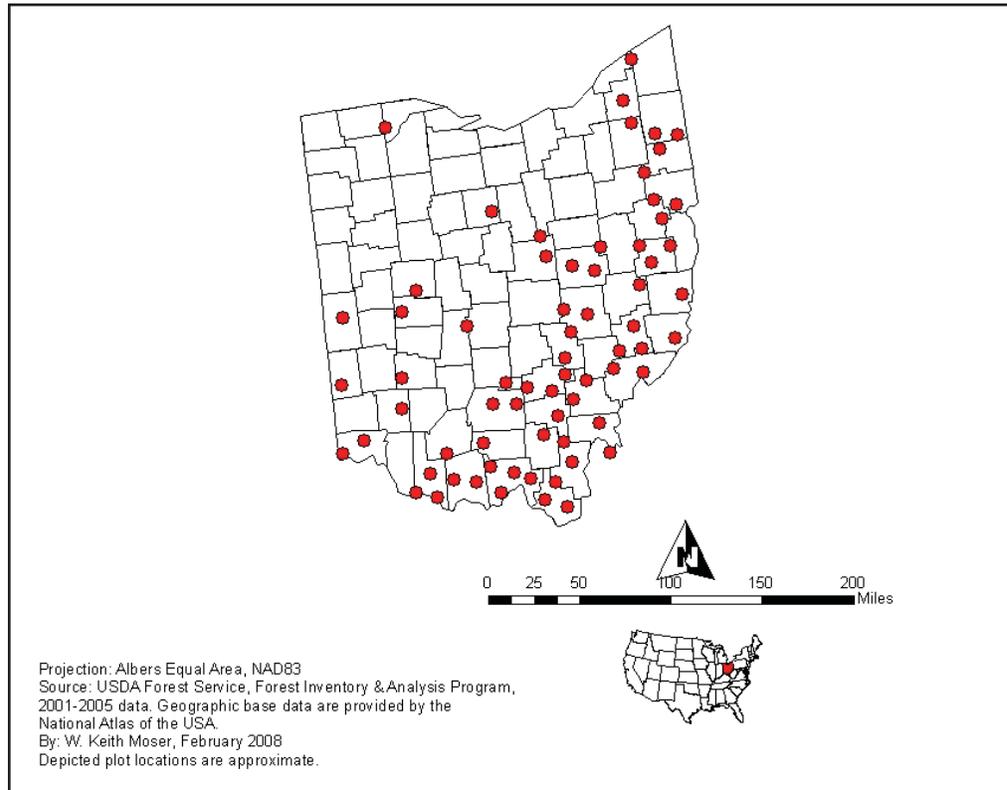
were trees. Of the plant species, 380, or 62 percent, were native to this country while 88, 14 percent, were exotic plants (Table 6). Poison ivy was the most common plant species, found on 71 of the 75 Phase 3 plots in the State (Table 7). The second most common species was a non-native invasive, multiflora rose. Of the top 30 species found on our plots, 12 were tree species.

**Table 6.—Number of species in Ohio, 2005, by domestic or foreign origin (per PLANTS database, USDA Natural Resources Conservation Service).**

Origin	Number of species
Cultivated, or not in the U.S.	3
Introduced to U.S.	88
Native and Introduced to U.S.	7
Native to U.S.	380
Probably Introduced to U.S.	1
Unclassified	130

In 2005, invasive species were prominent in Ohio’s forests. Besides the abovementioned multiflora rose (Fig. 74), garlic mustard (Fig. 75) and Japanese honeysuckle (Fig. 76) were also found in a substantial portion of our plots. Despite the concerns of many that non-native bush honeysuckles were devastating to the region’s biodiversity (Luken and Goessling 1995, Luken 1988), we found Amur honeysuckle

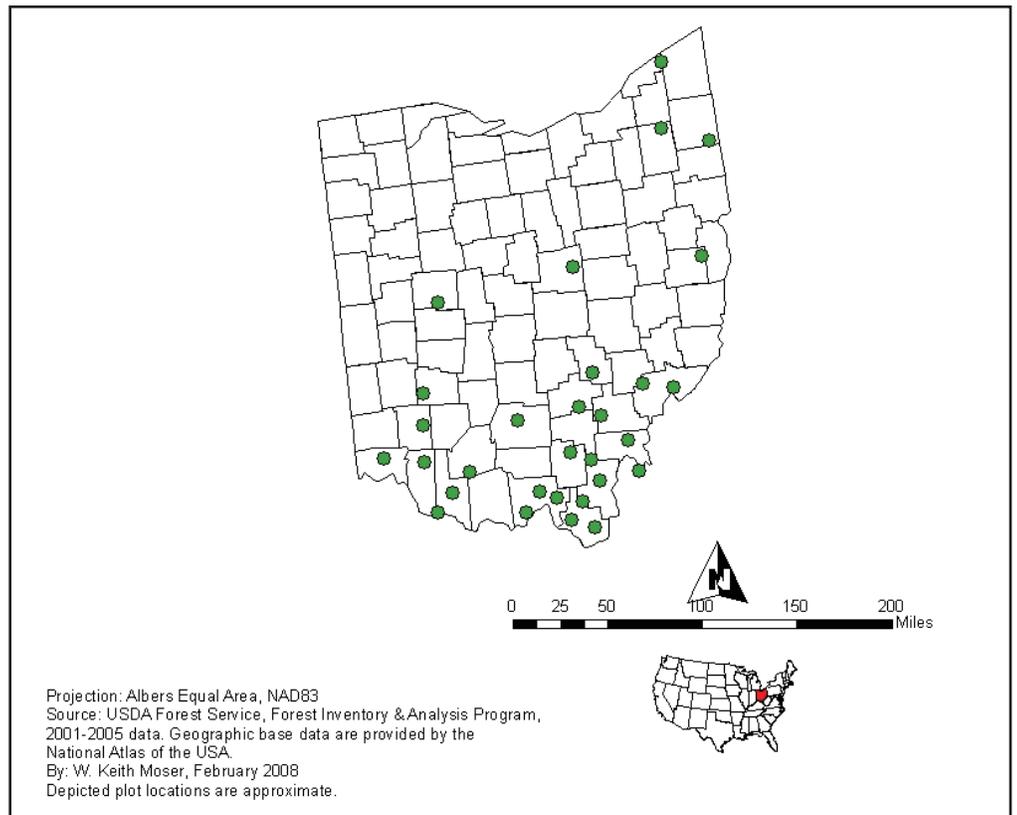
Figure 74.—Location of multiflora rose on Phase 3 vegetation plots in Ohio, 2005.





Multiflora rose: photo by James H. Miller, U.S. Forest Service, www.forestryimages.org

Figure 75.—Location of garlic mustard on Phase 3 vegetation plots in Ohio, 2005.





Tree of heaven; photo used with permission by Chris Evans, River to River CWMA, [www.forestryimages.org](http://www.forestryimages.org)

**Table 7.—The top 30 plant species or undifferentiated genera or categories found in Ohio; the number of plots where found (in parentheses) and the mean number of tree saplings per acre on those plots, Ohio, 2005**

Species name	Tree saplings per acre
Bitternut hickory (43)	479.94
Sedge (47)	555.54
White avens (48)	535.55
American elm (54)	500.41
Graminoid (grass or sedge) (52)	566.57
Sugar maple (51)	448.17
Grape (63)	535.08
Northern red oak (46)	515.23
Multiflora rose (69)	528.95
Plant (60)	552.33
Virginia creeper (69)	495.41
Eastern poison ivy (71)	513.24
Mayapple (34)	492.59
Black cherry (68)	501.61
Violet (57)	518.2
Black raspberry (50)	569.82
Aster (43)	493.25
Goldenrod (54)	522.37
Red maple (53)	499.94
White ash (53)	527.61
Sassafras (40)	454.7
Flowering dogwood (44)	549.34
Christmas fern (43)	489.34
Roundleaf greenbrier (35)	479.51
Northern spicebush (39)	483.32
White snakeroot (34)	493.05
American beech (39)	510.76
White oak (41)	519.09
Hawthorn (34)	579.95
Black oak (36)	506.5

on only a portion of our plots (Fig. 77). The apparent effect of these species on tree regeneration varied. The number of saplings (overstory tree species 1 to 5 inches in diameter) averaged 517 trees per acre across the 75 Phase 3 plots. Many of the plots with invasive species present had more saplings per acre than this, but a few invasive species—European privet, Amur honeysuckle, and Japanese honeysuckle—coincided with substantially fewer saplings per acre (Table 8).

**Table 8.—The top 18 non-native plant species found in Ohio, the number of plots where found (in parentheses), and the mean number of tree saplings per acre on those plots, Ohio 2005.**

Species name	Tree saplings per acre
Garlic mustard (21)	600
Timothy (12)	962
Multiflora rose (69)	529
Creeping jenny (8)	985
Common St. Johnswort (7)	677
Tree of heaven (7)	325
Queen Anne's lace (15)	663
Asian bittersweet (9)	665
Sulphur cinquefoil (16)	591
Ground ivy (17)	747
Japanese honeysuckle (30)	420
Russian olive (5)	1,153
Amur honeysuckle (9)	498
Japanese barberry (13)	604
Oxeye daisy (12)	870
White clover (8)	738
Orchardgrass (8)	888
European privet (11)	333



Amur honeysuckle; photo used with permission by Troy Evans, Eastern Kentucky University, [www.forestryimages.org](http://www.forestryimages.org)

Figure 76—Location of Japanese honeysuckle on Phase 3 vegetation plots in Ohio, 2005.

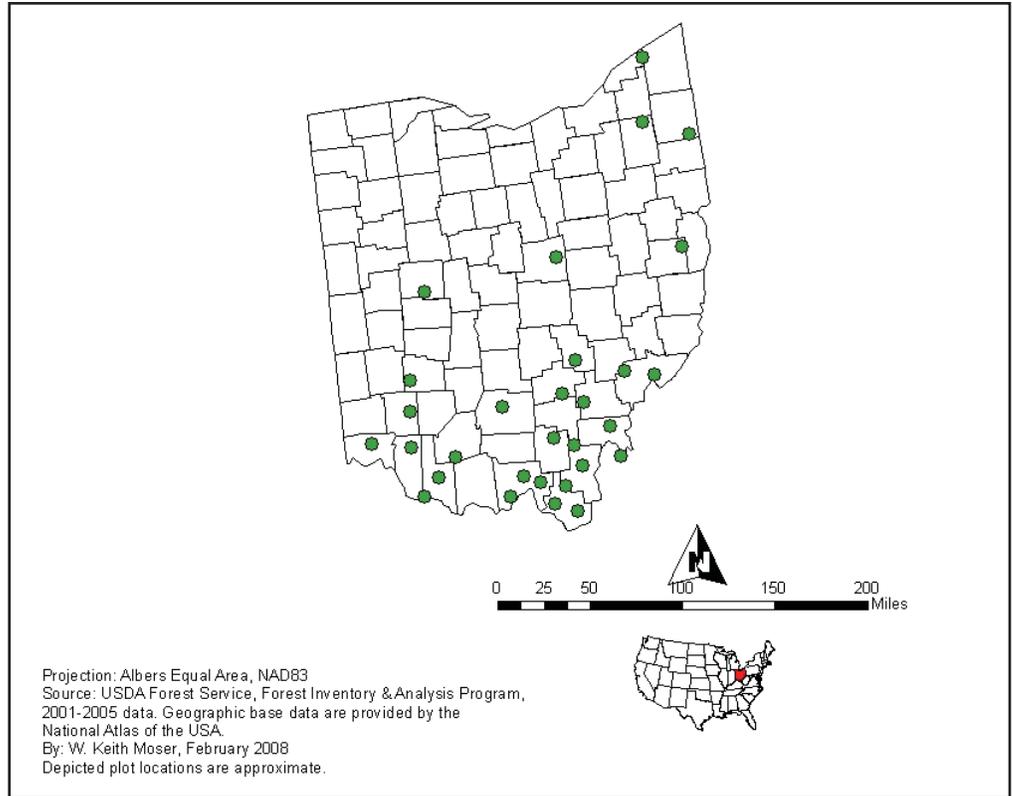
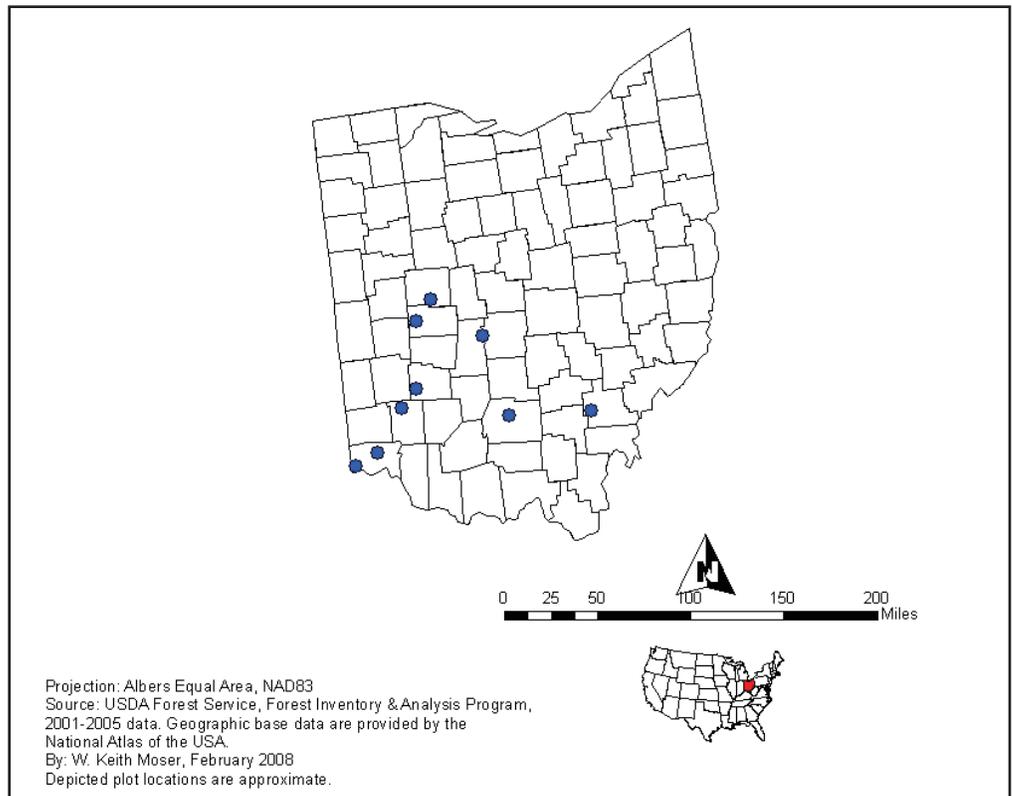


Figure 77—Location of Amur honeysuckle on Phase 3 vegetation plots in Ohio, 2005.



## What this means

Ohio's forests are the home of hundreds of vascular plant species. The 609 species found on FIA forested plots represent a diverse and, in some cases, challenging resource. The challenging segment of Ohio's plant diversity is that portion made up of non-native invasive plants (NNIP). Given the history of natural and human-caused disturbance and forest types, such as oak-hickory, whose shade intolerance results in understory growing space that is not completely occupied, we expected to find multiple relationships between NNIP and forest and site characteristics.

In a study of disturbance factors and NNIP presence in the Midwest (Moser et al. 2009), the authors observed that some species, such as multiflora rose and Japanese honeysuckle, significantly benefited from lower overstory basal areas, but this relationship did not apply to other species. Another measure of disturbance, distance to nearest road, appeared to have a significant negative relationship with non-native bush honeysuckles such as Amur honeysuckle. This observation implied that either the disturbed growing space near the road or the road as a surrogate for human presence had a positive influence that diminished with increasing distance from the road.

In evaluating the presence and influence of non-native invasive plants, the challenge is in separating the human influence from the ecological. One could easily argue that these results reflect the heavily disturbed nature of Ohio's second- and third-generation forests, which either re-established following abandonment of farm land or pasture or were influenced by heavily disturbed adjacent land. Invasive species are known to thrive on sites with more available resources (Richardson and Pyšek 2006).

The characteristics of the landscape that influenced invasive species presence may also have a significant relationship with homestead choice by settlers. Natural and human-caused disturbances, coupled with anthropogenic establishment of individual species, have a lingering influence on Ohio's forest ecosystem long after they occur. As with most situations where ecological restoration is the goal, elimination of NNIP on Ohio's landscape will require both aggressive treatment to halt the spread of the species and a considerable investment in ecosystem restoration.

## Threats to the Health of Important Tree Species in Ohio

The health and condition of forests are influenced by various biotic and abiotic stressors. Abiotic stressors include drought, flooding, cold temperatures or freeze injury, nutrient deficiencies, soil physical properties affecting soil moisture and aeration, and toxic pollutants. Biotic stressors include native or introduced damaging insects, diseases, invasive plant species, and animals.

Drought is an important stress that frequently precedes or contributes to the onset of major outbreaks of damaging insects. Seasonal or prolonged droughts have long been a significant stressor in Ohio. Below normal precipitation occurred in Ohio during 1991 and 1994; alternatively, 1996 and the years 2003-2006 were very wet. On poorly drained soils, too much moisture stresses trees, particularly species not adapted to these conditions. These extremes in precipitation can be more devastating when followed by insect outbreaks; they can also produce conditions that facilitate disease outbreaks.

Invasions by exotic diseases and insects are one of the most important threats to the productivity and stability of forest ecosystems around the world (Liebhold et al. 1995, Pimentel et al. 2000, Vitousak et al. 1996). Over the last century, Ohio forests have been affected by well-known exotic and invasive agents such as Dutch elm disease, chestnut blight, and gypsy moth (Mattson 1997). Invasions by alien species are known to result in many community-level direct and indirect effects, including changes in plant species diversity and richness, community structure, vegetation dynamics, and plant-animal interactions (Mack et al 2000, Mooney and Cleland 2001, Parker et al. 1999).

Insect and disease pests, both native and exotic, continue to damage and kill trees in the State's forests. Looking at changes in standing dead basal area since 1991, we see that most major species have remained stable or decreased, although white oak and elm have increased (Fig. 78). The most common types of damage recorded on trees in Ohio were decay and vines, 52 and 22 percent of trees, respectively. Grapevines damage trees by breaking tops and limbs and breaking and twisting boles, thereby reducing tree growth and quality. However, vines also provide food and cover for many species of wildlife. Across the State tree crowns are generally healthy for most species (Fig. 79); only white ash, black cherry, and elm species. have more than 5 percent of their basal area in the  $\geq 20$ -percent crown dieback categories. Although the amount of standing dead appears to be decreasing and crowns are generally healthy, some tree species in Ohio are facing additional risks from newly introduced insects and diseases that threaten their long-term health and sustainability. The following comments on forest tree species highlight the major stresses that pose current and potential problems.

Figure 78.—Percent of standing basal area that is dead for selected tree species and percent change, Ohio, 1991 and 2005.

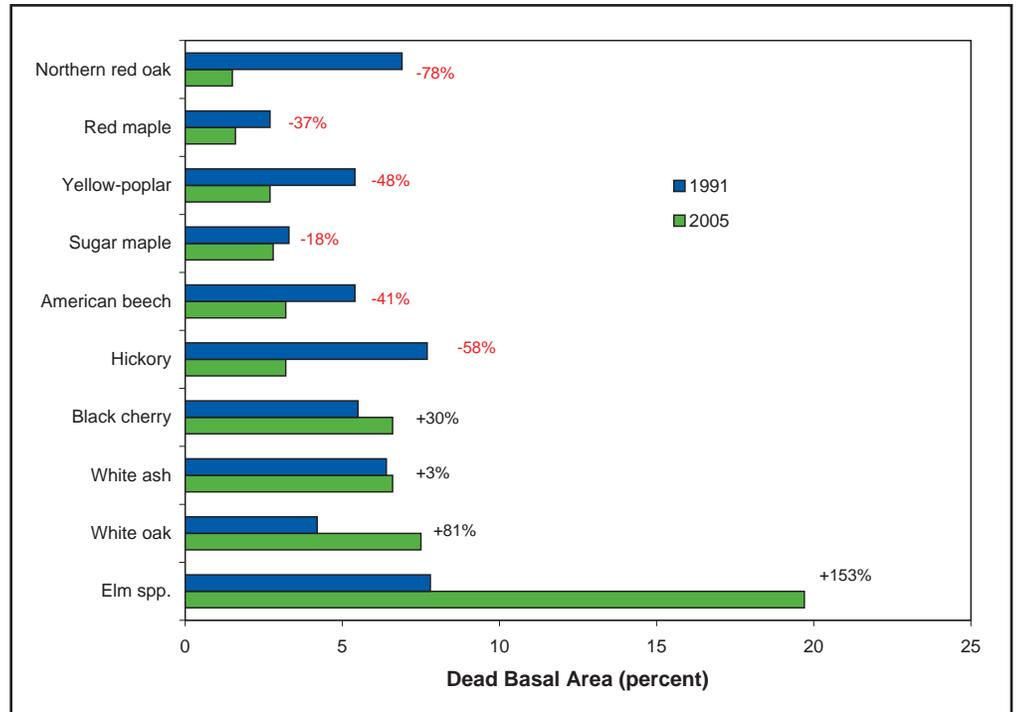
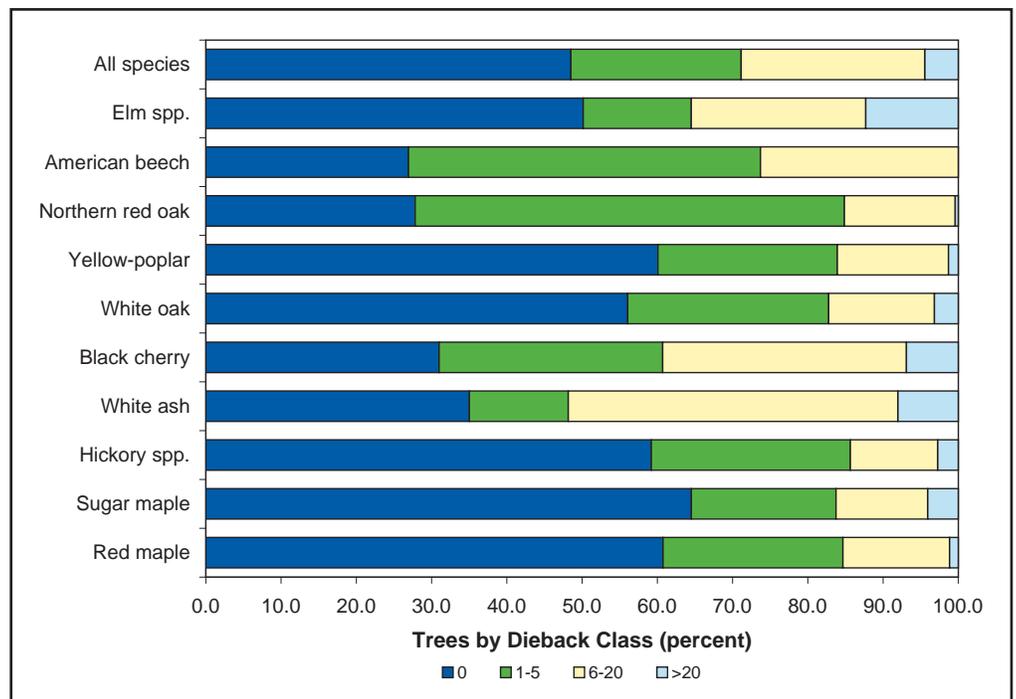


Figure 79.—Percent of basal area by crown dieback categories (percent) for selected tree species, Ohio, 2005.



## American Beech

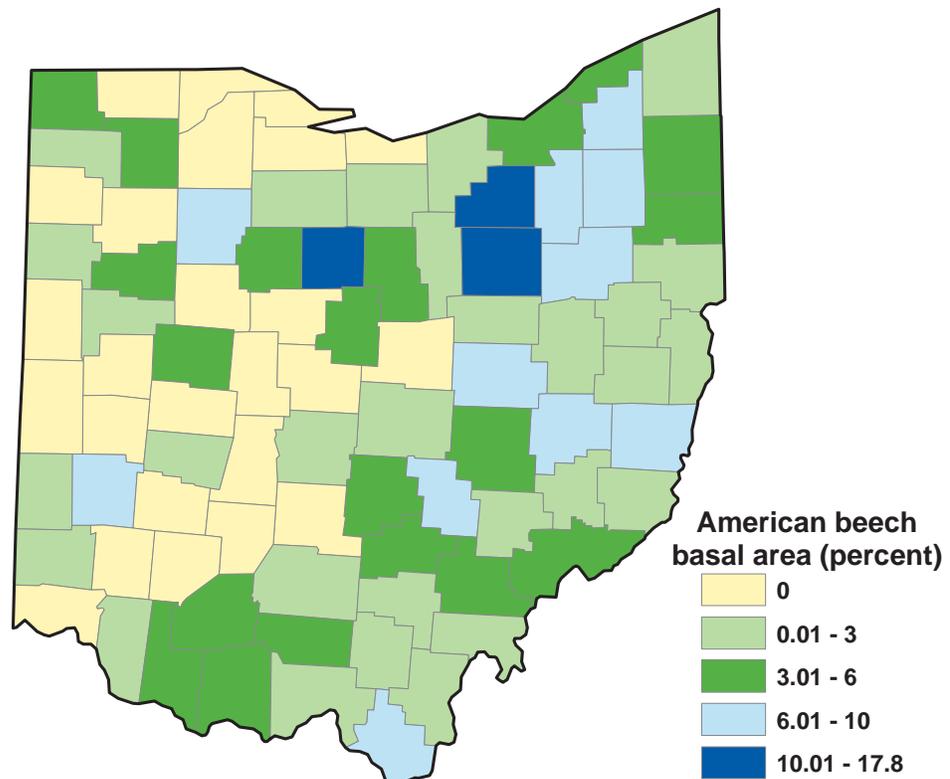
### Background

American beech (*Fagus grandifolia* Ehrh.) is a major component of the maple/beech/birch forest type part of the northern hardwoods group, which makes up 32 percent of the forest resource in Ohio. Forests with the highest proportion of American beech basal area are in the eastern half of the State (Fig. 80). American beech is an important wildlife and timber species. Beech bark disease (BBD) is an insect-fungus complex involving the beech scale insect (*Cryptococcus fagisuga* Lind.) and the exotic canker fungus *Neonectria coccinea* (Pers.:Fr.) var. *faginata* Lohm. or the native *Neonectria galligena* Bres. that kills or injures American beech. Three phases of BBD are generally recognized: 1) the “advancing front,” which corresponds to areas recently invaded by scale populations; 2) the “killing front,” which represents areas where fungal invasion has occurred (typically 3 to 5 years after the scale insects appear, but sometimes as long as 20 years) and tree mortality begins; 3) the “aftermath forest,” which are areas where the disease is endemic (Houston 1994, Shigo 1972).

### What we found

The scale insect was first observed in Lake County in northeastern Ohio in 2001. Since then it has spread south and east into Geauga, Ashtabula, Portage, and Trumbull Counties (Fig. 81). The first confirmed case of the disease complex was found in Lake County in 2003. Currently, significant amounts of standing dead beech are present in much of southeastern Ohio, which is outside of the range of the beech scale insect

Figure 80.—Percent American beech basal area, Ohio 2005.



(Fig. 82). In fact, the amount of standing dead American beech basal area has decreased by 2 percent since the 1991 inventory (Fig. 78). Decay and vines were noted on 74 and 10 percent of American beech trees, respectively.

#### What this means

Morin et al. (2007) estimated that the beech scale is spreading at a rate of approximately 9.1 miles/year. The scale insect is expected to continue spreading into the rest of Ohio over the next two decades (Fig. 83). As this spread occurs, it will be important to continue monitoring for fungal invasion and subsequent tree mortality. American beech mortality is expected to increase significantly as the “killing front” of the disease complex advances behind the “advancing front” of the scale insect.



Beech bark disease; photo used with permission Fengyou Jia, Division of Forest Pest Management, DCNR, PA, [www.forestryimages.org](http://www.forestryimages.org)

Figure 81.—Range of the beech scale insect in Ohio, 2006.

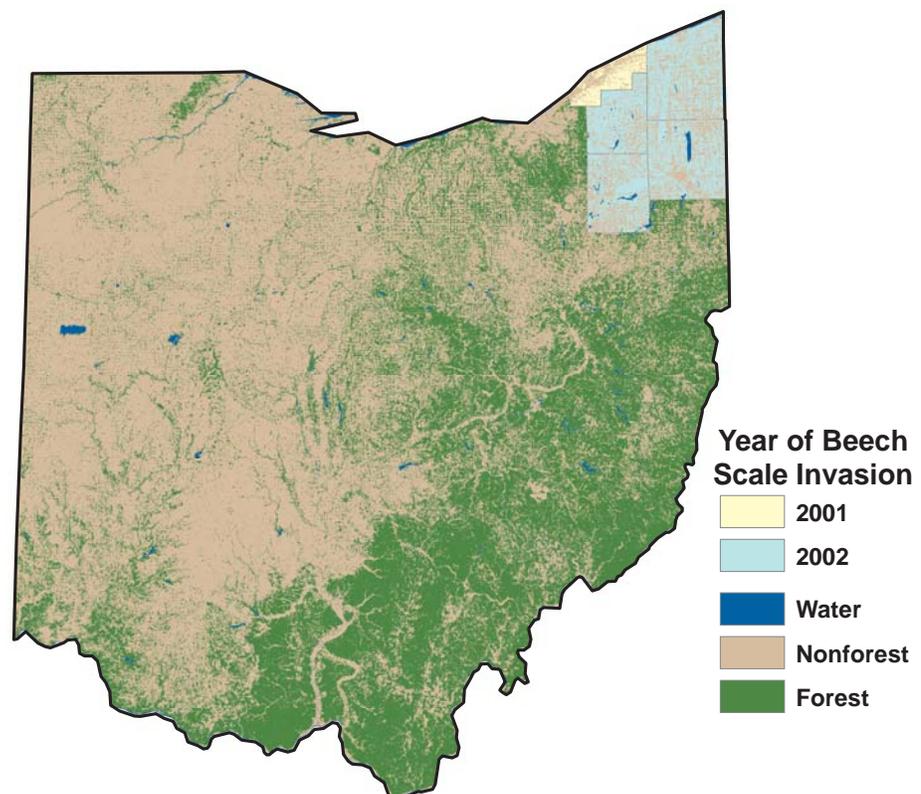


Figure 82.—Percent standing dead beech basal area, Ohio 2005.

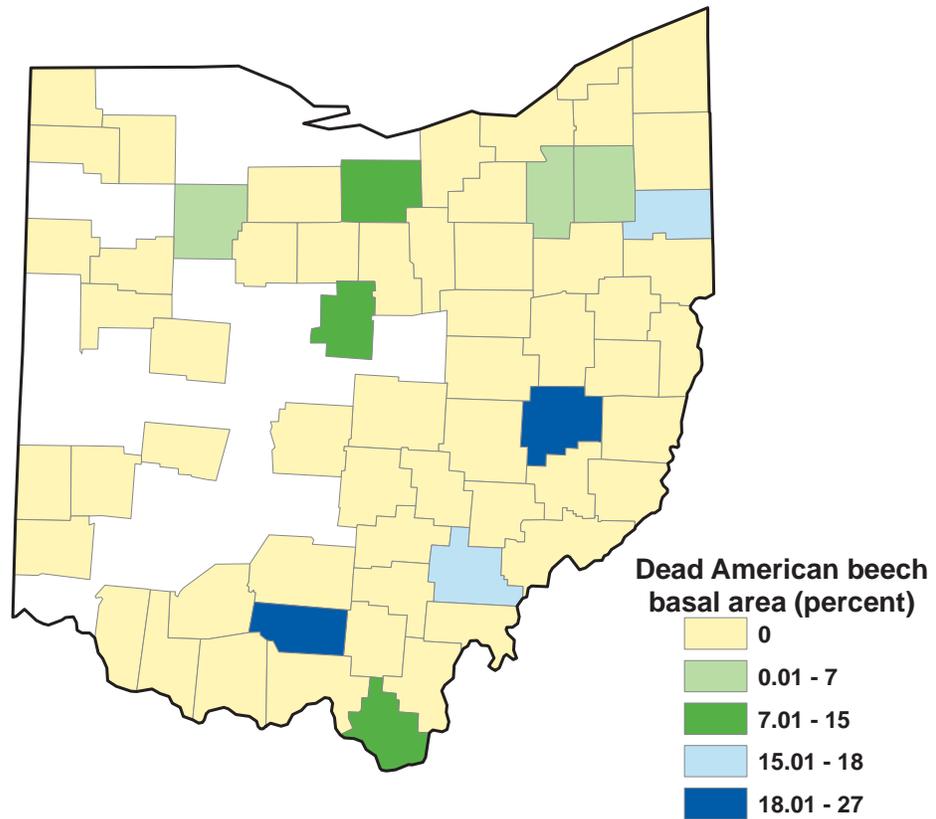
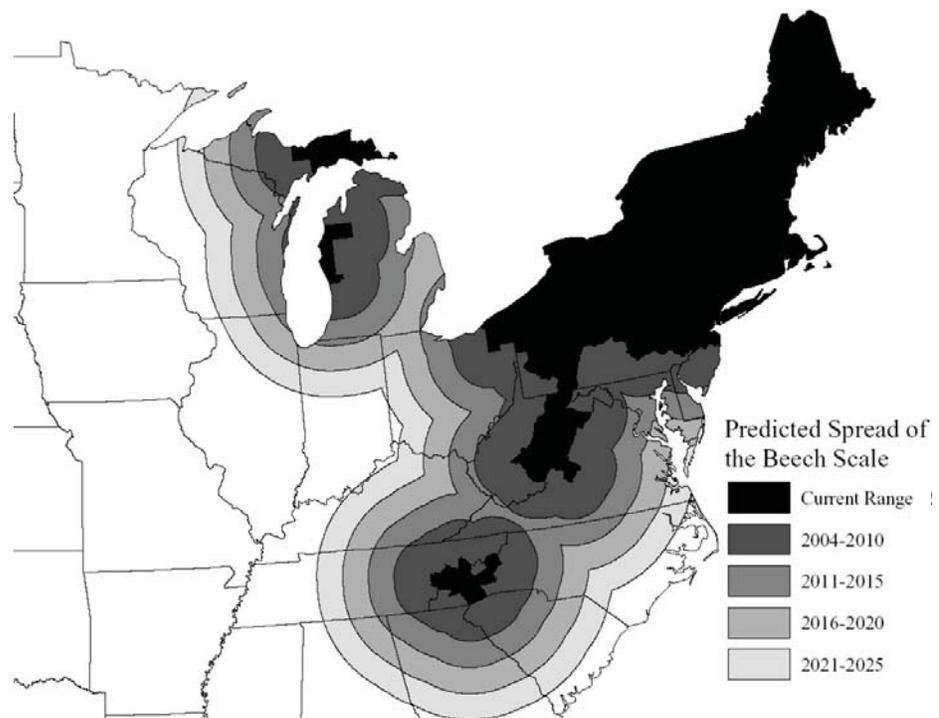


Figure 83.—Predicted spread of beech scale insect (from Morin et al. 2007).



## Oak

### Background

In Ohio the oak/hickory and oak/pine forest-type groups represent about 56 percent of forested land area. Forests with the highest proportion of oak (*Quercus* spp.) basal area are in the southern and western edges of the State (Fig. 84). Since 1990, defoliation, primarily of oaks, by gypsy moth has been a minor pest problem that may have impacted oak forests by altering productivity, species composition, and stand structure in localized areas.

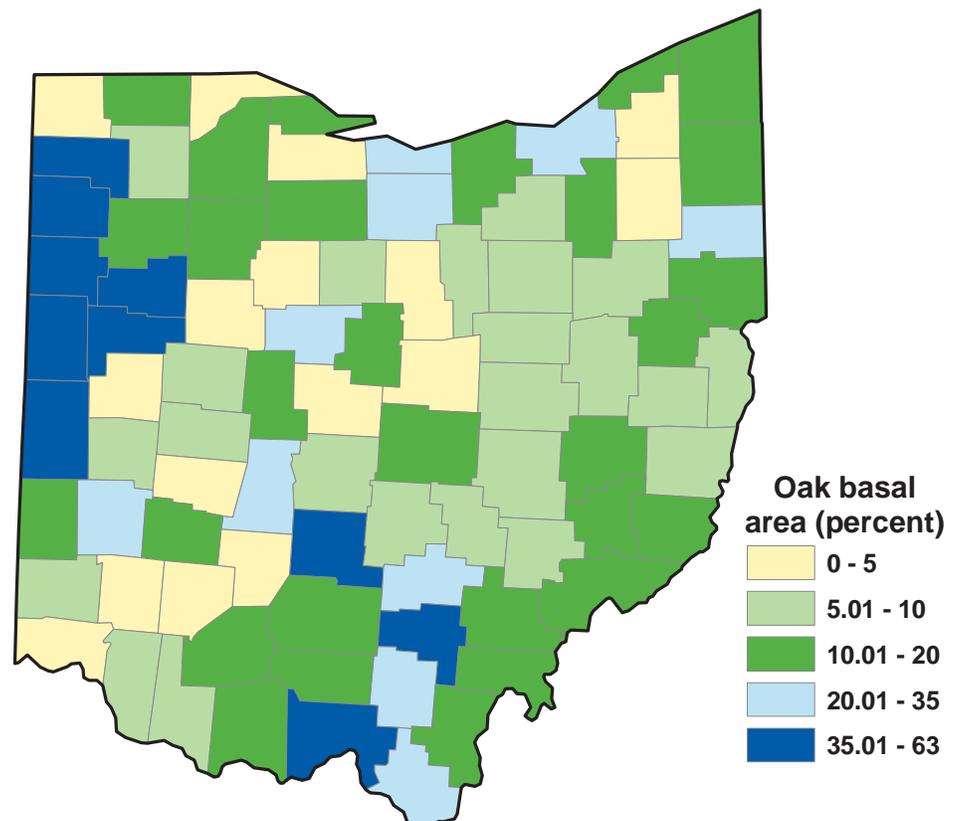


Gypsy moth; photo used with permission by USDA, APHIS PPO, [www.bugwood.org](http://www.bugwood.org)

A potential threat to the oak resources in Ohio is a tree disease called Sudden Oak Death (SOD) caused by the pathogen *Phytophthora ramorum*.

Over the past 10 years, large numbers of tanoaks (*Lithocarpus densiflorus*), coast live oaks (*Quercus agrifolia*), and black oaks (*Quercus kelloggii*) have been dying in California and Oregon's coastal counties as a result of infection. The disease pathogen has also caused leaf blight and shoot dieback on many other woody and non-woody plant species in these states. *P. ramorum* has since been

Figure 84.—Percent oak basal area, Ohio 2005.

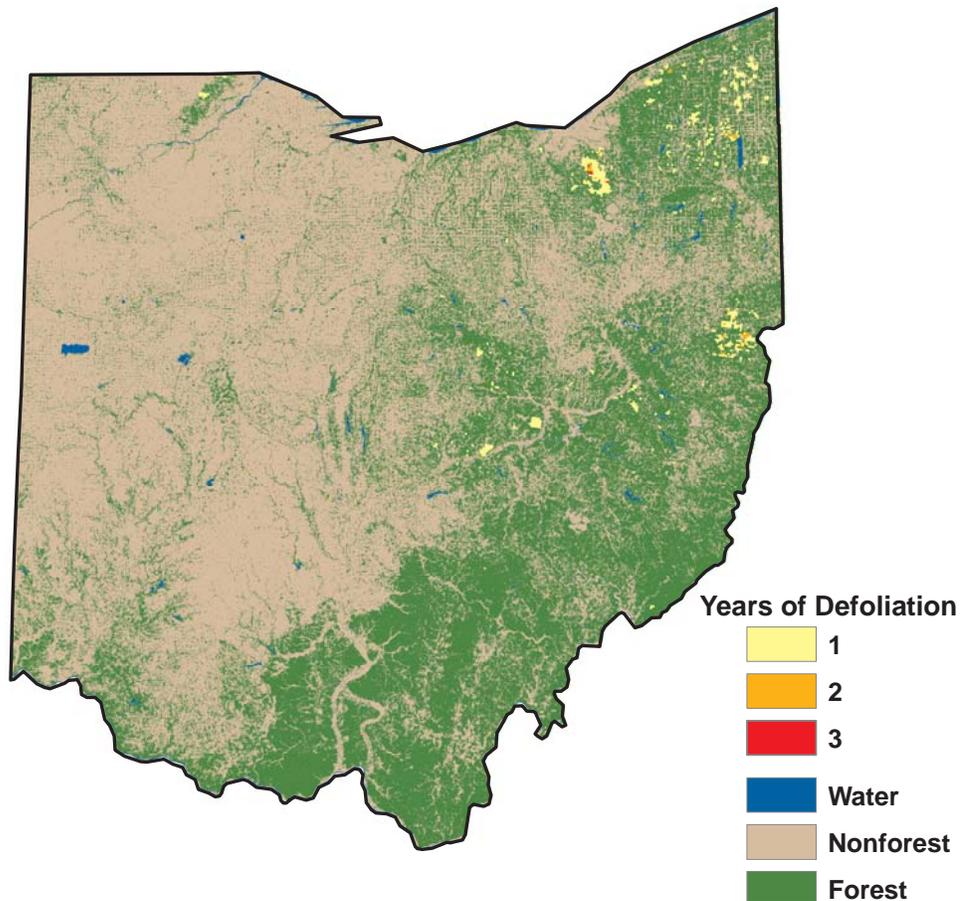


inadvertently transported to several eastern states via infected ornamental nursery stock such as *Rhododendron*. To date, no nurseries in Ohio have received infected plants, and forest surveys in nursery perimeters have not detected the pathogen on oaks or any of the many alternate host species. If the pathogen and disease do arrive, the oak resource in association with understory hosts such as *Rhododendron*, *Vaccinium*, and *Kalmia* would be most at risk.

What we found

Gypsy moth has defoliated thousands of acres of Ohio’s forests in the past 15 years (Fig. 85). Mapped estimates of percent standing dead oak basal area are shown in Figure 86. Decay was the most common form of damage recorded on white, chestnut, and red oaks (46, 66, and 41 percent, respectively). Vines were most common in red oak trees (31 percent) but less common in white and chestnut oak (12 and 10 percent, respectively). Open wounds were recorded on 15 percent of white oak trees. One possible explanation of this finding is logging damage.

Figure 85.—Numbers of years of gypsy moth defoliation (1990-2002).

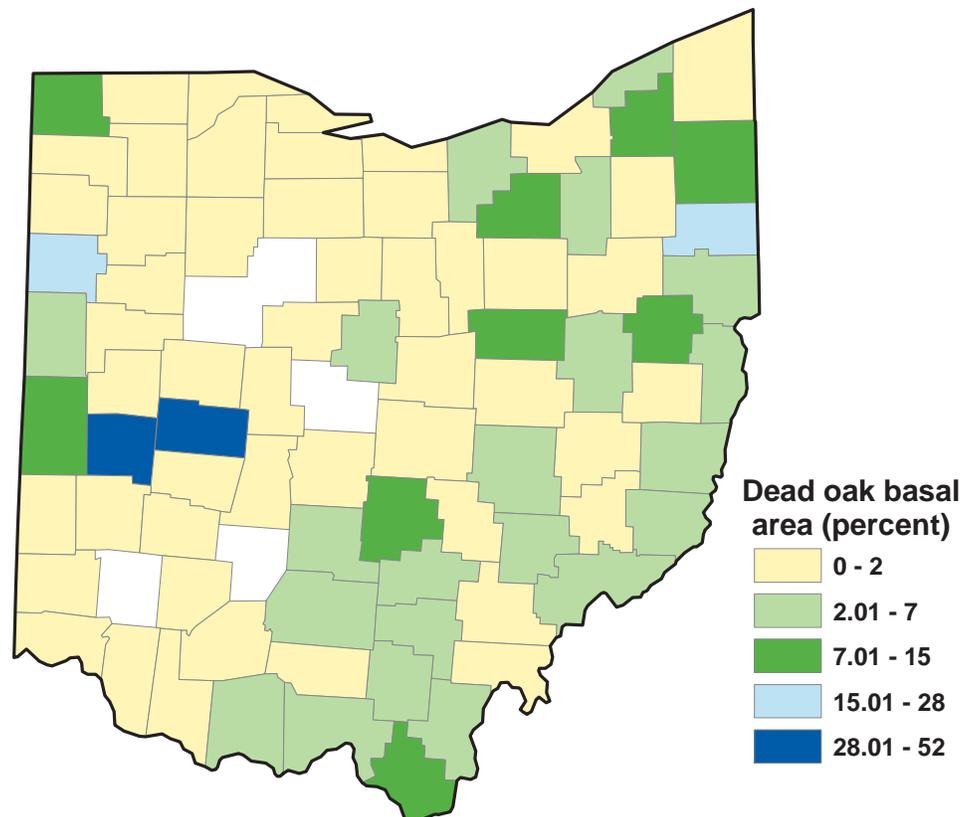


### What this means

Outbreaks of gypsy moth in the 1990s killed trees in localized areas, but this trend was not picked up with FIA plot data. Although the proportion of white oak basal area that is dead has increased, this proportion has decreased substantially for northern red oak (Fig. 78), which may indicate that dead red oak trees have been harvested or fallen down. Additionally, the crowns of the oak species across the State appear to be healthy (Fig. 79).

Future defoliation events and the potential arrival of SOD in the eastern United States are of particular concern to the oak resources in Ohio. Due to the extensive distribution of overstory hosts of SOD (Fig. 84), this disease could be devastating to Ohio's forests. Also of concern is the lack of oak in the smaller diameter classes that are needed to sustain the oak forest types in the State.

Figure 86.—Percent standing dead oak basal area, Ohio 2005.



## Ash

### Background

Ash species (*Fraxinus* spp.) are widely distributed throughout Ohio's forests but are rarely a major overstory component (Fig. 87). The elm/ash/maple forest-type group represents about 7 percent of forested land area in Ohio. Ash is a valuable timber species, and its seeds are important for many bird species. The two most significant diseases of ash are ash yellows and ash decline. However, the most significant future threat to all ash species is the emerald ash borer (EAB) (*Agilus planipennis*). EAB is an exotic insect pest that was first detected in Michigan in 2002 and has since been found on white and green ash in Indiana, Ohio, and several other places.

### What we found

Ash yellows and ash decline are likely to be the cause of much of the standing dead ash in the State (Fig. 88). EAB was first detected in the northwestern corner of Ohio along the Michigan border. Since it was first discovered in Ohio in 2003, EAB has been identified in 35 counties (Fig. 89). Presently, the spread of emerald ash borer is being monitored by the Ohio Department of Agriculture. For the latest quarantine map, go to the following Web site: <http://www.agri.ohio.gov/divs/plant/eab/eabquarantine.aspx>. Decay and vines were noted on 45 and 25 percent of ash trees, respectively.

Figure 87.—Percent ash basal area, Ohio 2005.

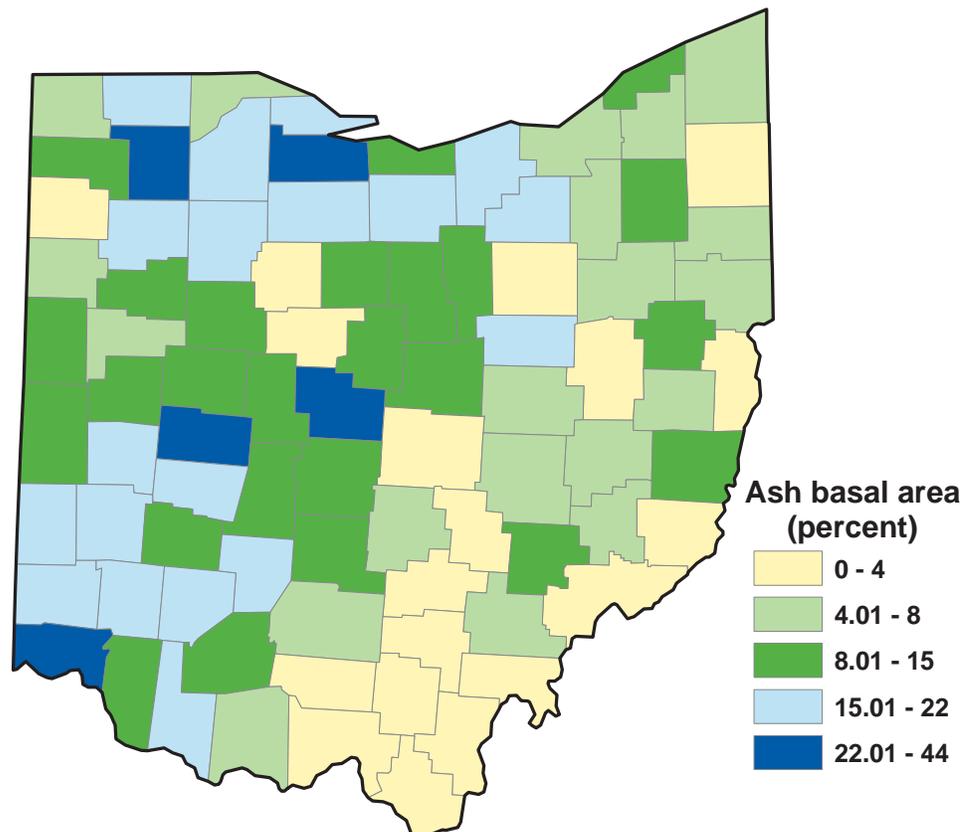
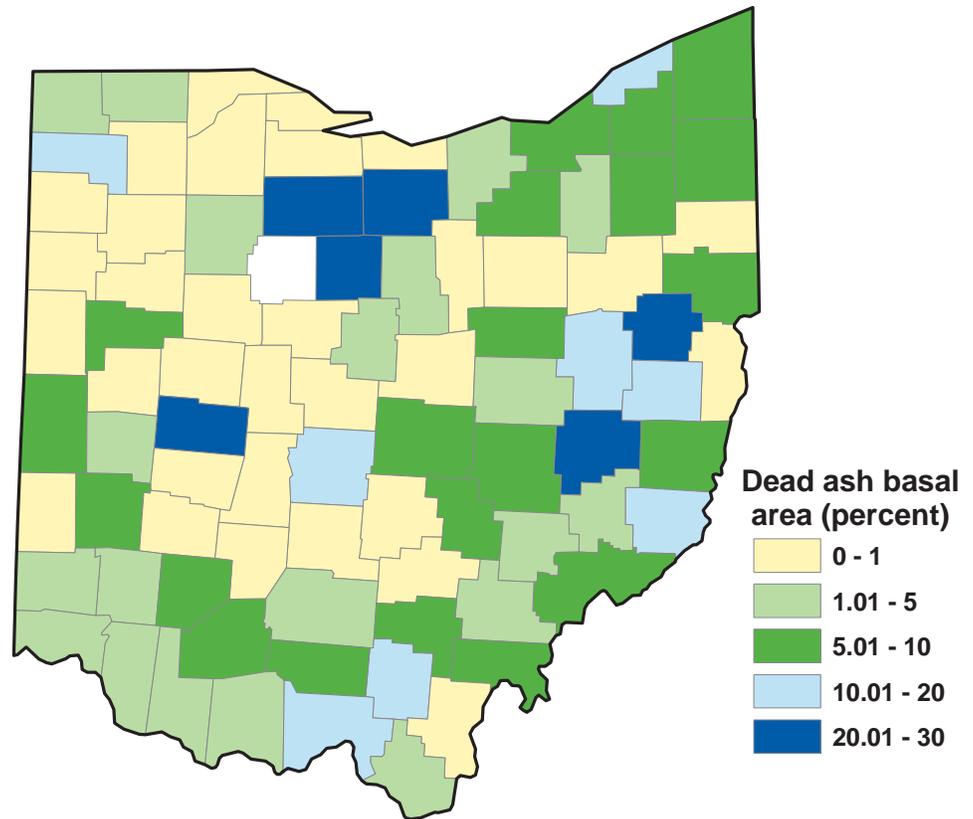


Figure 88.—Percent standing dead ash basal area, Ohio 2005.



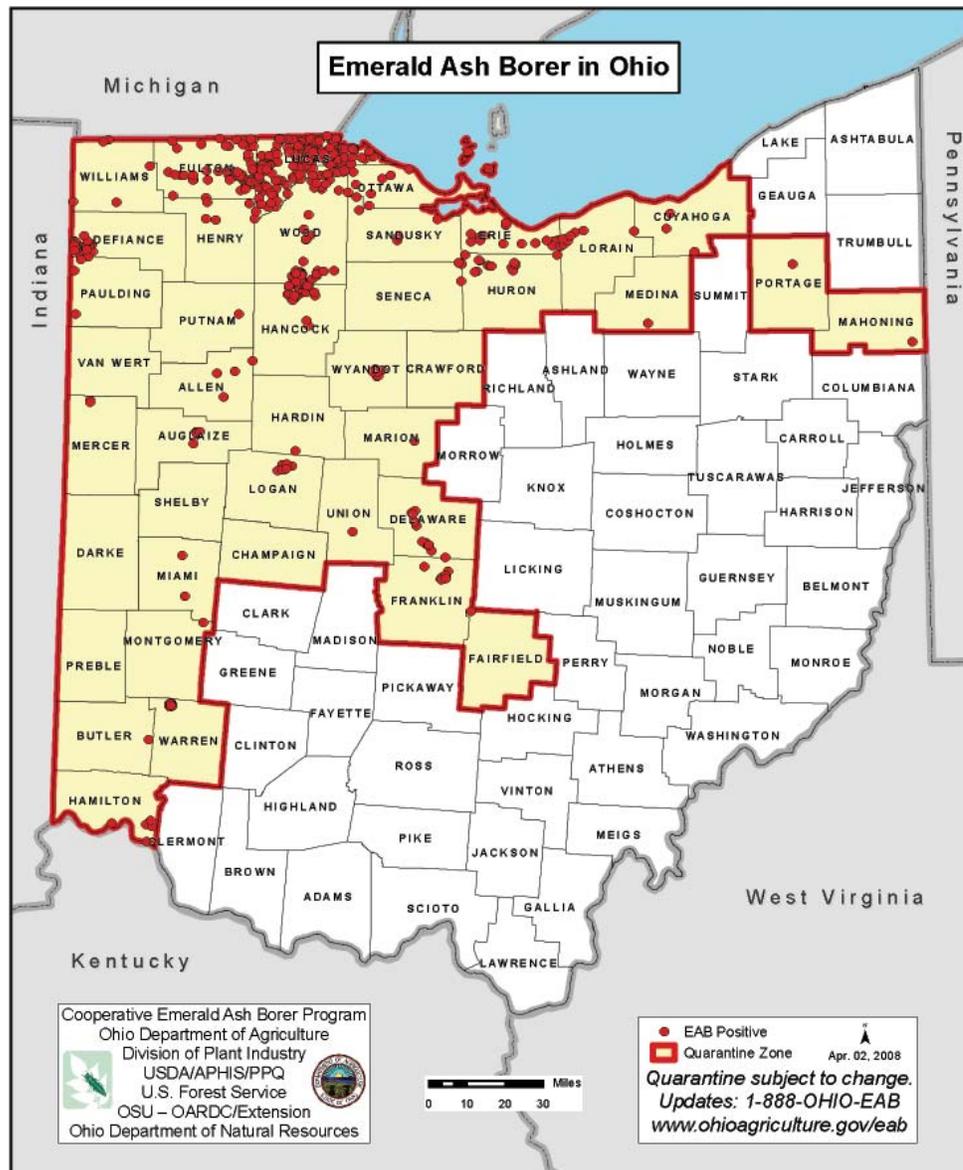
### What this means

EAB is considered a serious threat because the insect can be inadvertently transported across state lines in firewood and nursery stock. Counties with EAB have been quarantined to stop the movement of firewood and ash logs, which are the largest contributors to the spread of EAB. Emerald ash borer is a lethal pest and will result in increased ash mortality in both urban and forested landscapes. It will likely cause significant financial costs to municipalities, property owners, and the forest products industries in the State. It is hoped that one or more of the EAB natural enemies recently found in China will be useful biocontrol agents. Parasitic wasps that kill EAB eggs and larvae have been released at EAB-infested field sites as part of an ongoing search for tools to manage EAB populations.



Emerald ash borer; photo used with permission by David Cappaert, Michigan State University, [www.bugwood.org](http://www.bugwood.org)

Figure 89.—Known distribution of emerald ash borer.



## Elm

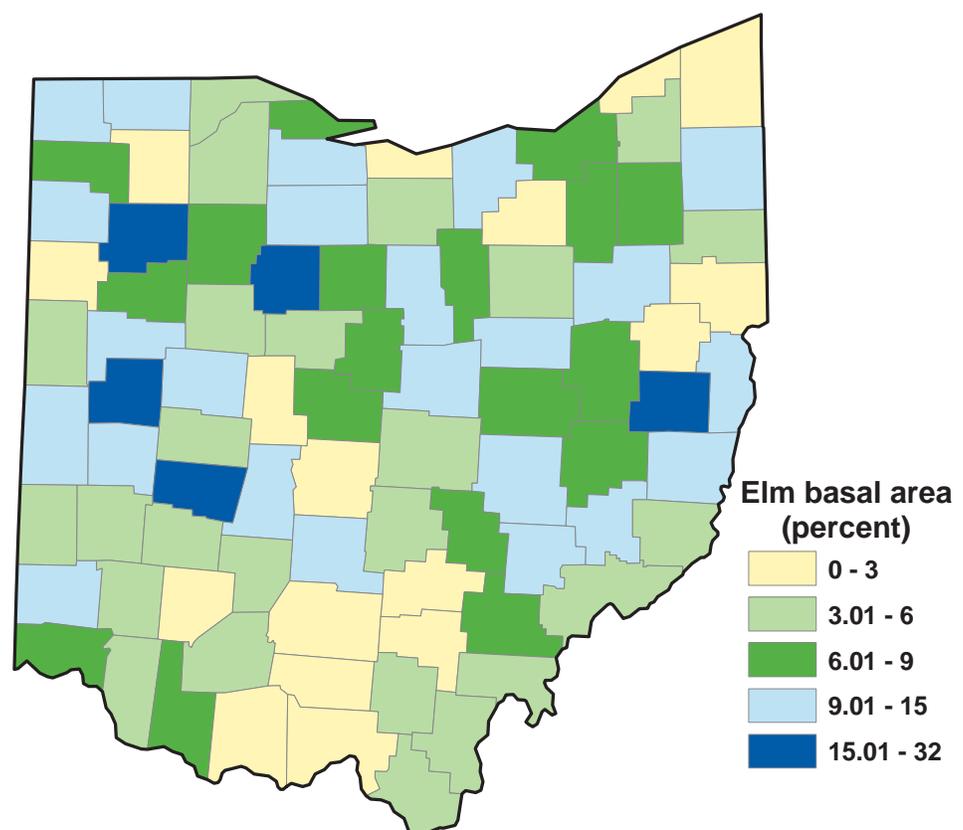
### Background

Before Dutch elm disease (DED), elms (*Ulmus* spp.) were a prominent species in Ohio's forests, especially in riparian and moist soils, and they were widely planted to provide a high green canopy over streets in cities and towns. Today, elm species are still widely distributed throughout Ohio's forests but are rarely a major overstory component (Fig. 90). The elm/ash/maple forest-type group represents about 7 percent of forested land area in Ohio. The exotic wilt, *Ceratocystis ulmi* or *Ophiostoma ulmi*, commonly known as Dutch elm disease, was first discovered in North America in Cleveland, Ohio, in 1930. DED has had a tragic effect on American elms throughout the range of the species. American elms are now a much less important overstory species than they once were.

### What we found

DED is likely to be the cause of much of the standing dead elm in Ohio (Fig. 91). Of the major tree species in the State, elm had the largest amount of basal area in trees with poor crowns in the latest inventory (Fig. 79). Elm was also the most vine-infested major species in Ohio (49 percent of trees). Decay was noted on 21 percent of elm trees.

Figure 90.—Percent elm basal area, Ohio 2005.



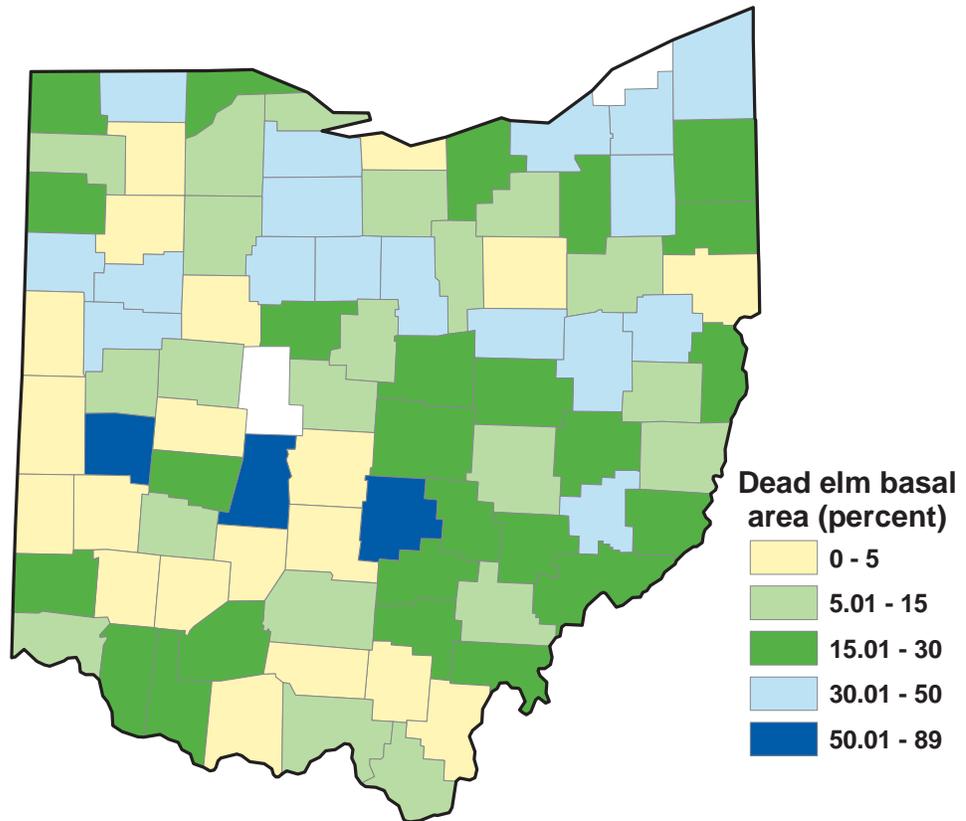
What this means

Elm is likely to remain a minor overstory component in Ohio’s forests due to the pervasive effects of DED. The recent increase in elm mortality is likely due to a new cohort of American elms reaching susceptible age. In Ohio, elms continue to reproduce and occupy growing space in stands, yet many are killed before they reach sawtimber size, providing little economic return. American elm is a prolific seed producer, and trees as young as 15 years produce seed (Bey 1990). Because small elms continue to grow into the resource base, elm mortality is an ongoing problem. Elms in natural stands can serve as reservoirs of elm bark beetles and DED fungus to infect high value landscape trees (Haugen 1998). The best management option for elms may be to eliminate them and manage for alternative species; however, it may be desirable to retain some elms for biodiversity and aesthetic reasons.



Dutch elm disease; photo by Joseph O'Brien, U.S. Forest Service, [www.bugwood.org](http://www.bugwood.org)

Figure 91.—Percent standing dead elm basal area, Ohio 2005.



## TIMBER PRODUCTS



Log pile; photo by Richard Widmann, U.S. Forest Service.  
Inset: Skidder; photo by Richard Widmann, U.S. Forest Service.

## Background

FIA, in conjunction with other research units, canvassed primary wood processors to enumerate the amount of roundwood harvested for products in Ohio, the types of products produced, and the species used. The harvesting of roundwood provides income for landowners and the raw material for Ohio's forest products industry. Income from the sale of roundwood is often used to subsidize other forest management activities such as improving access for recreation and enhancing wildlife habitat, and it helps offset the costs of land ownership. To better manage the State's forests, it is important to know the quantity, species, and disposition by product of wood harvested in Ohio.

## What we found

A total of 92 million cubic feet of wood was harvested from Ohio's forests in 2006 and used for products (Fig. 92) (Wiedenbeck 2008). This amount is nearly the same as the 1989 harvest; however, there was a shift in production from pulpwood to saw logs. Most wood harvested (66 percent) was used as saw logs and veneer logs in the production of lumber and veneer. The 60 million cubic feet of saw logs produced in 2006 (excluding log exports) are equivalent to 411 million board feet, which is 7 percent more than the 382 million board feet produced in 1989. Wood used for pulpwood and engineered products accounted for 23.5 million cubic feet—26 percent of the 2006 harvest. This is equivalent to 277,000 cords and is 23 percent less than the 361,000 cords produced for pulp in 1989. In addition to pulpwood produced from the harvest of trees for pulp, Ohio typically produces the equivalent of 250,000

cords of sawmill residues that are used as pulp. Ohio mills import more wood from surrounding states than is exported. In 2006, 30.0 million cubic feet of roundwood were received by Ohio mills from neighboring states, while 12.8 million cubic feet were shipped to neighboring states. Most shipments into the State were saw logs and veneer logs while exports to other states were predominantly pulpwood.

Nearly all of the saw log harvest is hardwood species and is predominantly made up of red oaks, white oaks, yellow-poplar, sugar maple, black cherry, and red maple: 21, 20, 13, 8, 7, and

6 percent of the total saw log harvest, respectively (Fig. 93). Since 1987, the portion of the saw log harvest made up of oak species has fallen from 45 to 41 percent while the portion made up of maples has increased from 8 to 15 percent.



Sawmill: photo by Richard Widmann, U.S. Forest Service

Figure 92.—Roundwood harvest by product, Ohio, 2006.

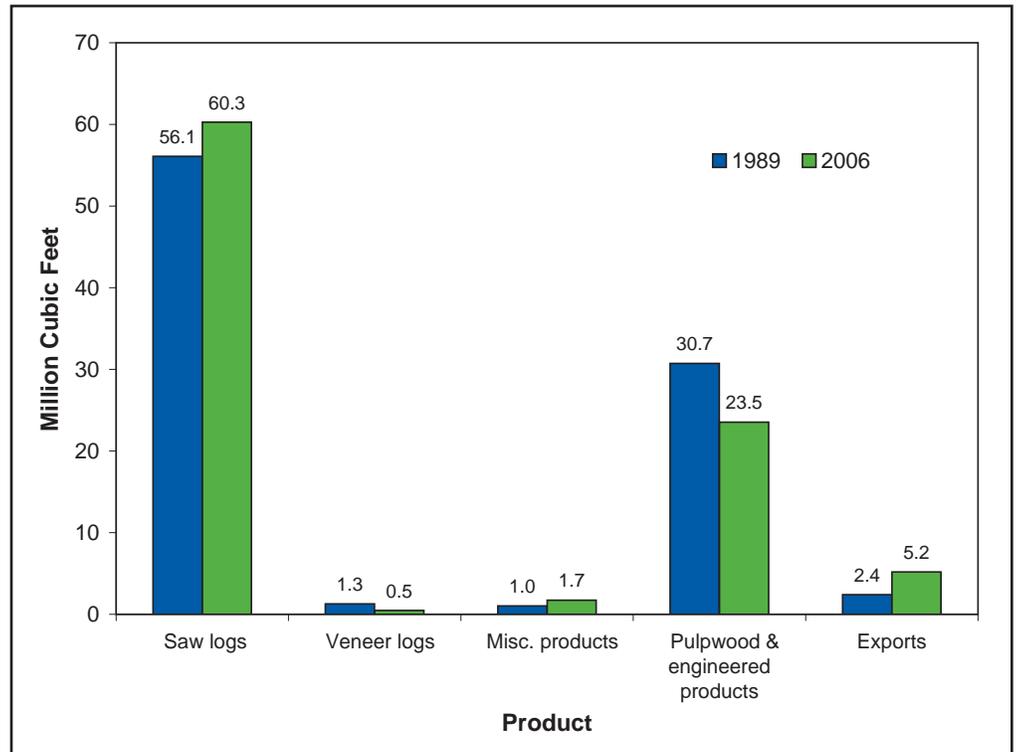
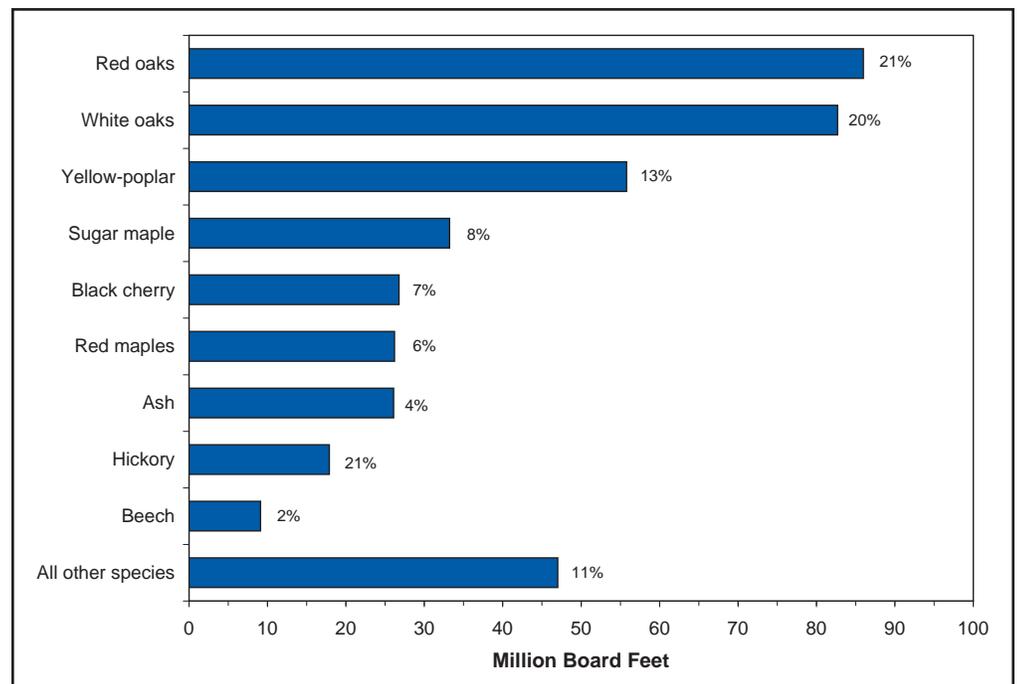


Figure 93.—Saw log harvest and percentage of total by major species group, Ohio 2006.



The number of sawmills processing logs in Ohio declined from 219 mills in 1989 to 197 mills in 2006 (Fig. 94). Most mills that are no longer operating processed less than a million board feet of log per year although losses occurred across all size classes of mills. In 2006 more than half the saw logs processed in the State were received at mills with a capacity of more than 5 million board feet per year, and nearly 30 percent were received at the eight mills that took in more than 10 million board feet.

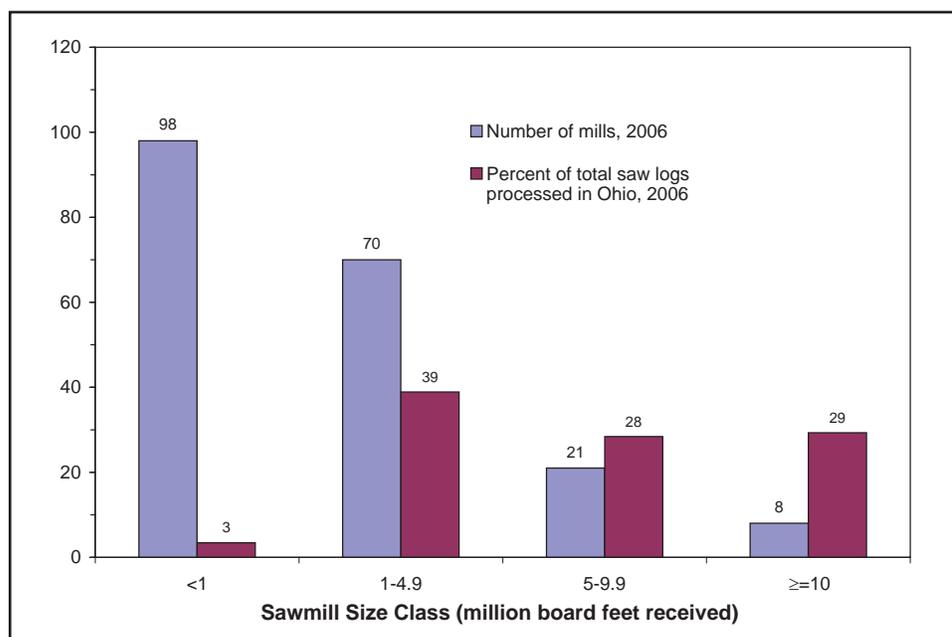
What this means

Markets for saw logs in Ohio have been strong, as indicated by a stable harvest from Ohio’s forests since 1989 and log imports into the State continuing to surpassing exports. However, this may change. In 2005 stumpage prices in Ohio and many other hardwood producing states fell to 5-year lows (Akers 2006), suggesting changes in the industrial demand for hardwood saw logs.

The shift in the species composition of the saw log harvest to more maple and less oak reflects changes in the forest resource. To remain sustainable, the composition of the harvest will need to continue to shift with changes in the resource.

Having markets for wood is essential to forest management. Despite the loss of some sawmills and a pulpmill, Ohio’s mills continue to provide landowners a complete market for their timber. The income landowners receive from selling timber is an incentive to keep land in forest. It can help pay property taxes and fund forest management activities such as wildlife habitat improvements and control of invasive species.

Figure 94.—Number of operating sawmills, 2006 by annual production and percentage of saw logs processed in 2006, Ohio.





Sawtimber stand; photo by Richard Widmann, U.S. Forest Service.

# Forest inventory

Historically, FIA inventoried each state on a cycle that averaged about 12 years. However, because of the need for timely and consistent data across large geographical regions along with national legislative mandates, FIA has changed to an annual inventory. This system was initiated in Ohio in 2001. Other changes made during the 2001-2006 inventory were the use of new algorithms to assign forest type and stand-size class to each condition observed on a plot. To make valid comparisons to the 1991 inventory, the 1991 data were used to recalculate previously published estimates using the new algorithms. In this report, comparisons to the 1991 inventory use these recalculated estimates.

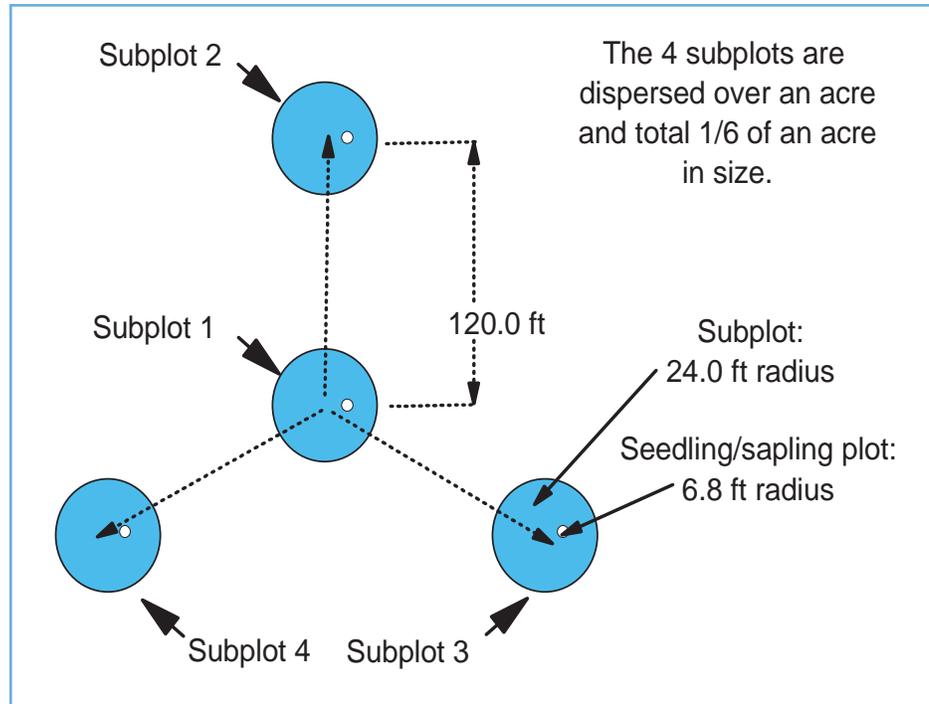
## Phase 1

Phase 1 procedures reduce variance associated with estimates of forest land area. A statistical estimation technique is used to classify digital satellite imagery and stratify the land base as forest or nonforest to assign a representative acreage to each sample plot. Source data are from Landsat Thematic Mapper (30-m resolution) imagery that ranged from 1999 to 2001. An image filtering technique is used to classify individual pixels using the 5- by 5-pixel region that surrounds each sample plot. The resulting 26 classes are collapsed for each estimation unit (county or combination of counties with small areas of forest land). Stratified estimation is applied by assigning each plot to one of these collapsed strata and by calculating the area of each collapsed stratum in each estimation unit. Stratified estimation produces more precise estimates than simple random sampling.

## Phase 2

Field measurements are conducted at sample locations situated within individual cells of a national hexagonal grid laid across Ohio. These sample locations are distributed about every 3 miles across the landscape. Each Phase 2 sample represents about 6,000 acres depending on the Phase 1 stratification of forest land. The new national design also incorporates a change to a four-subplot cluster (Fig. 95) (USDA 2002). At each location, a suite of variables is measured that characterizes the land and trees associated with the sample. Annually, a set of sample plot locations, referred to as an “inventory panel,” are measured. Each panel provides an unbiased representation of conditions across the State. As panels are completed, they can be combined with existing panels to produce the most precise estimates possible. The Ohio inventory was initially set up to be on a 7-year (7-panel) cycle. But, after completing 4 panels, FIA decided to accelerate the inventory to a 5-year cycle. The remaining 3 panels were completed in the following 2 years. This report is based on the initial measurement of all panels and plots that make up a complete inventory. Ohio is now on a 5-year cycle with 20 percent of the plots measured each year. Going forward, new inventory estimates will be available each year using the most recent complete set of plots.

Figure 95.—FIA Phase 2 and Phase 3 plot design.



### Phase 3

More extensive forest health measurements are collected during a 10-week period in summer on a subset of Phase 2 sample plots. The measurements are grouped into five general categories of indicators: crown condition, understory vegetation, down woody material, soil condition, and lichen communities. The intensity of the Phase 3 plots is one plot per 96,000 acres of land. The relatively small number of Phase 3 samples does not allow for detailed analyses in some cases. For example, breaking down tree damage for a particular species by region reduces the number of samples and yields a high sampling error (SE).

#### Statistical significance

This report contains a wealth of statistical estimates that are compared over time and among numerous variables. Changes in estimates are discussed in terms of direction and magnitude. All mention of “significant” changes are based on comparing 67-percent confidence intervals for the various estimates. If confidence intervals overlap, there has been no real change in a statistical sense. When confidence intervals do not overlap, significant change has occurred.

## **National Woodland Owner Survey**

The National Woodland Owner survey ([www.fia.fs.fed.us/nwos](http://www.fia.fs.fed.us/nwos)) is conducted annually by the Forest Service to increase our understanding of private woodland owners—the critical link between society and forests. Each year, questionnaires are mailed to individuals and private groups who own the woodlands where FIA has established inventory plots (Butler et al. 2005). About 6,000 owners are contacted each year. Results in Ohio are based on 225 responses received during 2002-2006.

## **Timber Products Inventory**

The timber products inventory study was a cooperative effort between the Ohio Department of Natural Resources-Division of Forestry and the Northern Research Station. The study canvassed all primary wood-using mills within the State using mail questionnaires designed to determine the size and composition of Ohio's primary wood-using industry, its use of roundwood, and its generation and disposition of wood residues. Division of Forestry personnel contacted nonresponding mills through additional mailings, telephone calls, and personal contacts. Estimates were made for a small number of mills that refused all our attempts to obtain their responses. Data on Ohio's industrial roundwood receipts have been added to a regional timber removals database and supplemented with data on out-of-state uses of State roundwood to provide a complete assessment of Ohio's timber product output.

# Glossary

**Average annual mortality of growing stock:** The average cubic foot volume of sound wood in growing-stock trees that died in one year.

**Average annual net growth of growing stock:** The annual change in cubic foot volume of sound wood in live sawtimber and poletimber trees, and the total volume of trees entering these classes through ingrowth, less volume losses resulting from natural causes.

**Average annual removals from growing stock:** The average net growing-stock volume in growing-stock trees removed annually for roundwood forest products, in addition to the volume of logging residues and the volume of other removals due to land use change.

**Basal area:** Tree area in square feet of the cross section at breast height of a single tree. When the basal areas of all trees in a stand are summed, the result is usually expressed as square feet of basal area per acre.

**Bulk density:** The mass of soil per unit volume. A measure of the ratio of pore space to solid materials in a given soil. Expressed in units of grams per cubic centimeter of oven dry soil.

**Commercial species:** Tree species suitable for industrial wood products.

**Compacted live crown ratio:** The percent of the total length of the tree that supports a full, live crown. For trees that have uneven length crowns, lower branches should be transferred ocularly to fill holes in the upper portions of the crown, until a full, even crown is created.

**Crown dieback:** Recent mortality of branches with fine twigs, which begins at the terminal portion of a branch and proceeds toward the trunk. Dieback is considered only when it occurs in the upper and outer portions of

the tree. When whole branches are dead in the upper crown, without obvious signs of damage such as breaks or animal injury, the branches are assumed to have died from the terminal portion of the branch. Dead branches in the lower portion of the live crown are assumed to have died from competition and shading. Dead branches in the lower live crown are not considered part of crown dieback, unless there is continuous dieback from the upper and outer crown down to those branches.

**Cull tree:** Live trees that are unsuitable for the production of some roundwood products, now or prospectively. Cull trees can include those with decay (rotten cull) or poor form, many limbs, or splits (rough cull). Rough cull is suitable for pulpwood and other fiber products.

**Decay class:** Qualitative assessment of stage of decay (5 classes) of coarse woody debris based on visual assessments of color of wood, presence/absence of twigs and branches, texture of rotten portions, and structural integrity.

**Diameter class:** A classification of trees based on diameter outside bark, measured at breast height (d.b.h.) 4.5 feet (1.37 m) above the ground. Note: Diameter classes are commonly in 2-inch (5 cm) increments, beginning with 2 inches (5 cm). Each class provides a range of values with the class name being the approximate mid-point. For example, the 6-inch class (15-cm class) includes trees 5.0 through 6.9 inches (12.7 through 17.5 cm) d.b.h., inclusive.

**Down woody material (DWM):** DWM, previously named down woody debris (DWD), is dead material on the ground in various stages of decay. It includes coarse and fine wood material. Also measured as part of the DWM indicator for FIA are the depth of duff layer, litter layer, and overall fuelbed; fuel loading on the microplot; and residue piles.

**Duff:** A soil layer dominated by organic material derived from the decomposition of plant and animal litter and deposited on either an organic or a mineral surface. This layer is distinguished from the litter layer in that the original organic material has undergone sufficient decomposition that the source of this material (e.g., individual plant parts) can no longer be identified.

**Effective Cation Exchange Capacity (ECEC):** The sum of cations that a soil can adsorb in its natural pH. Expressed in units of centimoles of positive charge per kilogram of soil.

**Federal land:** An ownership class of public lands owned by the U.S. Government.

**Fiber products:** Products derived from wood and bark residues, such as pulp, composition board products, and wood chips for export.

**Fine woody debris (FWD):** Downed, dead branches, twigs, and small tree or shrub boles <3 inches (7.4 cm) in diameter not attached to a living or standing dead source.

**Forest industry land:** An ownership class of private lands held by a company or individual(s) operating a primary wood-processing plant.

**Forest land:** Land at least 10 percent stocked by forest trees of any size, or land formerly having such tree cover, and not currently developed for a nonforest use. The minimum area for classification as forest land is one acre. Roadside, streamside, and shelterbelt strips of timber must be at least 120 feet wide to qualify as forest land. Unimproved roads and trails, streams and other bodies of water, or natural clearings in forested areas are classified as forest, if less than 120 feet in width or one acre in size. Grazed woodlands, reverting fields, and pastures that are not actively maintained are included if the above qualifications are satisfied. Forest land includes three

subcategories: timberland, reserved forest land, and other forest land.

**Forest type:** A classification of forest land based upon and named for the tree species that forms the plurality of live-tree stocking.

**Forest-type group:** A combination of forest types that share closely associated species or site requirements.

**Major eastern forest-type groups:**

**White-red-jack pine:** Forests in which eastern white pine, red pine, or jack pine, singly or in combination, comprise a plurality of the stocking. Common associates include hemlock, aspen, birch, and maple.

**Oak-pine:** Forests in which hardwoods (usually upland oaks) comprise a plurality of the stocking, but in which pine or eastern redcedar comprises 25-50 percent of the stocking. Common associates include gum, hickory, and yellow-poplar.

**Oak-hickory:** Forests in which upland oaks or hickory, singly or in combination, comprise a plurality of the stocking except where pines comprise 25-50 percent, in which case the stand is classified as oak-pine. Common associates include yellow-poplar, elm, maple, and black walnut.

**Oak-gum-cypress:** Bottomland forests in which tupelo, blackgum, sweetgum, oaks, or southern cypress, singly or in combination, comprise a plurality of the stocking except where pines comprise 25-50 percent, in which case the stand is classified as oak-pine. Common associates include cottonwood, willow, ash, elm, hackberry, and maple.

**Elm-ash-cottonwood:** Forests in which elm, ash, or cottonwood, singly or in combination,

comprise a plurality of the stocking. Common associates include willow, sycamore, beech, and maple.

**Northern hardwoods (also called maple-beech-birch):** Forests in which maple, beech, or yellow birch, singly or in combination, comprise a plurality of the stocking. Common associates include hemlock, elm, basswood, and white pine.

**Aspen-birch:** Forests in which aspen, balsam poplar, paper birch, or gray birch, singly or in combination, comprise a plurality of the stocking. Common associates include maple and balsam fir.

**Growing-stock tree:** All live trees 5.0 inches (12.7 cm) in d.b.h. or larger that meet (now or prospectively) regional merchantability requirements in terms of saw log length, grade, and cull deductions. Excludes rough and rotten cull trees.

**Hardwood:** Tree species belonging to the botanical subdivision Angiospermae, class Dicotyledonous, usually broad-leaved and deciduous.

**Industrial wood:** All roundwood products, except firewood.

**Land:** The area of dry land and land temporarily or partly covered by water, such as marshes, swamps, and river flood plains.

**Litter:** Undecomposed or only partially decomposed organic material that can be readily identified (e.g., plant leaves, twigs).

**Live cull:** A classification that includes live cull trees. When associated with volume, it is the net volume in live cull trees that are 5.0 inches in d.b.h. and larger.

**Logging residues:** The unused portions of trees cut or destroyed during harvest and left in the woods.

**National forest:** An ownership class of Federal lands, designated by Executive order or statute as national forests or purchase units, and other lands under the administration of the Forest Service including experimental areas.

**Net volume in cubic feet:** The gross volume in cubic feet less deductions for rot, roughness, and poor form. Volume is computed for the central stem from a 1-foot stump to a minimum 4.0-inch top diameter outside bark, or to the point where the central stem breaks into limbs.

**Noncommercial species:** Tree species of typically small size, poor form, or inferior quality, which normally do not develop into trees suitable for industrial wood products.

**Nonforest land:** Land that does not support, or has never supported, forests and lands formerly forested where use of timber management is precluded by development for other uses. Includes areas used for crops, improved pasture, residential areas, city parks, improved roads of any width and adjoining rights-of-way, powerline clearings of any width, and noncensus water. If intermingled in forest areas, unimproved roads and nonforest strips must be more than 120 feet (36.6 m) wide, and clearings, etc., must be more than one acre (0.4 ha) in size to qualify as nonforest land.

**Nonstocked areas:** Timberland less than 10 percent stocked with all live trees.

**Other red oaks:** A group of species in the genus *Quercus* that includes scarlet oak, northern pin oak, southern red oak, shingle oak, laurel oak, blackjack oak, water oak, pin oak, willow oak, and black oak.

**Ownership:** A legal entity having an ownership interest in land regardless of the number of people involved. An ownership may be an individual; a combination of persons; a legal entity such as a corporation, partnership,

club, or trust; or a public agency. An ownership has control of a parcel or group of parcels of land.

**Poletimber trees:** Live trees at least 5.0 inches in d.b.h., but smaller than sawtimber trees.

**Primary wood-using mill:** A mill that converts roundwood products into other wood products. Common examples are sawmills that convert saw logs into lumber and pulpmills that convert pulpwood into wood pulp.

**Productivity class:** A classification of forest land in terms of potential annual cubic-foot volume growth per acre at culmination of mean annual increment in fully stocked natural stands.

**Pulpwood:** Roundwood, whole-tree chips, or wood residues used for the production of wood pulp.

**Reserved forest land:** Land permanently reserved from wood products utilization through statute or administrative designation. Examples include national forest wilderness areas and national parks and monuments.

**Residues:** Bark and woody materials that are generated in primary wood-using mills when roundwood products are converted to other products. Examples are slabs, edgings, trimmings, miscuts, sawdust, shavings, veneer cores and clippings, and pulp screenings. Includes bark residues and wood residues (both coarse and fine materials) but excludes logging residues.

**Rotten tree:** A live tree of commercial species that does not contain a saw log now or prospectively primarily because of rot (that is, when rot accounts for more than 50 percent of the total cull volume).

**Rough tree:** (a) A live tree of commercial species that does not contain a saw log now or prospectively primarily

because of roughness (that is, when sound cull due to such factors as poor form, splits, or cracks accounts for more than 50 percent of the total cull volume) or (b) a live tree of noncommercial species.

**Roundwood products:** Logs, bolts, or other round timber generated from harvesting trees for industrial or consumer uses. Includes saw logs; veneer and cooperage logs and bolts; pulpwood; fuelwood; pilings; poles; posts; hewn ties; mine timbers; and various other round, split, or hewn products.

**Salvable dead tree:** A downed or standing dead tree considered currently or potentially merchantable by regional standards.

**Saplings:** Live trees 1.0 to 4.9 inches (2.5 to 12.5 cm) in diameter (d.b.h./d.r.c.).

**Saw log:** A log meeting minimum standards of diameter, length, and defect, including logs at least 8 feet long, sound and straight, and with a minimum diameter inside bark of 6 inches for softwoods and 8 inches for hardwoods, or meeting other combinations of size and defect specified by regional standards.

**Sawtimber tree:** A live tree of commercial species containing at least a 12-foot saw log or two noncontiguous saw logs 8 feet or longer and meeting regional specifications for freedom from defect. Softwoods must be at least 9.0 inches in d.b.h. Hardwoods must be at least 11.0 inches in diameter outside bark (d.o.b.).

**Sawtimber volume:** Net volume of the saw log portion of live sawtimber in board feet, International 1/4-inch rule (unless specified otherwise), from stump to a minimum 7.0-inch top d.o.b. for softwoods and a minimum 9.0-inch top d.o.b. for hardwoods.

**Seedlings:** Live trees smaller than 1.0 inch (2.5 cm) in d.b.h./d.r.c. that are at least 6 inches (15.2 cm) in height

for softwoods and 12 inches (30.5 cm) in height for hardwoods.

**Site index:** The average total height that dominant and codominant trees in fully stocked, even-aged stands will obtain at key ages (usually 25 or 50 years).

**Softwood:** A coniferous tree, usually evergreen, having needles or scale-like leaves.

**Stand:** A group of trees on a minimum of one acre of forest land that is stocked by forest trees of any size.

**Stand-size class:** A classification of forest land based on the size class of all live trees in the area. The classes include:

***Nonstocked:*** Forest land stocked with less than 10 percent of full stocking with all live trees. Examples are recently cutover areas or recently reverted agricultural fields.

***Seedling-sapling:*** Forest land stocked with at least 10 percent of full stocking with all live trees; half or more of such stocking is in seedlings or saplings or both.

***Poletimber:*** Forest land stocked with at least 10 percent of full stocking with all live trees; half or more of such stocking is in poletimber or sawtimber trees or both, and the stocking of poletimber exceeds that of sawtimber.

***Sawtimber:*** Forest land stocked with at least 10 percent of full stocking with all live trees; half or more of such stocking is in poletimber or sawtimber trees or both, and the stocking of sawtimber is at least equal to that of poletimber.

**State land:** An ownership class of public lands owned by states or lands leased by states for more than 50 years.

**Stocking:** At the tree level, stocking is the density value assigned to a sampled tree (usually in terms of basal area per acre), expressed as a percent of the total tree density required to fully utilize the growth potential of the land. At the stand level, stocking refers to the sum of the stocking values of all trees sampled.

**Timberland:** Forest land that is producing or is capable of producing crops of industrial wood and not withdrawn from timber utilization by statute or administrative regulation. (Note: Areas qualifying as timberland are capable of producing in excess of 20 cubic feet per acre per year of industrial wood in natural stands. Currently inaccessible and inoperable areas are included.)

**Timber products output:** All timber products cut from roundwood and byproducts of wood manufacturing plants. Roundwood products include logs, bolts, or other round sections cut from growing-stock trees, cull trees, salvable dead trees, trees on nonforest land, noncommercial species, sapling-size trees, and limbwood. Byproducts from primary manufacturing plants include slabs, edging, trimmings, miscuts, sawdust, shavings, veneer cores and clippings, and screenings of pulpmills that are used as pulpwood chips or other products.

**Tree size class:** A classification of trees based on diameter at breast height, including sawtimber trees, poletimber trees, saplings, and seedlings.

**Veneer log:** A roundwood product from which veneer is sliced or sawn and that usually meets certain standards of minimum diameter and length and maximum defect.

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Oak leaves; photo by Richard Widmann, U.S. Forest Service

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This report summarizes annual forest inventories conducted in Ohio from 2001 to 2006 by the Northern Research Station's Forest Inventory and Analysis unit. Ohio's forest land covers 7.9 million acres or 30 percent of the State's land area, changing little in forest land area since 1991. Of this land, 5.8 million acres (73 percent) are held by family forest owners. The current growing-stock inventory is 12.3 billion cubic feet—2 percent more than in 1991—and averages 1,603 cubic feet per acre. Yellow-poplar continues to lead in volume followed by red and sugar maples. Since 1991, the saw log portion of growing-stock volume has increased by 35 percent to 41 billion board feet. In the latest inventory, net growth exceeded removals for all major species except elm.

**KEY WORDS:** forest area, forest composition, timber volume, timber growth, timber removals, mortality, forest health, biomass, completed annual inventory

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