Ohio's Forests 2011

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Abstract

This report summarizes the second full cycle of annual inventories, 2007-2011, of Ohio's forests by the Forest Inventory and Analysis unit of the Northern Research Station in cooperation with the Ohio Department of Natural Resources, Division of Forestry. Since 2006, forest land increased by 2.1 percent and currently totals 8.1 million acres. Net volume of live trees on forest land increased by 7 percent totaling 15.9 billion cubic feet. Most stands are dominated by large trees, 66 percent are in sawtimber-size stands, although most stands are less than fully stocked with growing-stock trees. Annual growth outpaced removals by a ratio of 2.2:1. This report includes additional information on forest attributes, land-use change, carbon, and forest health. The included DVD contains 1) descriptive information on methods, statistics, and quality assurance of data collection, 2) a glossary of terms, 3) tables that summarize quality assurance, 4) a core set of tabular estimates for a variety of forest resources, and 5) a Microsoft Access database that represents an archive of data used in this report, with tools that allow users to produce customized estimates.

Acknowledgments

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Foreword

Ohio's forests provide us with many ecological, economic and social benefits and services. The ecological value of forests is demonstrated by the rich biodiversity they support, including 350 species of terrestrial wildlife and more than 500 species of plants, and forests play a critical role in maintaining quality aquatic habitat. They also provide significant economic benefits. Ohio ranks in the top 10 nationally for economic production from manufacturing of furniture and related products, and we are also a top 10 state for production of maple syrup, ginseng and Christmas trees. In 2010, Ohio's forest products industry contributed more than an estimated $22 billion to Ohio's economy and employed 118,000 people.

Forests provide many additional benefits that may not have a dollar amount assigned to them, such as providing recreational opportunities, increasing the quality of urban life and improving air and water quality. The Ohio Department of Natural Resources (ODNR) Division of Forestry strives daily to maintain these benefits through its mission of promoting and applying management for the sustainable use and protection of Ohio's private and public forests.

To achieve this mission and continue forest benefits into the future, we need to understand the current status of Ohio's forests and how they are changing over time. That need is met by this report, which is prepared every 5 years by the U.S. Forest Service, Forest Inventory and Analysis Program, in partnership with the ODNR Division of Forestry.

Some of the report's findings are encouraging for future forest benefits, including a net increase in forest land area statewide and the continuation of the decades-long trend of net annual growth in total tree volume. The report also highlights issues of concern, such as a shift in tree species composition away from oaks and emerging forest health threats like thousand cankers disease. This information on trends and issues is invaluable to natural resource managers as it leads to informed, science-based decisions that will help sustain Ohio's forests and their many benefits now and into the future.

Robert L. Boyles
State Forester and Chief
Ohio Department of Natural Resources Division of Forestry

Contents

Highlights

On the Plus Side

- Ohio's forests have doubled in area since the 1942 inventory totaling 8.1 million acres and covering 31 percent of the State's land area.
- Across the State, losses of forest land due to development have been more than offset by gains in forest land because of idle farm land reverting to forest. The 2011 inventory showed that forest land area increased by 169,000 acres (2.1 percent) since 2006.
- Public ownership of forest land has steadily increased, tripling since 1968. Publicly-owned forests now total 1.1 million acres or 14 percent of the State's forest land.
- Seven million acres (86 percent) of forest land in Ohio is privately owned. An estimated 336,000 family forest owners hold 5.8 million acres across the State.
- Stands have continued to shift to the sawtimber (large diameter) size class. In 2011, two-thirds of forest land in the State was in sawtimber-size stands representing 5.3 million acres.
- Since 2006, stocking levels have continued to shift toward fully stocked and overstocked levels. In Ohio, 3.6 million acres (44 percent) of forest are fully stocked or overstocked with live trees.
- Seventy-three percent of the live sound wood volume is categorized as growing-stock volume, amounting to 13.7 billion cubic feet.
- Since 1968, the net volume of live trees on timberland has steadily increased to 15.9 billion cubic feet, a 7 percent increase since 2006.
- The most recent inventory shows that since 2006, volume has increased in all diameter classes 12 inches and larger, while volume decreased in the 6-, 8-, and 10-inch classes.
- Red maple continues to lead in volume, followed by yellow-poplar and sugar maple.
- The sawtimber volume on timberland increased by 6 percent to 50.8 billion board feet. Yellow-poplar is the leading sawtimber species, by volume, followed by hickory, red maple, ash, and white oak.
- Ohio's forests are accumulating substantial biomass. Aboveground biomass of all live trees in Ohio's forests equals 417 million dry tons and averages 59 tons per acre.
- Components of annual change as a percentage of the current inventory were as follows: gross growth at 4.1 percent, mortality 1.1 percent, net growth 2.9 percent, and removals were 1.3 percent. These result in a net change in total volume of 1.6 percent annually.
- Statewide, the ratio of total growth-to-removals (G/R) averaged 2.2:1 from 2006 to 2011.
- Of the top species in Ohio, red maple and sugar maple had the largest G/R, 3.8:1 and 3.9:1, respectively.
- The 1.1 percent annual mortality rate in Ohio is similar to that in the neighboring states of Indiana (1.1 percent), Kentucky (1.0 percent), Pennsylvania (0.9 percent) and West Virginia (0.9 percent).

Forest at Caesar Creek State Park, Warren County, in southwestern Ohio. Photo by Ohio Department of Natural Resources, used with permission.

Issues to Watch

- Ohio's forests are being affected by urbanization and fragmentation; 20 percent of forest area is potentially affected by house densities greater than 15.5 per square mile, 59 percent is within 295 feet of an agricultural or developed edge, and 44 percent is within 650 feet from a road.

- 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, since idle farm land has been the source of much of the increase in forest land. Recently farm land prices have increased, indicating that losses in farmland will likely slow or reverse. Increasing farmland values could also shift more development pressure to forest land, since much of Ohio's forest land is in close proximity to urban and suburban areas.

- The 2.5 million acres (30 percent) of forest land that are poorly stocked or nonstocked with commercially important species represents a loss of potential growth, because trees are either widely spaced or low value trees occupy growing space that could otherwise be used to grow quality timber.

- In the current inventory, oaks represent more than 35 percent of the trees 20 inches and larger in diameter, but only 5 percent of trees in the 2- and 4-inch diameter classes. 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—7 percent of trees 20-inches diameter breast height (d.b.h.) and larger.

- The lack of recruitment of oaks into large diameter classes is changing the composition of the timber resource away from the oaks toward maples and other non-oak species.

- Currently, nearly a quarter of Ohio's sound wood volume on forest land is in low value trees. Nine percent is in the cull portion of growing-stock trees and 15 percent in rough and rotten trees on timberland.

- Ozone damage on indicator plants in Ohio has dropped substantially since 2001, based on monitoring protocols, even though Ohio is located in areas of medium and high risk to ozone exposure.

- Invasive plant species were detected on 93.2 percent of inventory plots. The data suggest that these plants are present throughout the State and have become widespread.

- Emerald ash borer is causing significant financial costs to municipalities, property owners, and the forest products industries. During the period 2008-2011, annual ash mortality averaged 1.9 million trees (2 percent), for trees 5-inches d.b.h. and larger.

- Thousand cankers disease has been found in Ohio. This disease infects and kills walnut and butternut trees. Because walnut is a high value species, it is important for landowners to monitor black walnut stands for its presence. A quarantine is in effect to prevent the spread of thousand cankers disease in the State.

An Overview of Forest Inventory

Tar Hollow State Forest, Hocking County, Ohio. Photo by Ohio Department of Natural Resources, used with permission.

What is a tree?

Trees are perennial woody plants with central stems and distinct crowns. In general, the Forest Inventory and Analysis (FIA) program defines a tree as any perennial woody plant species that can attain a height of 15 feet at maturity. A problem is deciding which species should be classified as shrubs and which should be classified as trees. A complete list of the tree species measured during this inventory is included in Statistics, Methods, and Quality Assurance found on the DVD in the back of this publication. Throughout this report, the size of a tree is expressed in diameter at breast height (d.b.h.), in inches. This is the diameter, outside bark, at a point 4.5 feet above ground.

What is a forest?

FIA defines forest land as land that is at least 10-percent stocked with trees of any size or formerly having had such tree cover and not currently developed for nonforest use (see Stocking). In general, the minimum area for classification must be at least 1 acre in size and 120 feet in width. There are more specific area criteria for defining forest land near streams, rights-of-way, and shelterbelt strips (U.S. For. Serv. 2010).

What is the difference between timberland, reserved forest land, and other forest land?

FIA defines three types of forest land:

- Timberland—forest land that is producing or is capable of producing crops of industrial wood and is not withdrawn from timber utilization by statute or administrative regulation. These areas are capable of producing in excess of 20 cubic feet per acre per year of industrial wood in natural stands. Inaccessible and inoperable areas are included.
- Reserved forest land is all forest land that is withdrawn from timber utilization through statute without regard to productive status, e.g., some natural areas in state parks, national parks, and Federal wilderness areas.
- Other forest land consist of forest land that is not capable of growing 20 cubic feet per acre (equivalent to about ¼ cord) per year and is not restricted from harvesting, e.g., some surface-mined areas with extremely degraded soil and some poorly drained areas where water inhibits tree growth. Sometimes such forest lands are referred to as being “less productive” or “unproductive” with respect to wood fiber production.

Prior to the 2001-2006 inventory cycle in Ohio, for most attributes, FIA only included data collected on timberland plots in reports and databases. As a result, trend analyses that use data prior to 2001 are limited to timberland for many attributes. Since 2001, the new annual inventory design allows us to report volumes on all forest land. We have one set of remeasured plots across all forest land with associated estimates of growth, removals, and mortality. In this report, most trend analyses focus on changes on forest land since 2006.

How do we estimate a tree’s volume?

To estimate volume, FIA uses several volume equations that have been developed at the Northern Research Station for each tree species found within the region. Models have been developed from regression analysis to predict volumes within a species group. We produce individual tree volumes based upon species, diameter, and total height. FIA expresses volume in cubic and board feet (International ¼-inch rule). Board foot volume measurements are only applicable for sawtimber-size trees. In Ohio, wood often is measured in cords (a stack of wood 8 feet long by 4 feet wide and 4 feet high). A cord of wood consists of about 79 to 85 cubic feet of solid wood and the remaining 43 to 49 cubic feet bark and air.

How much does a tree weigh?

The U.S. Forest Service’s Forest Products Laboratory developed estimates of specific gravity for a number of tree species (U.S. For. Serv. 1999). These specific gravities are applied to estimates of tree volume to estimate the biomass of merchantable trees (weight of the bole). Regression models are used to estimate the biomass of stumps (Raile 1982), limbs, and bark (Hahn 1984), and belowground stump and coarse roots (Jenkins et al. 2004). Currently, FIA does not report the biomass of foliage. FIA can report biomass as green or oven-dry weight. Green weight is the weight of a freshly cut tree. Ovendry weight is the weight of a tree with no moisture content and used to measure biomass in this report. On average, 1.9 tons (2,000 pounds/ton) of green biomass equals 1 ton of oven-dry biomass.

How can I analyze FIA data?

In the past, FIA inventories were completed every 10 to 20 years. With these periodic inventories, it took decades to identify trends. With the new annual inventory, some trends will be easier to identify because a subset of observations (approximately 20 percent) are made every year. It is still necessary to look over long time periods because many trends like succession can be difficult to discern in short time spans. Definitions, methods, location, ownership, precision, scale, and temporal trends are important factors to consider when analyzing FIA data. Estimates are derived from sample plots throughout a state. Larger areas of interest will contain more plots and thus produce more reliable estimates. For example, there usually are not a sufficient number of plots within a county or single forest type with which to provide reliable estimates. It also is important to consider the degree to which a variable can be measured precisely. For instance, a stand variable like age is not as precise as forest type and a tree variable like crown dieback is not as precise as diameter. Location and ownership also are important considerations when analyzing the status and trends of forests. Forest resources vary by geographic unit and ownership group.

Definitions and procedures have changed among inventories. As an example, stocking estimates prior to the 2001used a different stocking algorithm then what is currently used. Since 2006, field crews have changed how they applied rules to determine minimum growing-stock standards. As a result many trees that were previously classified as growing stock in the 2006 inventory cycle were reclassified as cull during the 2011 inventory. Because of this change in field procedure many analyses in this report compare estimates of live volume of all trees which is unaffected by this change. Comparisons of current growing-stock volume to previous estimates should be made with caution.

Sampling error—what is significant?

We measured approximately one plot for every 6,122 acres of land, noncensus water, and inland census water (Great Lakes excluded). Sampling errors are associated with the estimates. The sampling error represents one standard error, which is a 68-percent confidence interval. For instance, the estimate of forest land in Ohio is 8.09 million acres with a sampling error of ± 1.1 percent resulting in a range from 7.99 to 8.18 million acres. If the entire population were known, the odds are 2 to 1 (68-percent chance) that the area of forest land would be 7.99 to 8.18 million acres. Error bars shown in figures in this report use one standard error to represent the uncertainty in the estimates. We often try to determine whether there are statistically significant differences among estimates. Throughout this report, any statement indicating a significant difference means that the ranges of the estimates do not overlap based on one standard error for the level of uncertainty. For example, the estimate of total live volume for the State in 2006 ranged from 15.1 to 15.6 billion cubic feet at one standard error and the estimate for 2011 ranges from 16.1 to 16.7 billion cubic feet at one standard error. Since these ranges do not overlap, we can conclude that there was significantly more volume in 2011 than in 2006.

Comparing data from different inventories

The annual inventory measures a subset of observations (approximately 20 percent) every year. After 5 years of data collection, an analysis and report are created based on the full set, or "cycle" of plots. This creates a yearly moving window of 5-year cycles. The last year of each full cycle is used to identify the full set of plots. For example, the cycle of plots measured from 2007 through 2011 are collectively labeled the "2011 inventory" and were used to produce this 2011 report. Previous inventories of Ohio's forest resources were completed for 1952 (Hutchison and Morgan 1956), 1968 (Kingsley and Mayer 1970), 1979 (Dennis and Birch 1981), 1991 (Griffith et al. 1993), and 2006 (Widmann et al. 2009).

To improve the consistency, efficiency, and reliability of the inventory, updates have been implemented overtime. Major changes occurred with the annual inventory that started in 1999. For the sake of consistency, a new, national plot design was implemented by all five regional FIA units in 1999 (see Statistics, Methods, and Quality Assurance). Prior to this new plot design, fixed and variable-radius subplots were used in the 1979 and 1991 inventories. The new design uses fixed-radius subplots exclusively. Both designs have strong points but they often produce different classifications for individual plot characteristics. Unpublished FIA research comparing these plot designs showed no noticeable difference in volume and tree-count estimates. Methods for determining stocking, forest type, and stand-size estimates were improved twice since the annual inventory started. All annual data were updated with the improvements to facilitate easier temporal analyses. There were fewer and less precise forest types assigned in the periodic inventories. For additional information, see National Algorithms for Determining Stocking Class, Stand-Size Class, and Forest Type for Forest Inventory and Analysis Plots (Arner et al. 2003). Estimates of net growth, mortality, and removals were updated after the 2006 inventory. Estimates for the 2011 inventory use the updated methods. Improvements were made to compensate for changes in site conditions (e.g., site index and basal area) and/or tree class (e.g., growing stock and cull). In addition, an increase in the sample size of ingrowth (trees reaching minimum sample size of 5 inches d.b.h.) improved precision.

A word of caution on harvest suitability and availability

This FIA definition of reserved forest land does not account for all forest land that is unsuitable or unavailable for timber harvesting. FIA does not identify timberland withheld from timber utilization or timberland that is not suitable or accessible for timber harvesting. It would be difficult to identify and maintain an up-to-date list of all lands withheld and not suitable or accessible for timber harvesting due to changing laws, owner objectives, markets, and site conditions. Many factors make timberland unsuitable or unavailable for timber harvesting. For example, operability on some sites is poor, e.g., wet or steep, and there are limitations related to wildlife. Threatened or endangered species habitat and old-growth areas may be subject to harvest restrictions. Some landlocked locations maybe denied access and the cost of entering some sites is prohibitive. There also are visually sensitive areas where aesthetics outweigh gains from harvests. FIA includes variables such as slope, physiographic class, and disturbance class that could help identify some lands with timber harvest constraints. It is difficult to determine the availability of wood from private land. Many private land owners do not consider harvesting timber as an option for their timberland. The National Woodland Owner Survey (NWOS) conducted by FIA, quantifies private land owners management objects and attitudes toward timber harvesting. These data are useful in assessing how much timber is actually available for harvesting

Where can I find additional information?

Detailed information on forest inventory methods, data quality estimates, and important resource statistics can be found in Statistics, Methods, and Quality Assurance found on the DVD in the back of this publication. This DVD also contains most of the data used in this report accessible through the included software Evalidator (requires Microsoft Access). Some graphs and tables in the printed portion of this report show only a sample of the prominent categories and values available for summarizing data. Tables on the DVD have more categories; summary values and custom tables can be created with Evalidator. Definitions of tables and fields are available in the database user's manual (Woudenberg et al. 2010). The main web page for FIA is at http://www.fia.fs.fed.us/. From here there are resources such as publications (http://www.nrs.fs.fed.us/pubs/) and data and tools (http://www.fia.fs.fed.us/tools-data/default.asp and http://apps.fs.fed.us/fiadb-downloads/datamart.html). A primary web tool is FIDO or Forest Inventory Data Online (http://apps.fs.fed.us/fido/). Other tools including a web version of Evalidator also are available (http://fia.fs.fed.us/tools-data/ other/default.asp). Field guides are at http://www.fia.fs.fed.us/library/field-guides-methods-proc/. State-level reports are available at http://nrs.fs.fed.us/fia/data-tools/state-reports/default.asp. In addition to both the past and current annual reports, this site has supporting tables and other up-to-date information for each state.

Introduction

Mohican State Forest, Ashland County, Ohio. Photo by Ohio Department of Natural Resources, used with permission.

Introduction

This report summarizes Ohio's second cycle of annual forest inventory covering the years 2007 through 2011. The completion of this cycle provided the Northern Research Station's Forest Inventory and Analysis Program (NRS-FIA or FIA) with the opportunity to remeasure plots from the first annual inventory cycle (2001-2006, Widmann et al. 2009). Estimates of average annual change (growth, mortality, and removals) were generated by remeasuring plots from the first cycle.

FIA groups contiguous counties that have similar forest cover, soil, and economic conditions into geographic units. Ohio is subdivided into six geographic units (Fig. 1). Estimates of area and volume are more accurate

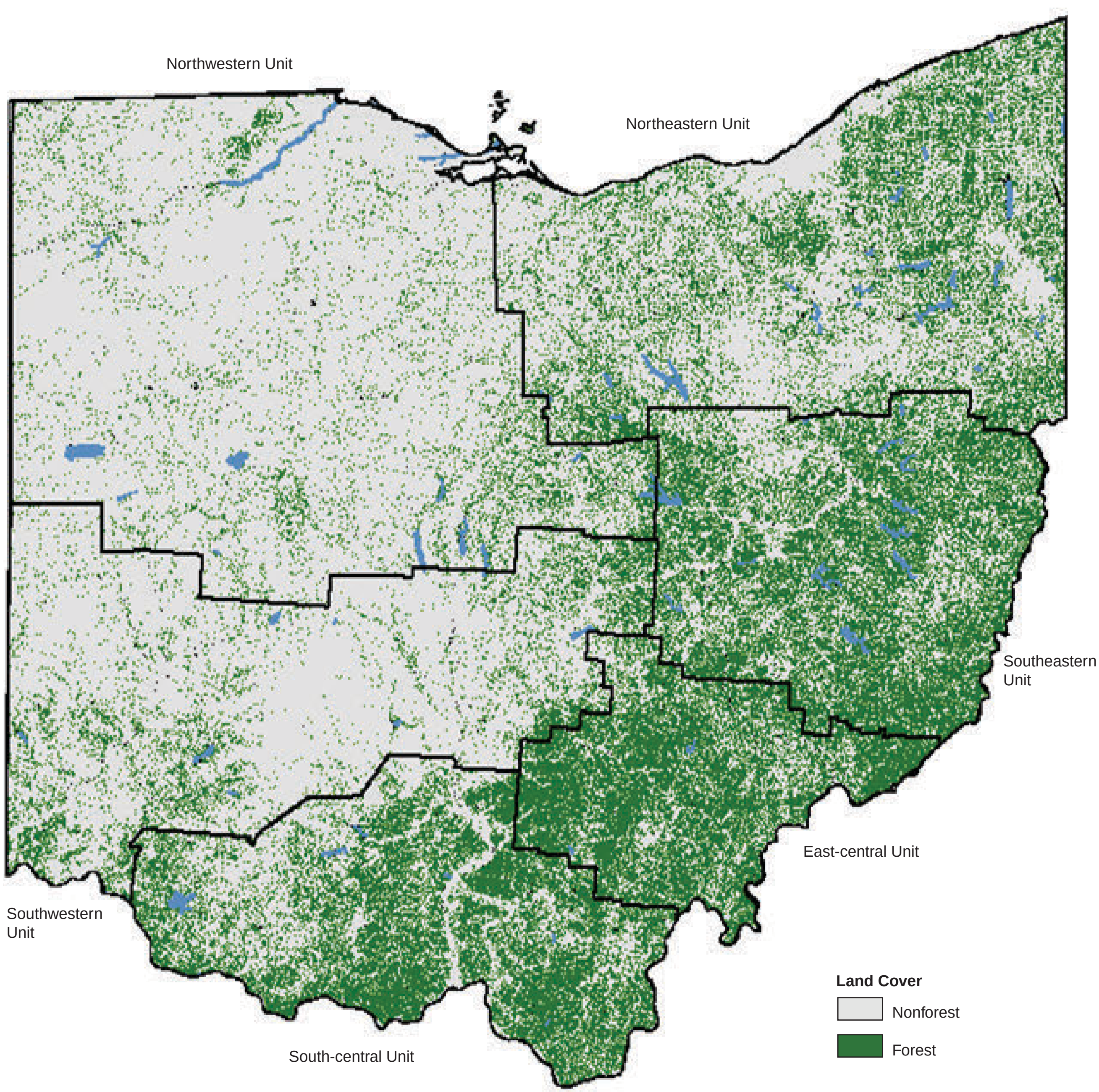


Figure 1.—Forest cover by geographic division, referred to as "units" used by Forest Inventory and Analysis program, Ohio, 2011. Forest cover was derived by linking plot data to MODIS satellite pixels (250 m) which utilizes gradient nearest neighbor techniques (Wilson et al. 2012).

at the unit level than at the individual county level. This is because of the larger number of plots used to make estimates at the unit level and because plots were stratified at the unit level into estimation units. Stratification at the unit level means that the area for each unit is set to a known value, usually taken from the U.S. Census Bureau, whereas the area for counties is determined by the distribution of plots. Because of this, most analysis in this report will be at the state or unit level. County level data are available but should be used with caution.

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 more uneven 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 Appalachian Mountains to the east. There is a close correlation between the amount of forest land and landscape relief. The flat Northwest is sparsely forested and the rugged Southeastern unit heavily forested.

History

Most of the forests in Ohio are in some stage of recovery from the impact of humans. At the time of settlement of Marietta in 1788, forests covered nearly 95 percent of the State. The remaining area was in poorly drained marshes or prairie vegetation maintained by fire. Over the next century and a half, forests were cleared for agriculture and development, and those areas that remained in forest were heavily cut over and subjected to frequent wildfires. In the 1930s, forest acreage was less than 4 million acres—only half of today's total. Timber volume averaged 2,500 board feet per acre, or less than half of current estimates. Since then, forest land acreage and timber volume have increased substantially as Ohio's forests have continued to recover. Concurrent with this recovery, Ohio's forests have continued to provide the raw materials needed by Ohio's forest products industry.

Although the condition of Ohio's forest land has steadily improved since 1942, there have been some setbacks. Starting with the chestnut blight (*Cryphonectria parasitica*) in the 1920s, the list of exotic insects and diseases found in Ohio continues to grow, with new additions becoming more frequent. In the 1970s, Dutch elm disease (*Ophiostoma ulmi*) devastated elms in the State. More recent forest health problems include the emerald ash borer (*Agrilus planipennis*), beech bark disease (*Neonectria faginata* or *ditissima*), gypsy moth caterpillar (*Lymantria dispar dispar*), hemlock woolly adelgid (*Adelges tsugae*), and thousand cankers disease (*Geosmithia morbida*) that infects black walnut (*Juglans nigra*). Many of these threats and other concerns are addressed in this report and make managing Ohio's future forests a continuing challenge.

Forest Land Features

Shawnee State Forest, Scioto County, in southern Ohio. Photo by Ohio Department of Natural Resources, used with permission.

Dynamics of the Forest Land Base

Background

The amount of forest land and timberland are vital measures for assessing forest resources and making informed decisions about their management and future. 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 amount of goods and services, including wood products, wildlife habitat, recreation, and watershed protection that forest can provide.

FIA broadly classifies forest land into three components that describe the potential of the land to grow timber products: reserved forest land, timberland, and other forest land. These categories help increase our understanding of the availability of forest resources and in forest management planning.

What we found

Ohio's forests have more than doubled in area since 1942 and now comprise 8.1million acres (Fig. 2) and represent 31 percent of the State's land (Fig. 3). Successive inventories have shown forest land area steadily increasing, although the most recent data show a slowing in this trend (2006 to 2011). The net increase of 169,000 acres (2.1 percent) since 2006 is just barely large enough to be statistically different from the 2006 estimate, although data from other sources showing decreases in farm land acreage supports this increase in forest land. In terms of gross change, plot data show both gains and losses in forest. Since 2006, 235,000 acres of forest land have been converted to nonforest land uses, and 404,000 acres of nonforest land have reverted to forest (Fig. 4).

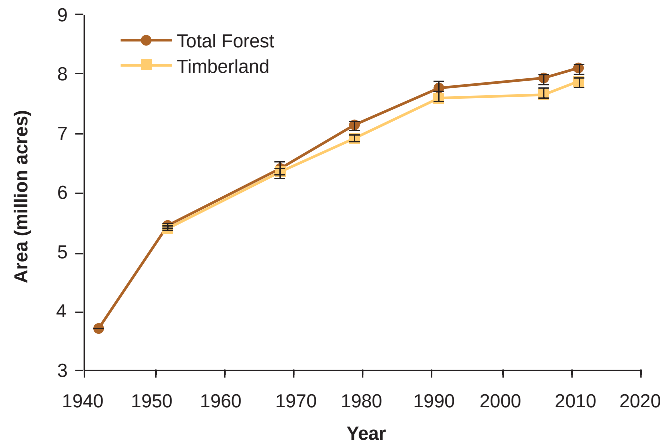


Figure 2.—Area of forest land and timberland in Ohio by inventory year, 1952, 1968, 1979, 2006, and 2011, and approximation of forest land area for 1942 (Kingsley and Mayer 1970). Error bars represent 67-percent confidence intervals around the estimated mean.

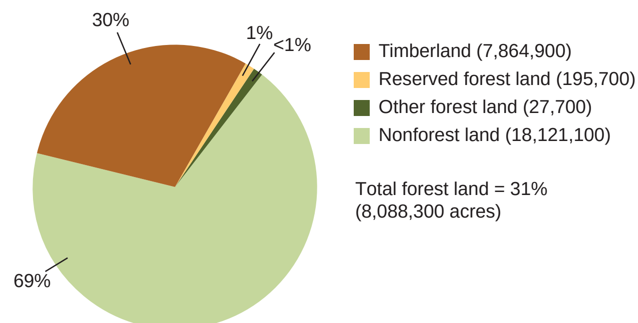


Figure 3.—Land area (acres) by major use, Ohio, 2011.

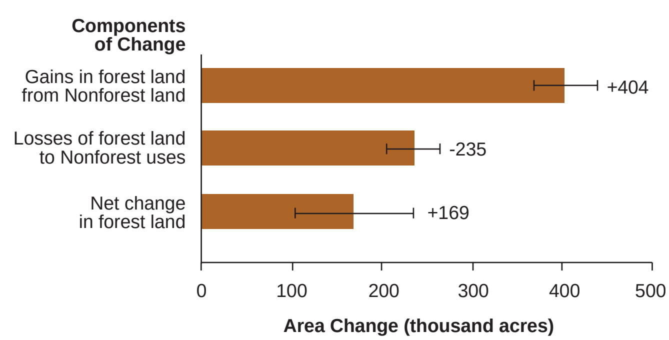


Figure 4.—Components of change in forest land, 2006-2011.

Increases in forest land have corresponded with decreases in farmland. Since 1950, the amount of land in farms has decreased by 8.1 million acres (includes farm woodlots; Fig. 5), while forest land has increased by 2.6 million acres. Although a large amount of farm land has been developed to meet the needs of a growing population, a substantial portion has also been left untended and has reverted to forest through natural succession.

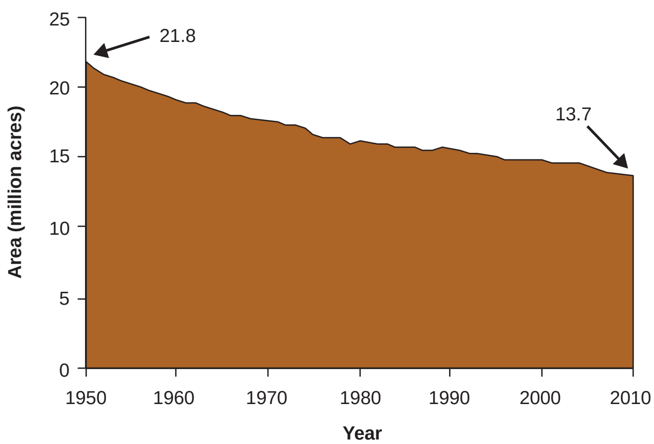


Figure 5.—Farm and agricultural acreage (including farm woodlots), Ohio, 1950-2011 (National Agriculture Statistics Service, n.d.).

The percentage of land in forest cover increases from northwest to southeast in Ohio (Fig. 6, and Fig. 7). The Northwestern Unit is the least forested portion of the State with only 10 percent of its land area in forest. This unit has lost 13 percent of its forest acreage since 1991. The East-central, Southeastern, and South-central Units are the most heavily forested portion of the State and account for nearly two-thirds of the State's forest land (Fig. 6). The South-central unit was the only other unit to show a loss since 1991. Other units experienced gains in forest land and account for the recent increase for the State.

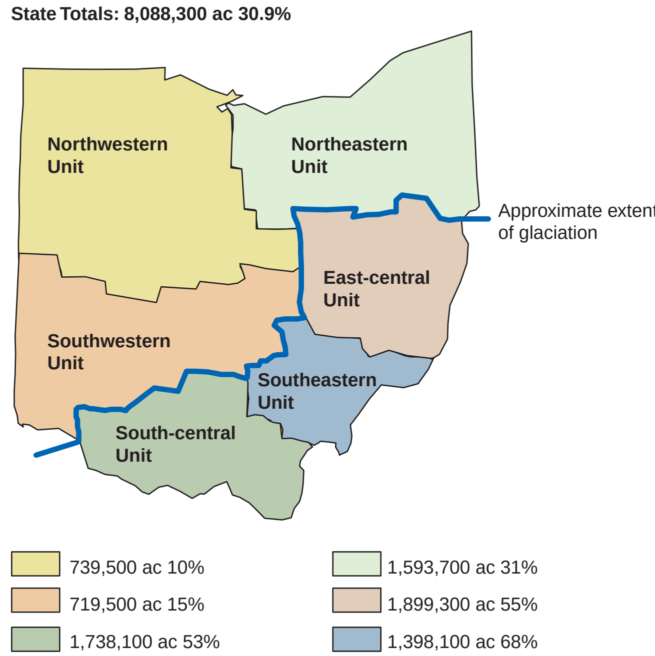


Figure 6.—Acreage of forest land and percentage of land in forest by FIA unit, Ohio, 2011.

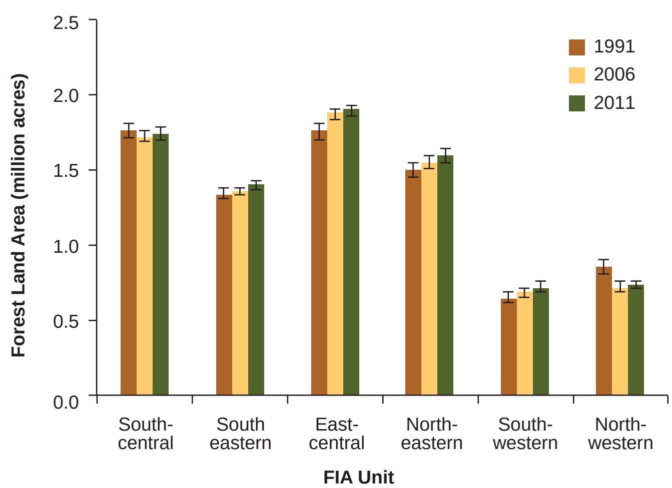


Figure 7.—Forest land area by FIA unit, Ohio, 1991, 2006, and 2011. Error bars represent 67-percent confidence intervals around the estimated mean.

Ohio's forests span two major watersheds. Fifteen percent of Ohio's forest acreage drains into Lake Erie and 85 percent into the Ohio River system. The Lake Erie drainage is 16 percent forested whereas the Ohio drainage is 37 percent forested.

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 idle farmland reverting to forest. Over the past 60 years, a side benefit of modern farming techniques is that nationally fewer acres are needed to grow crops. Because of increased development in Ohio 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 nearing a peak. 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, since idle farmland has been the source of much of the increase in forest land. Recently, farmland prices have increased indicating that losses in farmland will likely slow or reverse. Increasing farmland values could also shift more development pressure to forest land. Much of Ohio's forest land is in close proximity to urban areas and derives value from its potential to be developed for residential housing and other nonforest purposes. In Ohio, a small percentage change in the area of nonforest land can significantly affect forest land area, especially in sparsely forested areas like Ohio's Northwestern Unit.

Ownership of Forest Land

Background

How land is managed is primarily the owner's decision. Therefore, to a large extent, the availability and quality of forest resources are determined by landowners, including recreational opportunities, timber, and wildlife habitat. By understanding the priorities of forest land owners, leaders of the forestry and conservation communities can better help land owners meet their needs, and in so doing, help conserve the States forests for future generations. The National Woodland Owner Survey (NWOS) conducted by the Forest Service studies private forest landowners' attitudes, management objectives, and concerns (Butler 2008). The most dominant, diverse, and dynamic group of owners is the one we understand the least; that is families, individuals, and other unincorporated groups that we collectively refer to as "family forest owners."

What we found:

Public owners hold 1.1 million acres, or 14 percent of Ohio's forest land. The Federal Government holds 304,400 acres, or 4 percent of the forest land in the State (Fig. 8). Included in this are 241,300 acres of forest land in the Wayne National Forest. The State of Ohio holds 522,600 acres (6 percent) in various state agencies, including state parks and forests, and local governments hold 303,800 acres (4 percent). Public ownership of forest land has increased threefold since 1968.

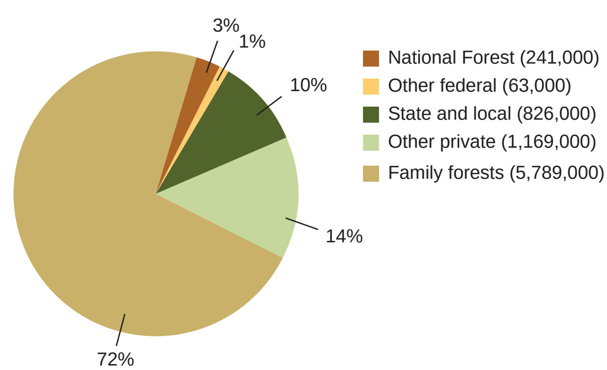


Figure 8.—Ownership of forest land (acres) by ownership category, Ohio, 2011.

Seven million acres (86 percent) of forest land in Ohio is privately owned (Butler 2008). Of these private acres, 5.8 million acres are owned by 336,000 family forest owners across the State. Fifty-eight percent of these owners have between 1 and 9 acres of forest land, another 41 percent of family forest acreage is in holdings of 10 and 49 acres (Fig. 9). During the period 1991-2006, 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, Butler 2008). The primary reasons for owning forest land are related to the forest land being part of a home site, privacy, aesthetics, nature protection, and family legacy (Fig. 10). Although timber production is not a major ownership objective, nearly a quarter of family forest owners have harvested trees in the last 5 years. As a group, family forest owners tend to be older, with 29 percent being at least 65 years old, while less than 14 percent are younger than 45.

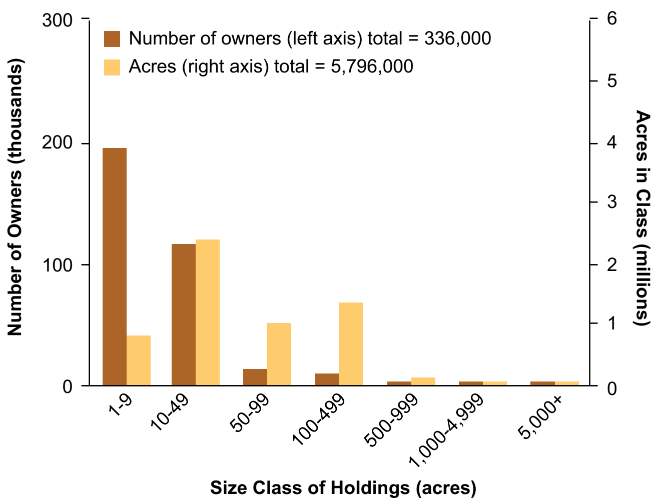


Figure 9.—Number of family forest owners and acres of forest land by size of forest land holdings, Ohio, 2006.

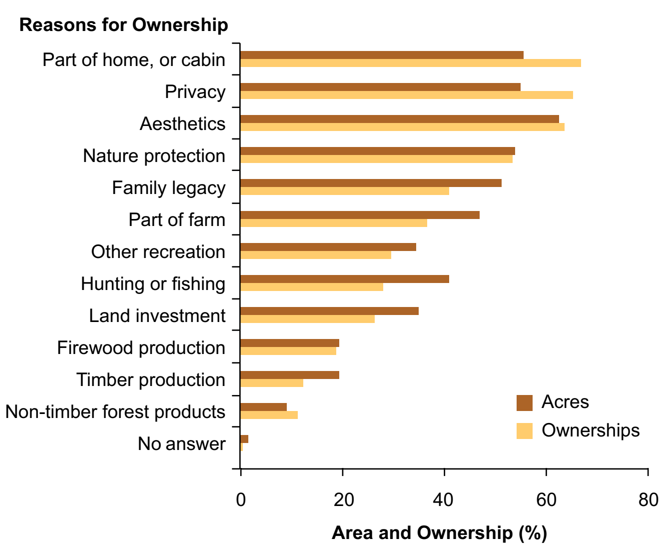


Figure 10.—Area forest land and the number of family forest owners (percent) in Ohio by reason for owning forest land, Ohio, 2006. (Note: Numbers include landowners who ranked each objective as very important or important on a seven-point Likert scale. Categories are not exclusive.)

What this means:

The average parcel size is decreasing and much land will soon be changing hands. Family legacy is a major ownership objective: passing land on is a major planned activity, but family legacy is also a major concern. Changes in forest land ownership is at a critical juncture. Forest land is at increased risk of parcelization and poor harvesting practices shortly before and after transfer of ownership. What can be done to help the landowners and the land? It is clear that timber production is not a priority in landowners' minds, but it is also clear that many landowners are not adverse to harvesting and other activities in their woods. How can natural resource professionals better communicate with family forest owners and help them better manage their woods? As Ohio's forest is diverse, so too are the people who own it. It is important to provide programs that meet the landowners' needs. General statistics are good for a broad overview, but a better understanding of the different types of owners, their attitudes, and their behaviors, as well as effective and efficient ways of communicating with them is needed (see www.engaginglandowners.org for additional information on types of landowners and tools for engaging them).

Urbanization and Fragmentation of Forest Land

Background

The expansion of urban lands that accompanies human population growth often results in the fragmentation of natural habitat (Wilcox and Murphy 1985). Forest fragmentation and habitat loss is recognized as a major threat to animal populations worldwide (Honnay et al. 2005, Rosenberg et al. 1999), particularly for species that require interior forest conditions for all or part of their life cycle (Donovan and Lamberson 2001) and for species that are wide-ranging, slow-moving, and/or slow-reproducing (Forman et al. 2003). Forest fragmentation can also affect forest ecosystem processes through changes in micro-climate conditions and tree species' migration in response to climate change (Iverson and Prasad 1998).

The spatial and physical fragmentation of habitats is only one of the human-induced processes affecting natural habitats and their biodiversity (Honnay et al. 2005). Urbanization increases the proximity of people and development to natural habitats and changes the ways in which people use those natural habitats. It can also lead to environmental/habitat deterioration, changes in hydrology, and the introduction of exotic species. In addition to the negative effects on ecosystems, the fragmentation and urbanization of forest land may have direct economic and social effects as well. For example, smaller patches of forest or those in more populated areas are less likely to be managed for forest products (e.g., Kline et al. 2004, Wear et al. 1999) and are more likely to be "posted" (i.e., not open for public use) (Butler et al. 2004), potentially affecting local forest industry, outdoor recreation opportunities, and local culture. Forest land is also a significant factor in the protection of surface waters and groundwater supplies, while fragmentation and urbanization of that forest land has been observed to affect both water quality and quantity (e.g., Hunsaker et al. 1992, McMahon and Cuffney 2000, Riva-Murray et al. 2010).

The metrics presented in this report relate to aspects of urbanization or fragmentation that are suspected of, or have been documented to have an effect on the forest, its management, or on its ability to provide ecosystem services and products (Riemann et al. 2008). These measures include forest edge versus interior, proximity to roads, patch size, human population density, and the extent of houses intermixed with forest. It is based on analysis of the Census 2010 (U.S. Census Bureau 2010) and National Land Cover Database (NLCD) 2006 data (Fry 2011) rather than FIA plot data, hence some of the numbers (such as percent forest) are not exactly equal to those reported based on FIA plot data.

Edge effects vary somewhat with distance from forest edge, depending on the type of edge and species of vegetation or wildlife, (e.g., Chen et al. 1992, Rosenberg et al. 1999, Flaspohler et al. 2001), but 100 to 300 feet is frequently used as a general range for the 'vanishing distance' or the distance into a patch where the edge effect disappears and interior forest conditions begin.

Roads have a variety of effects on the environment, including hydrologic, chemical (salt, lead, nutrients), sedimentary, and noise. Roads function as vectors for the introduction of invasive species, contribute to habitat fragmentation, and increase in human access; all of these factors impact forest ecosystem processes, wildlife movement and mortality, and the utilization of the surrounding area.

The impacts of roads diminish when distances range from about 650 feet for secondary roads (a rough estimate of a highly variable zone), to 1,000 feet for primary roads in or near forests (assuming 10,000 vehicles per day), and as high as 2,650 feet from roads in urban areas (50,000 vehicles per day) (Forman 2000).

Wildlife habitat requirements vary by species, but for reporting purposes it is often helpful to summarize forest-patch data, and edge-interior data using general guidelines. Many wildlife species prefer contiguous forest patches that are at least 100 acres. This "100 acre" patch area is often used as a minimum size that contains enough interior forest to be a source rather than a sink for populations of some wildlife species.

Higher human population densities are generally recognized as having negative effects on the viability and practice of commercial forestry (Barlow et al. 1998, Kline et al. 2004, Munn et al. 2002, Wear et al. 1999). Working in Virginia, Wear et al. (1999) identified a threshold of 150 people per square mile as that population density at which the probability of commercial forestry dropped to practically zero.

What We Found

Thirty-two percent of Ohio is forested, ranging from 10 percent in the Northwestern Unit to 70 percent in the Southeastern Unit (NLCD 2006). However, it is a fragmented forest: almost 29 percent is less than 98 feet from an agricultural or developed edge; another 30 percent is between 99 to 295 feet from an edge; while 41 percent of the forest qualifying as interior forest greater than 295 feet from an edge (Fig. 11). Within Ohio, the percent interior forest ranges from only 14 percent in the heavily agricultural Northwestern Unit to 54 percent in the South-central Unit (Table 1).

Roads are pervasive throughout the State and the proximity of forests to roads is great. Forty-four percent of the forest land is within 650 feet of a road and 77 percent is within 1310 feet. Only, 23 percent of the forest land is greater than 1310 feet from a road (Fig. 12). As both Forman (2000) and Riitters and Wickham (2003) report, roads can be quite extensive, even in areas that appear to be continuous forest land from the air. Forests in the agricultural Northwestern Unit average the greatest distance from roads (Table 1) compared to other parts of the State.

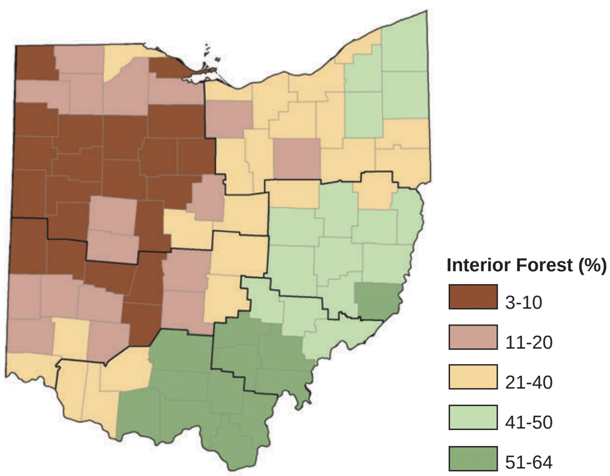


Figure 11.—Percentage of forest land in each county greater than 295 feet from an agricultural or developed land use (i.e., "interior" forest), Ohio, 2006.

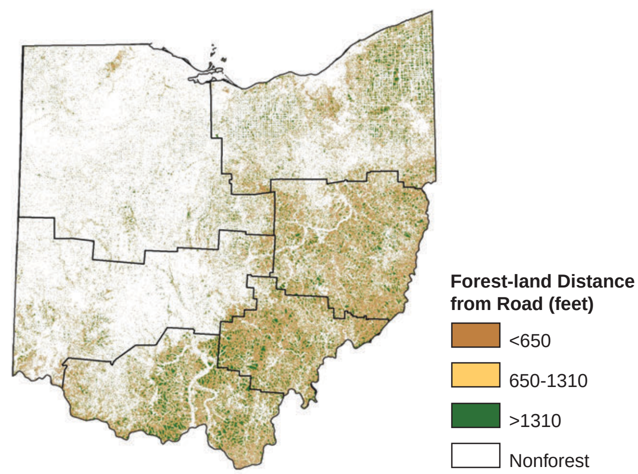


Figure 12.—Forest land distance to nearest road, Ohio, 2006.

Table 1.—The distribution of forest land by urbanization and fragmentation measures, expressed as a percent of the total forest land, by FIA unit, Ohio

Unit	Forest land[a]	Forest land >98 ft from edge	Forest land >295 ft from edge[b]	Forest land located in patches >100 acres in size[c]	Forest land >1,310 ft from a road[d]	Forest land with population density >20 per square mile	Forest land with population density >45 per square mile	Forest land with population density >70 per square mile	Forest land with population density >150 per square mile[e]	Forest land with house density >15.5 per square mile[f]
	………	………	………	………	……… percent	………	………	………	………	………
South-central	54	79	54	91	26	67	38	25	9	15
Southeastern	70	79	53	95	22	60	25	12	3	7
East-central	60	74	43	90	18	55	27	15	5	9
Northeastern	33	67	33	73	24	85	68	53	28	39
Southwestern	16	54	21	59	21	84	65	51	29	38
Northwestern	10	51	14	36	29	72	42	26	11	16
State	32	71	41	80	23	68	42	28	13	19

[a]Percent forest estimte based on NLCD 2006. Values are generally higher than estimates from FIA data.

[b]Approximating the forest land undisturbed by edge conditions.

[c]Approximating the forest land with potentially enough core area for sustainable interior species populations.

[d]Approximating the forest land undisturbed by recreation or invasive species.

[e]Approximating the forest land not available for commercial forestry.

[f]Approximating the forest land in Wildland Urban Interface.

The landscape in Ohio ranges from predominantly agricultural in the northwest, in which forest and development occur in patches within this agricultural matrix, to a primarily forested matrix in the southeast, within which urban development, agriculture, roads, and other nonforest areas occur in patches (Riitters et al. 2000). Between these extremes lie a much more urban area in a roughly southwest-northeast corridor across the State that includes the cities of Cincinnati, Dayton, Columbus, Akron, and Cleveland, and urban areas near Lake Erie. The region containing the smallest proportions of forest in large patches (>100 acres) is the Northwestern Unit. Three units in Ohio (South-central, Southeastern, East-central) maintain large forest patches, having 90 percent or more of their forest land in large patches over 100 acres. The more urban Southwestern and Northeastern Units have 59 and 74 percent of forest land in patches greater than 100 acres, respectively (Table 1).

The wildland—urban interface (WUI) is the area where houses meet or intermingle with undeveloped wildland vegetation (Radeloff et al. 2005.) In 2010, 20 percent of Ohio's forest land was classified as WUI (Fig. 13). Radeloff et al. (2005) define this area in terms of the density of houses (greater than 15.5 houses per square mile), the percentage of vegetation coverage present, and proximity to developed areas. In Ohio, 20 percent of the forest land is affected by underlying house densities greater than the threshold of 15.5 houses per square mile, with individual units ranging from 7 percent of the forest land in the WUI of the Southeast Unit, to 40 percent in Northeast Unit. This change is greatest in the urbanized southwest-to-northeast corridor and near Lake Erie. In Ohio, 13 percent of the forest land is located in a U.S. census block with population densities greater than 150 people per square mile at which the probability of commercial forestry dropped to practically zero (Table 1). However this varies considerably across the State, from 28 percent in the Northeast and Southwest to less than 5 percent in the Southeastern and East-central Units.

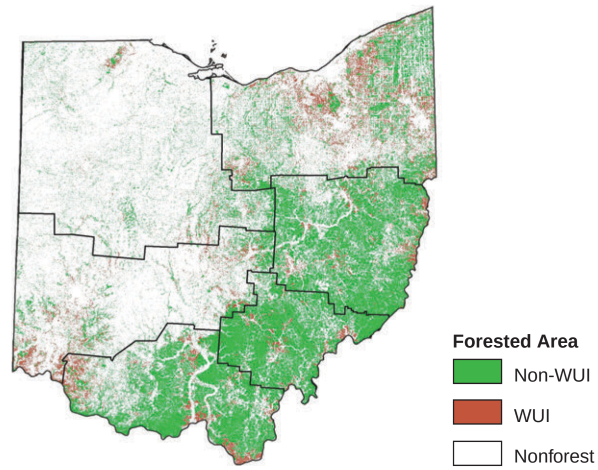


Figure 13.—Forest land in the wildland-urban interface (WUI), Ohio, 2006.

Table 1 presents the extent to which the current forest land base is being influenced by one or more of the urbanization factors. For example, the Southeastern Unit is 70 percent forested, with 95 percent of that forest occurring in large patches (>100 acres) and only 3 percent occurring in census blocks with population densities so high that forest management may be affected. However, 33 percent of forest area is potentially affected by house densities greater than 15.5 per square mile, 47 percent is within 300 feet of an agricultural or developed edge, and 45 percent is less than 650 feet from a road of some sort.

In the Northeastern unit, a region that is only 33 percent forested, 73 percent of forest occurs in patches larger than 100 acres. However it is still a forest in close proximity to houses (51 percent of that forest has underlying house densities greater than 15.5 per square mile), edge (33 to 67 percent can be considered in edge [vs. interior] forest conditions), roads (44 percent is less than 650 feet from a road), and people (13 percent is located in census blocks with population densities that are high enough to limit forest management options).

Change from Census 2000/NLCD2001 to 2010

Although there has been little change in the amount of forest land in Ohio over the past 10 years, the population density of Ohio has increased from 117 to 126 people per square mile between 2000 and 2010. This has increased the WUI areas by 8 percent, or 124,096 acres of forest land—approximately 30,000 acres in each of the South-central, Northeastern, and Southwestern Units, and 10,000 acres each in the Northwestern, East-central, and Southeastern Units.

What this means

Forest health, sustainability, management opportunities, and the ability of forest land to provide the products and ecosystem services are affected to varying degrees by fragmentation and urbanization of that forest land.

If we ignore the impact of roads or houses that do not substantially disrupt the tree canopy, 80 percent of Ohio's forest land is in patches larger than 100 acres, although only 576,000 acres of forest land in Ohio are in patches greater than 5000 acres in size, most of it in the South-central Unit. In addition, the frequency of more linear patch shapes along with moderate patch sizes results in nearly two-thirds of Ohio's forest land being within 295 feet of an agricultural or developed edge (Fig. 11). These additional characteristics, as well as the proximity of houses and roads, should be considered in addition to patch size when examining wildlife habitat quality.

Most of Ohio's forests are affected to some extent by their proximity to roads. Actual ecological impacts of roads will vary by the width of the road and its maintained right-of-way, number of cars, level of maintenance (salting, etc.), number of wildlife-friendly crossings, hydrologic changes made, imperviousness of road surfaces, location with respect to important habitat, etc. These variables also suggest some of the changes that can be made to moderate the impact of roads on the forest (Charry 2007, Forman 2000, Forman et al. 2003,).

Forest intermixed with houses represents areas more likely to experience pressures from recreation, invasive plant species, and other effects caused by close proximity to people. This intermix area also represents a challenge to managing forest fires. A threshold of 15.5 houses per square mile represents the approximate density at which firefighting switches from 'wildland' to 'structure' firefighting techniques and costs (Radeloff et al. 2005). Although the other pressures from high housing densities are likely to be more of an issue than forest fires in Ohio, thresholds with respect to those issues are less developed at this point. Therefore, the map should be interpreted as identifying areas where increased pressure from residential development are likely to occur (Fig. 14). Looking into the future, nationwide increases in lower density "exurban" development have been forecast to occur particularly at the urban fringe and in amenity rich rural areas (Hammer et al. 2004, Theobald 2005).

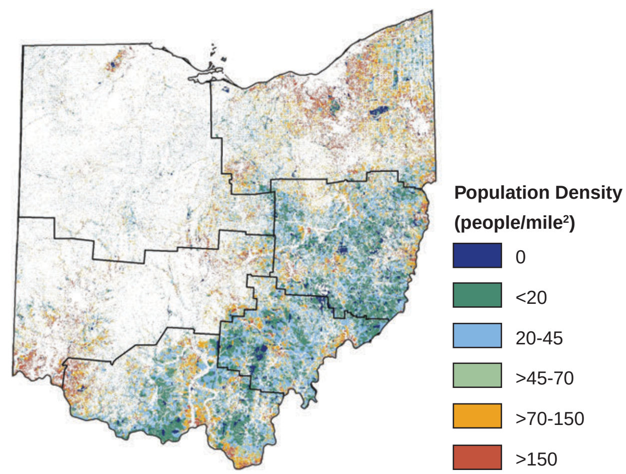


Figure 14.—Human population density on forest land, Ohio, 2010.

Even though forest land area is stable in Ohio, fragmentation is changing how these forests function. Fragmentation diminishes the benefits and services forests provide and makes forest management more difficult. As Ohio's population continues to sprawl into rural areas, fragmentation of forest land is a growing concern to land managers

Forest Resource Attributes

Harrison State Forest, Harrison County, in eastern Ohio. Photo by Ohio Department of Natural Resources, used with permission.

Forest Structure—How Dense are the Woods?

Background

How well forests are populated with trees is determined by two measurements: the of trunk diameter taken at 4 ½ feet above the ground and referred to as diameter at breast height (d.b.h.), and by the number of trees. Generally, as stands mature and trees become larger, the number of trees per acre decreases and stand volume increases. The number of trees per acre and their diameters are used to determine levels of stocking. Stocking is a measure of how well a site is being utilized to grow trees. Stocking levels for Ohio's forests are provided in this report based upon "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 rough and rotten trees with little or no commercial value. Poorly stocked stands can develop on abandoned agricultural land, or result from major disturbances such as windstorms, disease outbreaks, 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 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. If stands are not disturbed, stocking levels increase over time as trees naturally reproduce and grow. As disturbances such as harvesting lower stocking levels, changes in species composition, diameter distribution, residual tree quality, and regeneration become of increasing concerns to forest managers.

Tree diameter measurements are used by FIA to assign a stand-size class to sampled stands. The categories are determined by the class that accounts for the most stocking of live trees per acre. Sapling or small-diameter stands are dominated by trees less than 5 inches d.b.h. Poletimber or medium-diameter stands have a majority of trees at least 5 inches d.b.h. but less than the large-diameter stands. Sawtimber or large-diameter stands consist of a preponderance of trees at least 9 inches in d.b.h. for softwood species and 11 inches d.b.h. for hardwood species.

What we found

The number of trees 1-inch in diameter and larger increased by 1.7 percent between 2006 and 2011(Fig. 15). This increase was not distributed evenly across diameter classes. Figure 16 shows that a shift has occurred toward larger diameter trees. Numbers of trees in diameter classes less than 16-inches increased by 1.3 percent while tree numbers in classes 16-inches and larger increased by 14.9 percent. This is also reflected in the continued increase in the average diameter of trees 5-inches d.b.h. and larger; average diameter was 9.3 inches in 1991, 9.7 inches in 2006, and 9.8 inches in 2011.

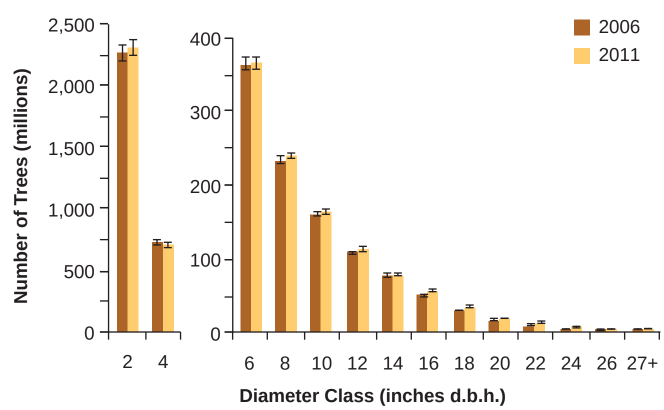


Figure 15.—Number of live trees by diameter class on forest land, Ohio, 2006 and 2011. Error bars represent 67-percent confidence intervals around the estimated mean.

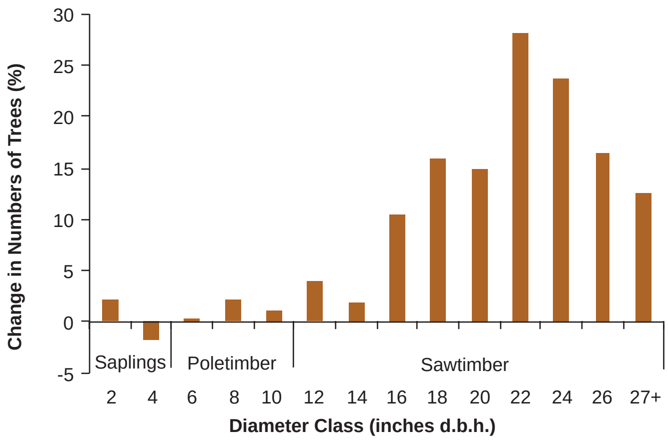
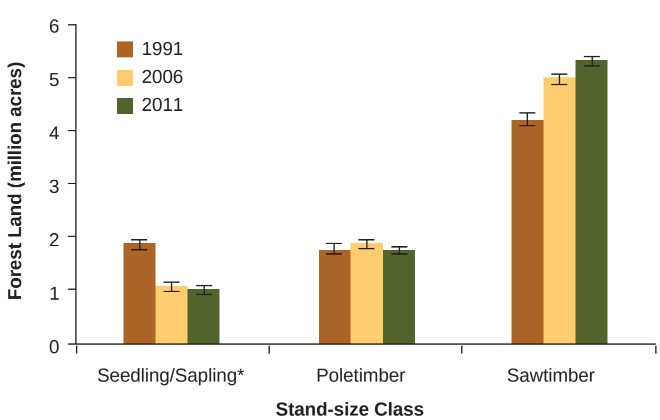


Figure 16.—Percent change in the number of live trees by diameter class, Ohio, 2006 to 2011.

The shift to larger size trees has brought about an increase in stands dominated by sawtimber size trees (Fig. 17). Trends show sawtimber size stands continuing to increase at the expense of poletimber and sapling/seedling-size stands. In 2011, two-thirds (5.3 million acres) of forest land in the State was in sawtimber size stands. Poletimber stands have experienced little change since 1991 and total 1.8 million acres in 2011. Sapling/seedling-size stands and nonstocked forest land continued to decrease and currently represent 12.5 percent of forest land (1 million acres). On forest land that was cut since the 2006 inventory, 23 percent (145,000 acres) is now in a seedling/sapling or nonstocked size class; and of the land that reverted to forest since 2006, 136,000 acres are now a seedling/sapling or nonstocked size class. Ohio has a higher percentage of forest land in sapling/seedling size stands (23 percent) than the surrounding states of West Virginia (7.7 percent), Kentucky (10.3 percent), Indiana (8.4 percent), and Pennsylvania (10.9 percent).



*Includes nonstocked stands-75,000 acres

Figure 17.—Forest land area by stand-size class, Ohio, 1991, 2006, and 2011. Error bars represent 67-percent confidence intervals around the estimated mean.

In Ohio, 3.6 million acres (44 percent) of forest are fully stocked or overstocked with live trees, 3.4 million acres (42 percent) have medium stocking, and 1.2 million acres (14 percent) are either poorly stocked or nonstocked (Fig. 18). Since 2006, stocking levels have shifted toward fully stocked and overstocked levels. Acreage in fully stocked and overstocked stands has increased by 269,000 acres since 2006; but more than half of all stands are less than fully stocked with live trees. Considering only the commercially important growing-stock trees, the area with poor stocking is 2.1 million acres, or double the area when including all trees (Fig. 19). Most of the acreage in these stands is in older age classes and/or in stands dominated by large trees. Sixty-four percent are in age classes more than 40 years old, (Fig. 20), and 53 percent are in sawtimber-size stands (Fig. 21). Ohio's forests are still fairly young with 59 percent of the forest land in stands where overstory trees average less than 60 years old.

Figure 18.—Area of forest land by stocking class for all live trees, Ohio. 1991, 2006, and 2011. Error bars represent 67-percent confidence intervals around the estimated mean.

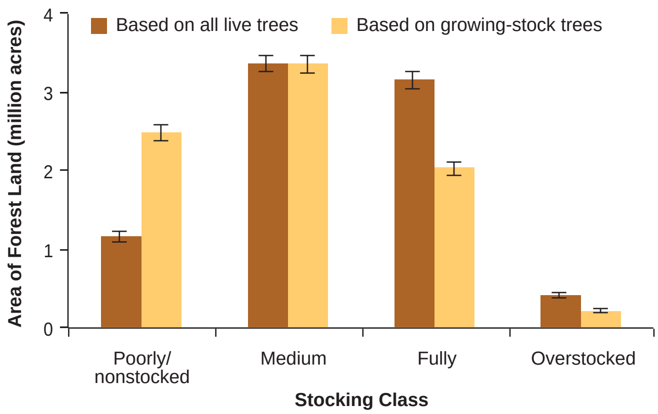


Figure 19.—Area of forest land by stocking class for all live trees and growing-stock trees, Ohio, 2011.

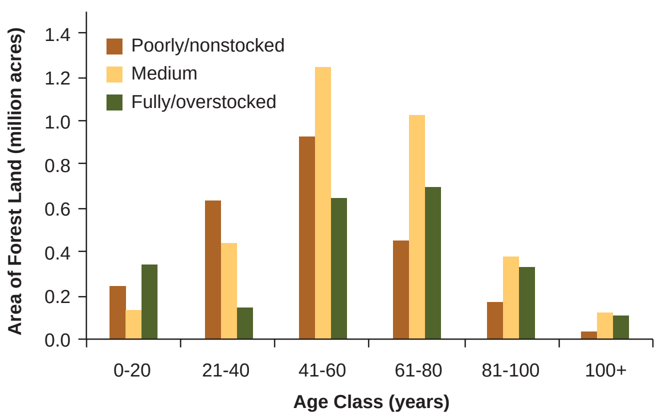


Figure 20.—Area of forest land by stand-age class and stocking level (growing-stock trees only), Ohio, 2011.

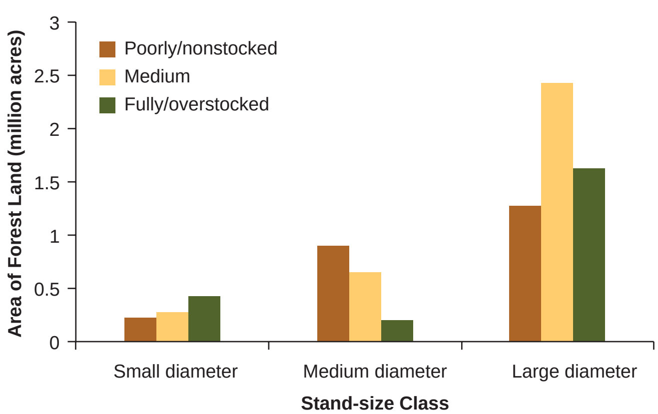


Figure 21.—Area of forest land by stand-size class and stocking level (growing-stock trees only), Ohio, 2011.

What this means

The continued shift to larger size trees and the increase in area of sawtimber-size stands indicates that Ohio's forests are maturing. Increases in tree size have also brought about an overall improvement in stocking levels in Ohio's forests. These improvements have occurred while these same forests have contributed to Ohio's economy by supporting the timber products industry. The 2.3 million acres in fully stocked and overstocked stands present opportunities for forest management. Managing these stands can keep them growing optimally.

Fifty-six percent of forest land is less than fully stocked with trees but when only growing-stock trees are considered, this level increases to 72 percent. The broad extent of these stands that are less than fully stocked indicates that a large amount of disturbance, natural and human-caused, has occurred in Ohio's forests. The 2.5 million acres of forest land that are poorly stocked or nonstocked represents a loss of potential growth. Trees in these stands are either widely spaced or are low value trees that occupy growing space that could otherwise be used to grow quality timber. These stands may have originated as farmland that has reverted to forest or from poor harvesting practices. The estimate of poorly stocked stands includes 1.5 million acres that are more than 40 years old and dominated by medium- and large-size trees. They are likely the result of poor harvesting practices (e.g., high-grading), although they could stem from acceptable forestry practices such as shelterwood or seed tree harvesting methods being used to regenerate the stands. Poorly stocked stands represent a challenge to forest managers because they contain little value to pay for improvement and although they are considered a sign of poor management, they still provide wildlife habitat. The difference in stocking levels, when using only growing-stock trees versus all live trees, implies that many low-quality trees have been left behind after harvesting. These cull and noncommercial species occupy space and inhibit effective new growth of more valuable trees. Retaining large amounts of residual trees during harvesting also impedes the start of new age classes that are important to maintaining forest health and future timber supplies.

The 12 percent of forest land in seedling/sapling stands are likely the result of farmland being allowed to revert to forest or timber harvesting using even-age management. Currently agricultural land reverting to forest is a major source of seedling/sapling stands and a slowing of this process will likely continue the decline in this stand size class. While young stands offer opportunities for further increases in Ohio's timber resource, young stands also provide unique early successional wildlife habitat features that are not provided by sawtimber-size stands. Across the northeastern states, a number of animal species that require early-successional habitats are declining because of changing habitats. Besides offering diverse habitats and providing a steady flow of wood products, forests that contain stands of various sizes might be more resistant to devastating outbreaks of insects and diseases. The shift to denser levels of stocking indicates that growing conditions in Ohio are becoming crowded and therefore more shaded.

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 disturbances in Ohio include timber harvesting, windstorms, insects and diseases (e.g., Dutch elm disease), ice storms, droughts, wildfires, and land clearing followed by abandonment. As forests recover from disturbances and mature, changes in growing conditions favor the growth of shade-tolerant species over shade-intolerant species in the understory unless forest management practices intervene to work toward the perpetuation of shade intolerants.

Forest attributes recorded by FIA that describe forest composition include forest-type group and numbers of trees by species and size. Forest types describe groups of species that frequently grow in association with one another and dominant the stand. Similar forest types are combined into forest-type groups. Changes in area by forest type are driven by changes in the species composition of the large diameter trees, and while these large trees represent today's forest, the composition of the smaller diameter classes represents the future forest. Comparisons of species composition by size can provide insights into future changes in overstory species.

What we found

The 2011inventory identified 99 tree species, 53 forest types, and 14 forest-type groups. The oak/hickory group covers more than half (5.1 million acres) of Ohio's forests, and the northern hardwood group covers another third (1.6 million acres; Fig. 22). The oak/hickory group consists of white oak, northern red oak, hickory species, white ash, walnut, yellow-poplar, and red maple. In Ohio, 87 percent of oak volume and 68 percent of red maple volume grows in the oak/hickory group, while 68 percent of sugar maple volume and 51 percent of beech volume grows in the northern hardwood group. These broad species groups have undergone little change in extent since 2006. The elm/ash/cottonwood forest-type group reaches its greatest extent in the Southwestern Unit where it comprises 25 percent of the forest land area.

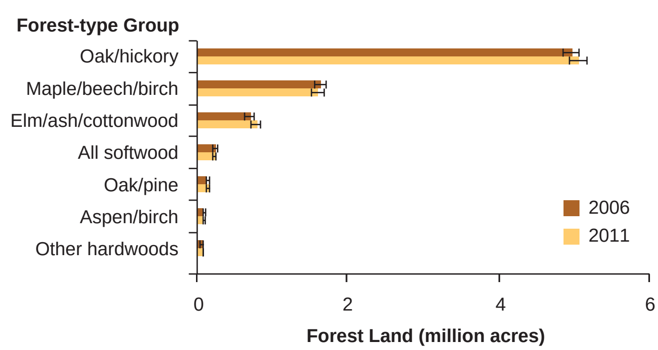


Figure 22.—Area of forest land by forest-type group, Ohio, 2006 and 2011. Error bars represent 67-percent confidence intervals around the estimated mean.

Ash are the most numerous trees in the seedling size class (trees less than 1-inch d.b.h. and greater than 1-foot tall), representing about 20 percent of all seedlings, followed by sugar maple, black cherry, red maple, and elm (Fig. 23). Oaks occur at low densities in the seedling size class. The ranking of saplings (1- to 4.9-inches d.b.h.) is somewhat different than that of seedlings (Table 2). Sugar maple is the most numerous sapling followed by red maple and ash. Oak species are ranked poorly in this size class, too. White oak and northern red oak saplings each declined by 4 percent since 2006. American hornbeam, eastern hophornbean, and boxelder saplings had the largest percentage gains since 2006, increasing by 32, 25, and 25 percent, respectively. Species with the largest decreases in numbers of sapling were red cedar, flowering dogwood, black locust, and black cherry, declining by 18, 17, 14, and 13 percent, respectively from the previous inventory period. Among trees 5-inches d.b.h, and larger, red maple again is the most numerous followed by sugar maple, and black cherry (Fig. 24). If only trees in the 18-inch and larger diameter classes are considered, yellow-poplar is the leading species followed by white oak, red maple, and northern red oak. The oaks are better represented in diameters larger than 11 inches (Fig 25). In the current inventory, oaks represent more than 35 percent of the trees 20 inches and larger in diameter, but only 5 percent of trees in the 2- and 4-inch diameter classes (Fig. 26). Since 1968, oaks have decreased from 38 percent of the timber resource to 22 percent (Fig 27). Conversely, maple species have a disproportionate share of trees in the 2- and 4-inch diameter classes amounting to 27 percent, compared to their presence in the larger diameter classes at 7 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 representing 8 percent of all saplings, but less than 2 percent of trees larger than 15-inches.

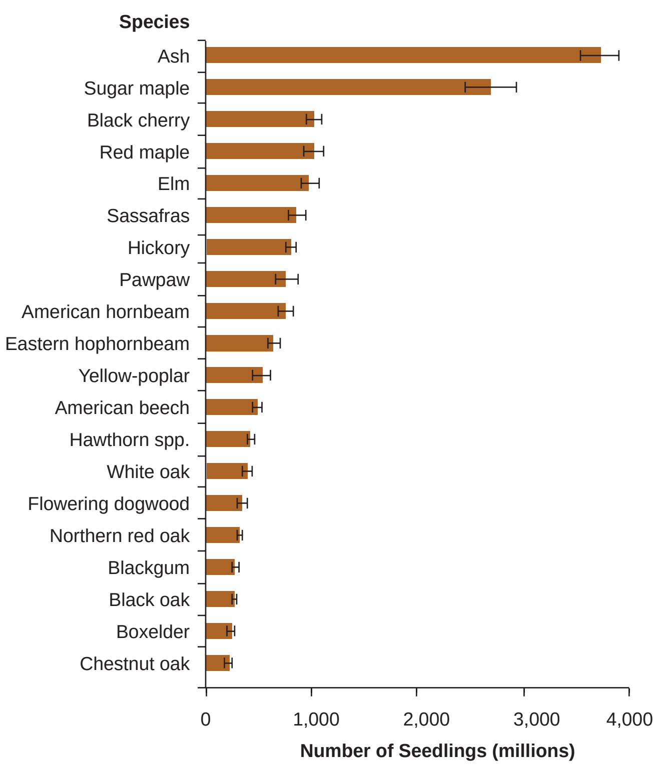


Figure 23.—Species ranked by number of seedlings (trees less than 1-inch d.b.h. and at least 1-foot tall), Ohio, 2011. Error bars represent 67-percent confidence intervals around the estimated mean.

Table 2.—Species ranked by numbers of saplings (trees at least 1 inch and less than 5 inches d.b.h.) 2006 and 2011, total number of stems 2011, and percent change 2006-2011, Ohio

Rank 2011	Rank 2006	Species	Number of saplings 2011 (millions)	Percent change 2006-2011
1	1	Sugar maple	437	2.3
2	2	Red maple	359	-5.1
3	4	Ash	196	0.2
4	3	American elm	196	-4.5
5	6	Hawthorn spp.	146	-4.7
6	5	Black cherry	136	-13.2
7	9	Yellow-poplar	120	17.1
8	8	Hickory	107	-0.8
9	7	Flowering dogwood	98	-17.2
10	12	A. hornbeam, musclewood	95	31.7
11	10	American beech	89	2.1
12	11	Sassafras	87	10.9
13	13	Eastern hophornbeam	76	24.6
14	14	Blackgum	56	1.2
15	17	Eastern redbud	52	6.5
16	21	Boxelder	51	24.6
17	16	Northern red oak	47	-4.4
18	18	Pawpaw	45	-2.8
19	15	Black locust	44	-14.1
20	20	Slippery elm	41	-1.8
21	23	Black oak	36	10.4
22	22	American basswood	35	4.9
23	17	Eastern redcedar	34	-17.9
24	24	Ailanthus	33	3.9
25	25	White oak	29	-4.3
Total all species			**3,024**	**1.2**

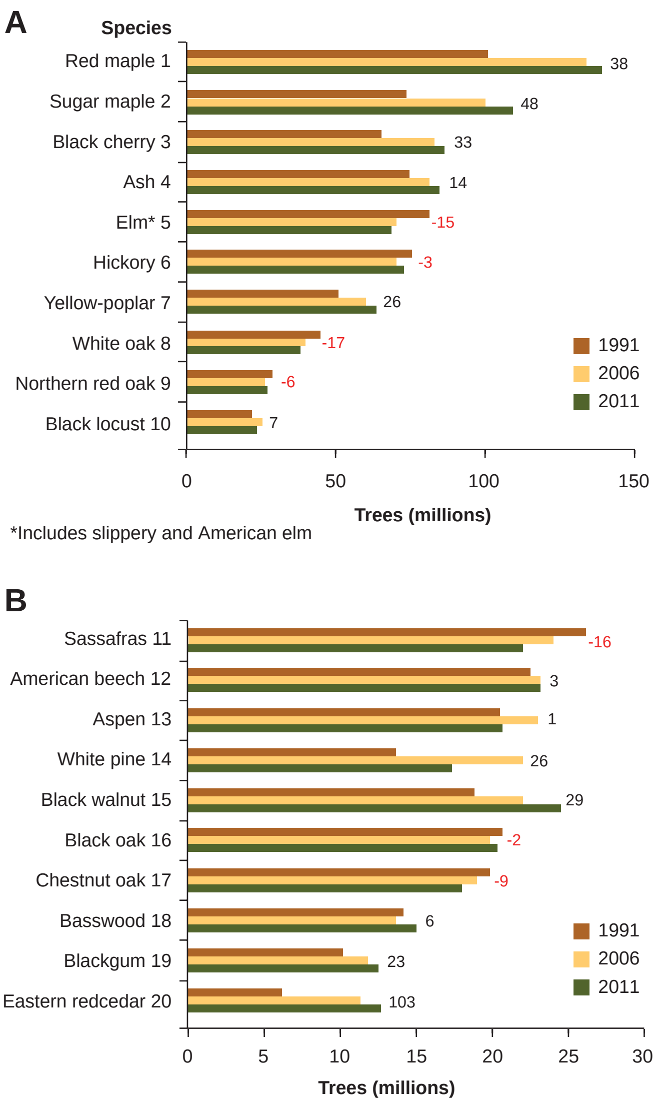


Figure 24.—Most abundant species ranked by the numbers of trees >5.0 inches d.b.h in 2011, with estimates for number of trees in 1991, 2006, and the percent change from 1991 to 2011, on timberland, Ohio. Ten most abundant species are depicted in A, with the second group of 10 in B. (Note the difference in the x-axis scale for A and B.)

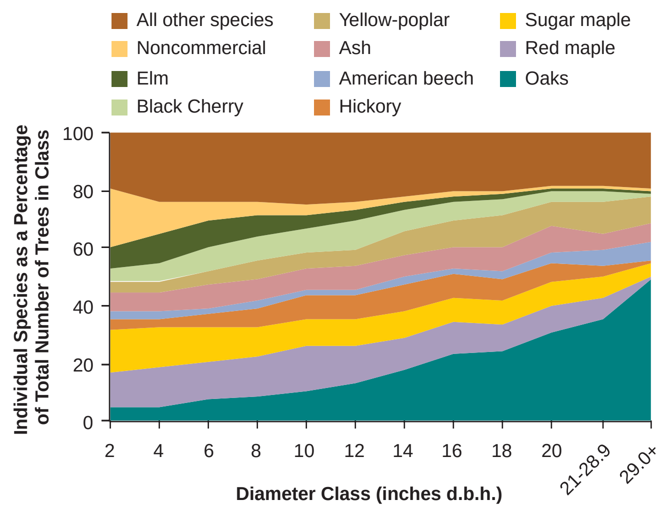


Figure 25.—Species composition by diameter class on forest land, Ohio, 2011.

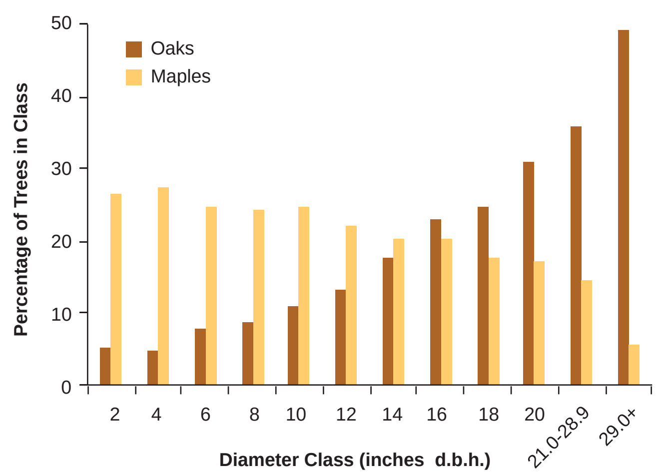


Figure 26.—Oaks and maples as a percentage of all trees by diameter class on forest land, Ohio, 2011.

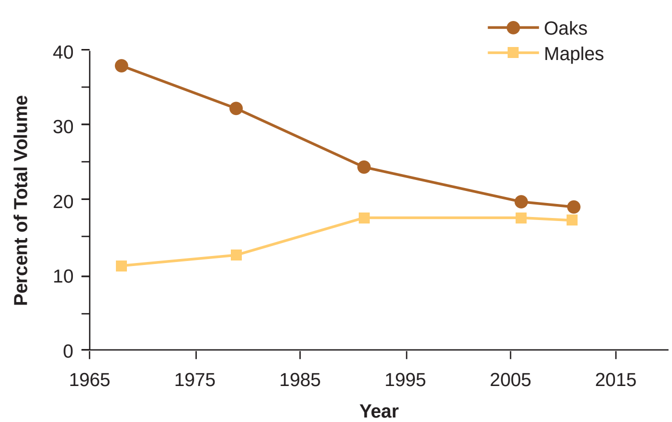


Figure 27.—Oak and maple species groups as a percentage of total growing-stock volume, Ohio, 1968 to 2011.

What this means

The stability in the area of the oak/hickory forest-type group and other major forest-type groups since 1991 does not fully depict the underlying shifts 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 maple that dominate the smaller diameter classes. Maples will play an increasing role in Ohio's future forest. This will likely cause the area occupied by the oak/hickory forest-type group to undergo a long-term decline and be replaced by the northern hardwood group. Large increases in numbers of sapling-size American hornbeam and eastern hophornbeam may be due to these species responding to gaps created by partial harvests and other disturbances. Both of these species are tolerant of shade and grow well in the understory. They may also be filling niches vacated by flowering dogwoods that are dying from dogwood anthracnose, a fungal disease.

Decreases in the oak portion of the resource have been attributed to inadequate oak regeneration, the subsequent lack of oaks growing into the 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 (fencing to exclude deer, controlled fires to inhibit oak competition, and use of oak seed trees) to promote oak regeneration are seldom 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 the low intensity harvesting practices that leave only small gaps in the canopy. Long-term changes in forest composition can alter wildlife habitats and affect the value of the forest for timber products. The lack of recruitment of oaks into the larger diameter classes is changing the composition of the timber resource away from oaks toward more maples and other non-oak species.

Projected changes in species composition due to climate change predict that by 2100, growing conditions in the Northeastern United States will become more suitable for oaks and less suitable for maples (Iverson and Prasad 1998, Rustad et. al. 2012, Vose et. al. 2012). Since current trends in Ohio do not reflect these projected changes, it indicates that to date, other factors, such as successional stage, cutting practices, and fire suppression, are driving changes in forest composition. Current trends may also suggest that Ohio's forests are becoming less resilient to predicted changes in climate. To maintain forest productivity and ensure a sustainable supply of ecosystem goods and services, natural resource managers will need new management strategies and practices that promote adaptation to climate variability and change.

Tree Condition—Crown Position and Live Crown Ratio

Background

The crown position of a tree indicates how well it is competing for light with neighboring trees. A tree crown in an intermediate or overtopped 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, defined as 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 to compete with the surrounding trees for light and space and are unlikely to ever recover or grow into an overstory position unless their crowns are "released" from their neighbors by timber harvesting or another disturbance.

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. Ninety-three percent of 2-inch trees and 53 percent of 8-inch trees are considered suppressed

(Fig. 28). Conversely, 92 percent of trees with diameters 14 inches or larger are dominant, codominant, or open grown. A fifth of all trees in the 10-inch diameter class and below have live crown ratios of less than 20 percent. For the 6-inch class, 22 percent have live crown ratios below 20 percent and 51 percent have crown ratios below 30 percent (Fig. 29).

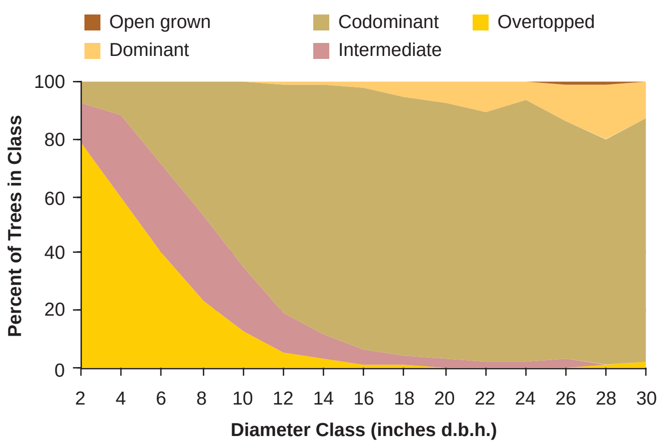


Figure 28.—Percentage of trees by diameter class and crown position on forest land, Ohio, 2011.

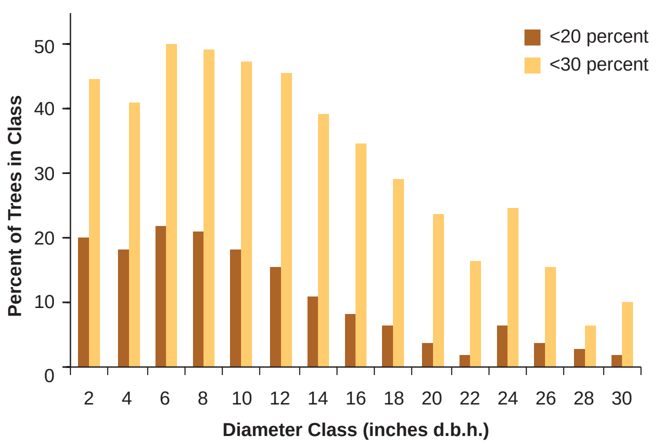


Figure 29.—Percentage of trees with a live crown ratio less than 20 percent and less than 30 percent, by diameter, on forest land, Ohio, 2011.

What this means

Shaded conditions created by overstory trees are stressing a large portion of trees less than 10 inches in diameter. This finding is consistent with the maturing of Ohio's forests and the likely cause for observing small increases in the number of trees in diameter classes less than 12-inch when compared to changes in larger trees (Fig. 16). Shaded conditions favor the growth of shade-tolerant species such as sugar maple over that of less shade-tolerant species such as aspen, black locust, black cherry, eastern redcedar, yellow-poplar, and the oaks.

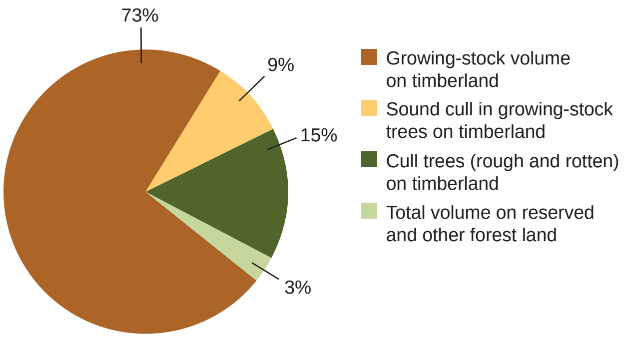
Volume of Live Trees

Background

The assessment of the volume of live trees provides information on trends in the resource, the potential uses of that wood, and its economic value. Current volumes and changes in volume over time can characterize forests and reveal important resource trends. FIA reports tree volume in several ways: sound and net volume of live trees, growing-stock and sawtimber volume of live trees of commercial species, and biomass in dry tons. Each of these measures characterizes the wood resource in a different way and provides insights into its use and management. And, as discussed in the next section, biomass estimates are a means for quantifying carbon storage. Because of changes in procedures, comparisons to past inventories are less consistent for some measures than others.

What we found

Seventy-three percent (13.7 billion cubic feet) of the live sound wood volume is categorized as growing-stock volume (Fig. 30). Also contained within these growing-stock trees is an additional 1.7 billion cubic feet categorized as sound cull. Trees not meeting growing-stock standards either because they have large amounts of defect or are noncommercial species are classified as rough and rotten trees. On timberland, rough and rotten trees account for a combined 2.9 billion cubic feet and represent 14 percent and 1 percent of total sound volume, respectively.



Total sound volume = 18.9 billion cubic feet

Figure 30.—Components of live sound wood volume, on forest land, Ohio, 2011.

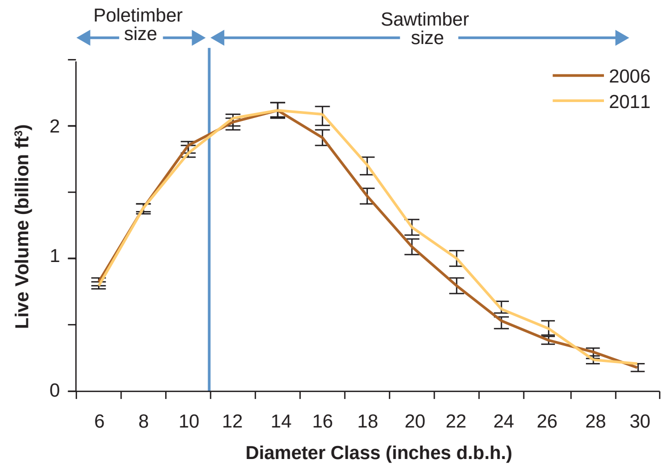


Figure 32.—Net volume of live trees by diameter class on forest land, Ohio, 2006 and 2011. Error bars represent 67-percent confidence intervals around the estimated mean.

Since 1968 the net volume of live trees on Ohio timberland has steadily increased to now total 15.9 billion cubic feet—a 7 percent increase from 2006 (Fig. 31). On a per-acre basis, this volume averages 2,020 cubic feet per acre—a 170 percent increase since 1968. Volume has been shifting toward the sawtimber-size classes (Fig. 32). The most recent inventory shows that since 2006, volume has increased in all diameter classes 12 inches and larger, while volume has decreased in the 6-, 8-, and 10-inch classes (Fig. 33). Trees less than 11 inches now comprise about a third of the total volume—2 percent less than in 2006. All of the gains in volume were in trees large enough to produce saw logs (≥11inches in d.b.h. for hardwood species), which reflects the changes in the numbers of trees discussed previously. Recent gains are a continuation of the increases that have been occurring over the last 50 years.

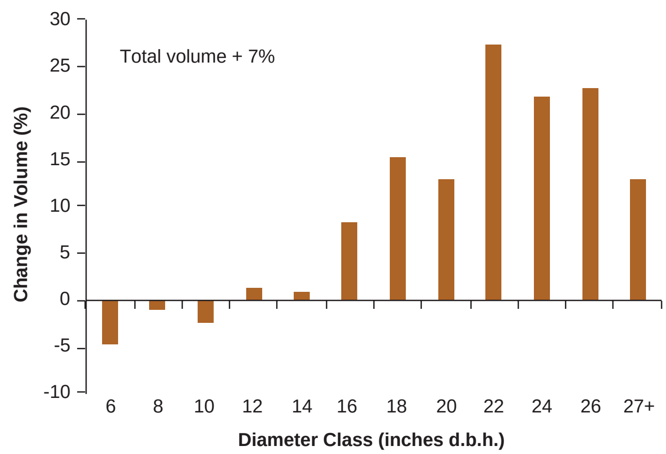


Figure 33.—Percent change in live volume by diameter class on forest land, Ohio, 2006 and 2011.

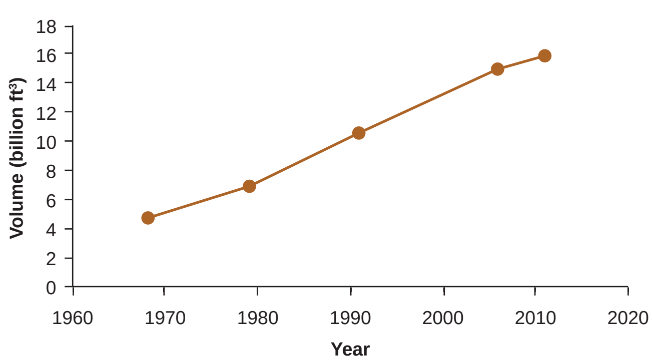
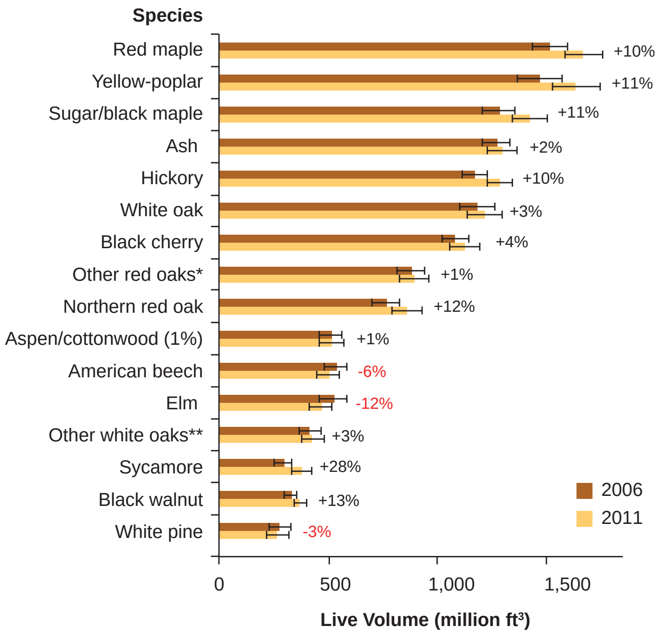


Figure 31.—Net volume of live trees on timberland by inventory year, Ohio, 1968, 1979, 2006, and 2011.

Red maple continues to be the most voluminous species followed by yellow-poplar and sugar maple (includes black maple) (Fig. 34). These three species each had above average increases in volume. American sycamore had the largest percentage increase in volume—28 percent. Although most major species had increases in volume, beech, elm, and white pine decreased.



* Includes black, scarlet, pin, and shingle oak
**Mostly chestnut oak, but also includes post, and overcup oak

Figure 34.—Live volume by selected species on forest land Ohio, 2006 and 2011. Percent change depicted as numbers at right of bar pairs. Error bars represent 67-percent confidence intervals around the estimated mean.

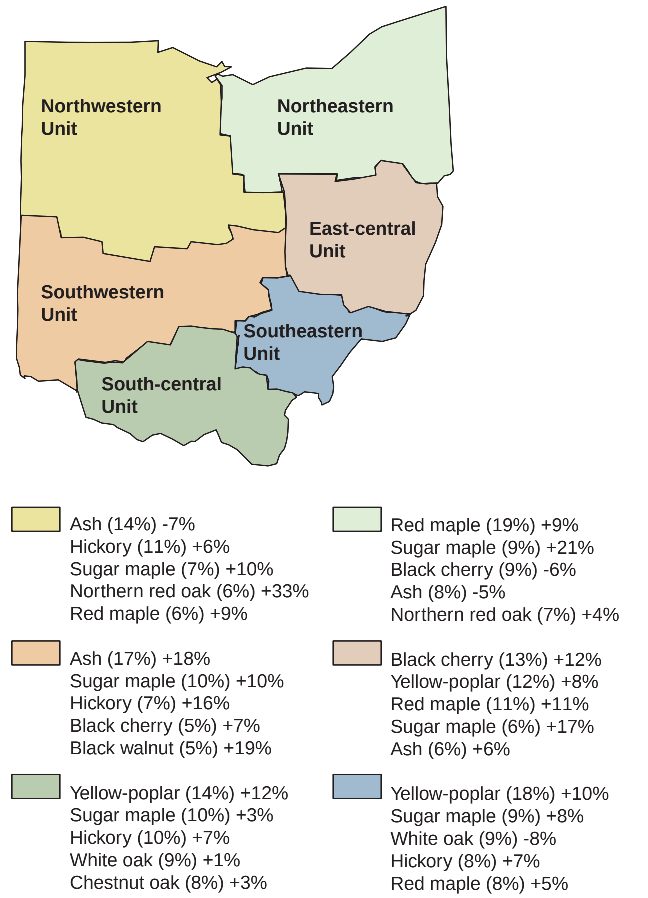


Figure 35.—Top five species by FIA unit, ranked by 2011 live volume; also includes percent of total volume in FIA unit (in parentheses), and percent change in volume (+ or -), 2006-2011, on forest land, Ohio.

The top five species by volume differ by unit, but they represent about half the total volume in each unit (Fig. 35). Ash is the top species in the Northwestern Unit where it comprises 14 percent of the total volume and experienced a 7-percent decrease in volume since 2006. Ash is also the leading species in the Southwestern Unit where it represents 17 percent of total volume, and has increased in volume by 18 percent. Yellow-poplar is the top species in the South-central and Southeastern Units, while red maple followed by sugar maple are the leading species in the Northeastern Unit.

The sawtimber volume on timberland increased by 6 percent to total 50.8 billion board feet. Yellow-poplar is the leading sawtimber species, by volume, followed by hickory, red maple, ash, and white oak (Fig. 36). Sycamore, followed by yellow-poplar, had the largest increases in board-foot volume since 2006, increasing by 34 and 15 percent, respectively. Elm, beech, black cherry, ash and the other red oak species group had decreases of 19, 12, 2, and 2 percent, respectively.

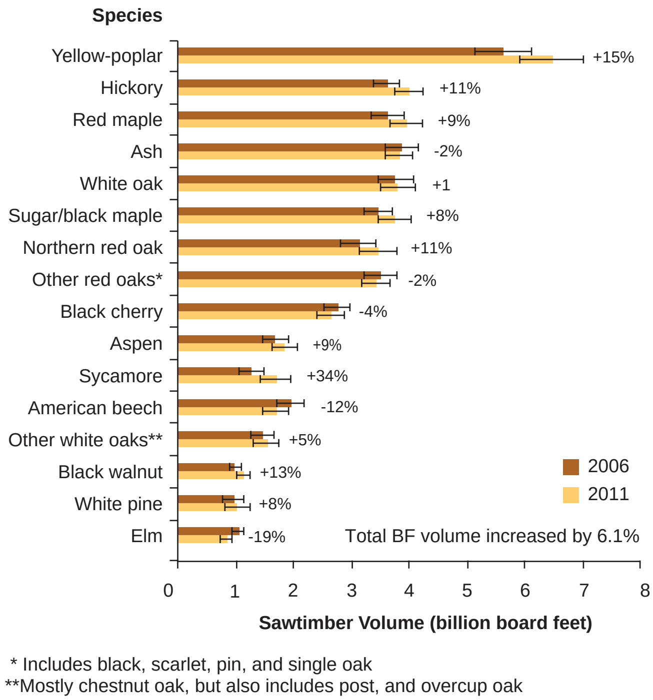


Figure 36.—Sawtimber volume in board feet (International 1/4 inch rule) on timberland by species, Ohio, 2006 and 2011. Percent change, depicted as numbers at the right of the bar pairs.

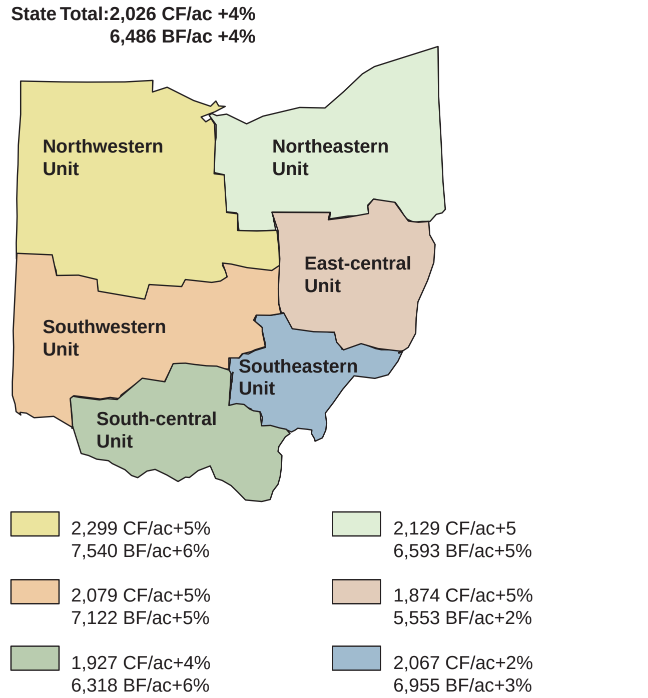


Figure 37—Average cubic foot (ft³) volume per acre of live trees on forest land and average board foot (BF) volume per acre on timberland, by FIA unit, 2011, with percent change (+ or -) in volume per acre, 2006-2011, Ohio.

Average volumes per acre were highest in the Northwestern Unit and lowest in the East-central Unit (Fig. 37). The Northwestern Unit also had the largest increase in the average board foot volume per acre of timberland.

What this means

Continuous increases in volume have brought Ohio's forest resources to levels not seen in the past 100 years in terms of both total net volume of live trees and board-foot volume. This gain, combined with a stable forest land base, shows tremendous stewardship and conservation of Ohio's forest resources. Most of the volume is on timberland and in trees that meet minimum requirements to qualify as growing-stock trees. Since timber growth is concentrated on sawtimber-size trees, it would be expected that increases in board-foot volumes would exceed those for total volume because it excludes poletimber-size trees that exhibited little change. But because of changes in field procedures between 2006 and 2011, a large numbers of trees were reclassified as cull trees that are now excluded from board-foot volume estimates. Increases in sawtimber volume were not as large as they would have been if changes in field procedures had not occurred. Therefore changes in the net volume of all live trees are a better indication of change than either growing-stock volume or board-foot volume. Because most volume increases have occurred on the larger and more valuable trees, Ohio forests are likely adding value at a greater rate than increases in volume alone indicate.

Currently, nearly a quarter of Ohio's sound wood volume is in low value wood on timberland. Nine percent is in the cull portion of growing-stock trees and 15 percent in rough and rotten trees on timberland. This amounts to 4.6 billion cubic feet of sound wood and should be considered in addition to growing-stock volume when evaluating Ohio's forest resources. Cull volume is typically underutilized, especially in areas with poor markets for pulpwood and fuelwood. Improving markets for low value wood would help landowners better manage their timber resource.

Yellow-poplar leads in board-foot volume and is concentrated in the South-central, Southeastern and East-central Units, where it is a valuable part of the timber resource. Yellow-poplar trees tend to be larger in diameter than red maples which have the most total cubic foot volume. Decreases in beech and elm can be explained by diseases affecting these species, beach bark disease and Dutch elm disease, respectively. Most of the white pine in Ohio grows in plantations established by the timber industry; the decreases in volume suggest that these plantations are not being replanted after harvesting.

In each of the six FIA units, the top five species represent about half of the total volume, with no one species representing more than a fifth of the total volume by unit. There are few areas in Ohio where any one species dominates. This diverse mix of species reduces the impact of insects and diseases that target a single species. In the Northwestern Unit, the emerald ash borer (EAB) is the likely cause for decreases in ash volume—the top species in the unit. Since the impact of EAB will be proportional to the total volume in ash, units with high percentages of ash will likely be impacted the most. Because the Southwestern Unit has 17 percent of its live volume in ash, it can be expected that tree mortality in the unit will increase significantly as EAB spreads.

Despite having highly fragmented forests, the Northwestern Unit has the largest volumes per acre with ash representing a major portion. Future inventories will monitor how these forests respond to decreases in ash caused by EAB.

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 increase 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 in trees on forest land, is the total weight of both live and dead trees, including branches, roots, and stumps. Typically the carbon content of biomass is equal to half the biomass weight measured in dry tons. Estimates of biomass are important for knowing not only the amount of carbon storages but also the potential amount of biomass available for energy uses.

What we found

Aboveground biomass of all live trees in Ohio's forests equals 417 million dry tons and averages 59 tons per acre. The greatest portion (62 percent) is found in the merchantable boles of commercially important trees representing growing-stock volume (Fig. 38). It is this component that can be converted to high value wood products. Other portions of tree biomass are underutilized and can be considered as potential sources of fuel for commercial power generation. Biomass in live trees has increased by 7 percent since 2006. The greatest concentration of biomass in Ohio is found in the southeastern portion of the State (Fig. 39).

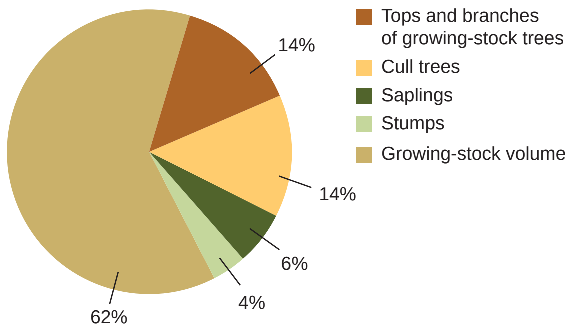


Figure 38.—Components of tree biomass on forest land, Ohio, 2011.

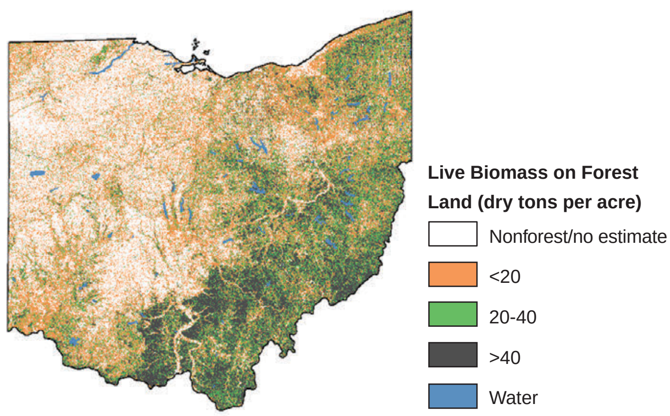


Figure 39.—Distribution of live biomass (oven-dry tons/acre of land) on forest land, Ohio, 2011.

What this means

Ohio's forests are accumulating substantial biomass. These stores of carbon will receive increasing attention as the Nation seeks sources of 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. Utilizing biomass for fuel can provide markets for low grade and underutilized wood. As biomass markets develop, forest managers will need to integrate the harvesting of biomass into their management plans.

Carbon Stocks

Background

Collectively, forest ecosystems represent the largest terrestrial carbon sink on earth. The accumulation of carbon in forests through sequestration helps to mitigate emissions of carbon dioxide to the atmosphere from sources such as forest fires and burning of fossil fuels. The FIA program does not directly measure forest carbon stocks in Ohio. Instead, a combination of field-based carbon estimates (e.g., standing live and dead trees) and models (e.g., carbon in soil organic matter [SOM] based on stand age and forest type, are used to estimate Ohio's forest carbon. Estimation procedures for modeled forest attributes (i.e., carbon in SOM, understory vegetation, litter, and downed dead wood) are detailed in Smith et al. (2006) and field-based estimation procedures for standing live and dead trees are detailed in Woodall et al. (2011) and Domke et al. (2011), respectively.

What we found

Ohio forests currently contain more than 597 million tons of carbon. Live trees represent the largest forest ecosystem carbon stock in the State at more than 285 million tons, followed by soil organic carbon at more than 230 million tons (Fig. 40). Within the live tree pool, merchantable boles contain the bulk of the carbon (~ 174 million tons) followed by roots (~ 46 million tons) and tops and limbs (~ 41 million tons). Most of Ohio's forest carbon stocks are found in moderately-aged stands 41 to 80 years old (Fig. 41). Early in stand development most of forest ecosystem carbon is in the SOM and belowground tree components. As forest stands mature, the ratio of above to belowground carbon slowly shifts and by the 41 to 60 year age class the aboveground components represent the majority of ecosystem carbon. This trend continues well into stand development as carbon accumulates in live and dead aboveground components. A look at carbon by forest-type group on a per-unit-area basis found that 8 of the

10 types have between 60 to 90 tons of carbon per acre (Fig. 42). The soil organic matter and live trees account for the majority of ecosystem carbon in each forest-type group, however the distribution of forest carbon across forest types is quite variable. In the maple/beech/birch group, for example, 14 percent (~ 12 tons) of the forest carbon is in litter biomass, whereas in the elm/ash/cottonwood group, only 3 percent (~ 3 tons) is in litter biomass.

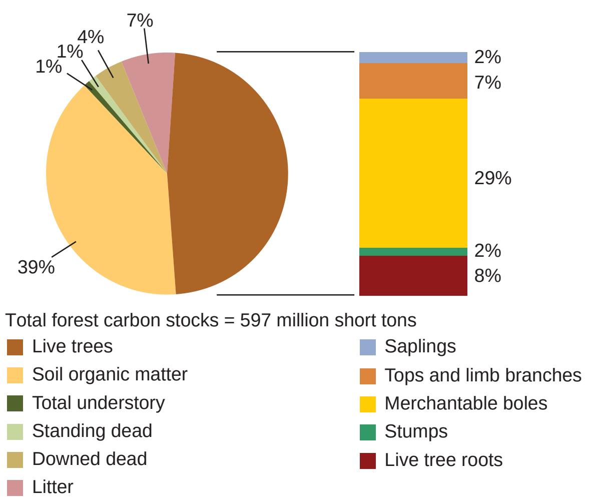


Figure 40.—Estimated total carbon stocks on forest land by forest ecosystem component, Ohio, 2011.

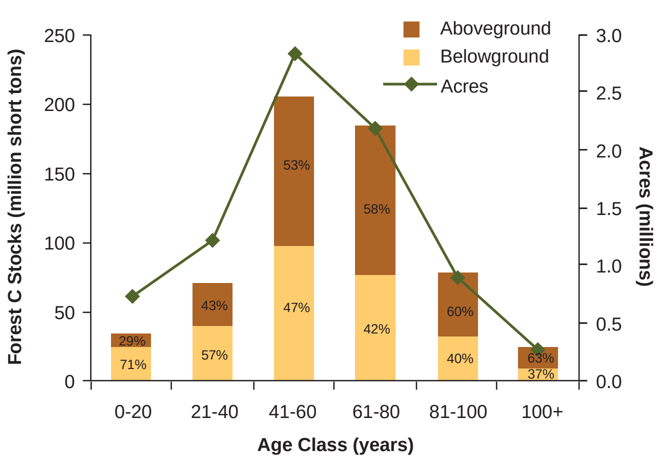


Figure 41.—Estimated aboveground and belowground carbon stocks on forest land by stand age class, Ohio, 2011. Note: estimates without stand age information (i.e., not measured) are not included in this figure.

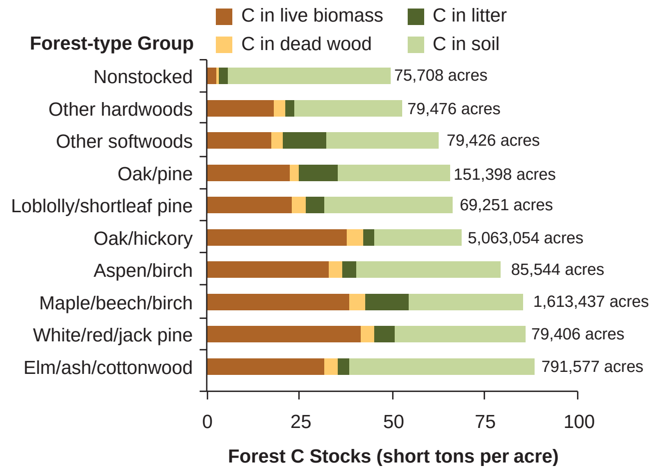


Figure 42.—Estimated carbon stocks on forest land by forest-type group and carbon pool per acre, Ohio, 2011. (Note: the "Other hardwoods" forest-type group includes estimates for the other hardwoods, oak/gum/forest-type group includes estimates for the other hardwoods, oak/gum/cypress, and exotic hardwoods groups; the "Other softwoods" forest-type group includes estimates for the other softwoods, other eastern softwoods, fir/spruce/mountain hemlock, and exotic softwoods groups).

What this means

Carbon stocks in Ohio's forests have increased substantially over the last several decades. Most forest carbon in the State is found in moderately-aged stands dominated by relatively long-lived species. This suggests that Ohio's forest carbon will continue to increase as stands mature and accumulate carbon in both the above and belowground components. Given the age class structure and species composition of forests in Ohio, there are many opportunities to increase forest carbon stocks. That said, managing for carbon in combination with other land management objectives (e.g., wildlife habitat, species diversity) will require careful planning and creative silviculture beyond simply managing to maximize growth and yield.

Components of Annual Volume Change: Growth, Removals, and Mortality

Background

Well-tended forests supply a continuous flow of products without impairing long-term productivity. One way to judge the sustainability of a forest is to examine the components of annual change in inventory volume: growth, removals, and mortality. Net growth includes growth (accretion) on trees measured previously, ingrowth of trees over the 5-inch threshold for volume measurement, deductions for mortality due to natural causes, and volume of trees on lands reverting to forest. Removals include trees harvested and trees lost because the forest land was developed for a nonforest use. Analysis of these individual components can help us better understand what is influencing net change in volume.

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 2006, the gross growth in the net volume of live trees has totaled 664 million cubic feet annually (Fig. 43). Annual mortality averages 182 million cubic feet, resulting in a net growth of 482 million cubic feet per year. The removals of trees due to both harvesting and land use change averaged 218 million cubic feet, leaving an annual surplus or net increase of 265 million cubic feet on Ohio's forest land. As a percentage of the current inventory, gross growth was 4.1 percent; mortality—1.1 percent; net growth—2.9 percent; and removals—1.3 percent. These result in a net change in total volume of 1.6 percent annually and higher than the 1.4 percent annual net change in growing-stock volume reported for the period 1991-2006.

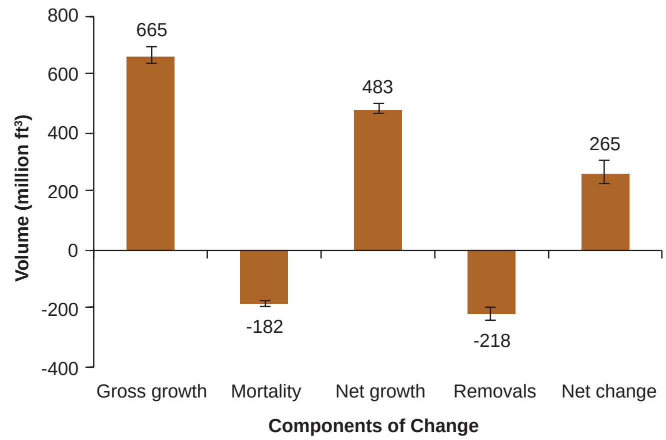


Figure 43.—Annual components of change in live volume on forest land, Ohio, 2006-2011.

Seventy-seven percent of net growth was on trees that were on land that was forested in both 2006 and 2011, and the remaining 23 percent is from trees on land that was previously nonforest and is now forest land. On land that was forest in both 2006 and 2011, 87 percent of net growth was accretion (growth on trees 5.0 inches d.b.h. and larger) and the remaining 13 percent was ingrowth from trees growing into the 5-inch diameter class. Accretion was well distributed across diameter classes. Fifty-seven percent of accretion was on trees that previously were at least 11-inches d.b.h. (Fig. 44).

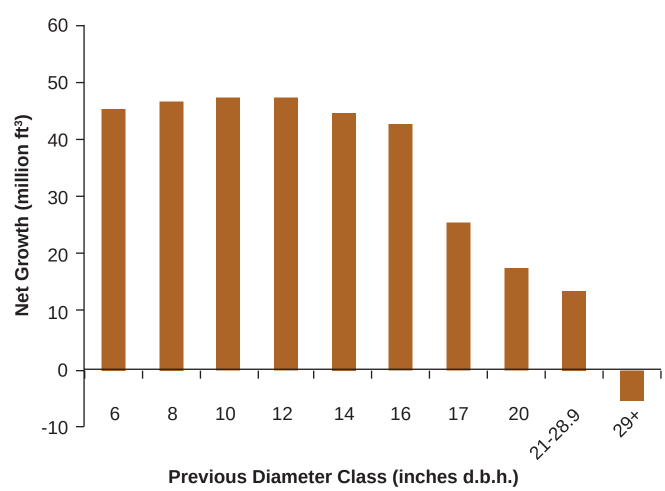


Figure 44.—Net growth on previously measured live trees (accretion) by previously measured diameter class on forest land, 2006 to 2011, Ohio.

Statewide, 83 percent of the removals was due to the harvesting of trees on land that remained in forest and the remaining 17 percent was due to forest land being diverted to nonforest land. The percentage of removals due to land-use change was highest in the Northeastern and Southwestern Units. On land that was forested in both 2006 and 2011, removals were concentrated on the larger trees with 86 percent of removals, by volume, being sawtimber-size trees in 2006 (Fig 45).

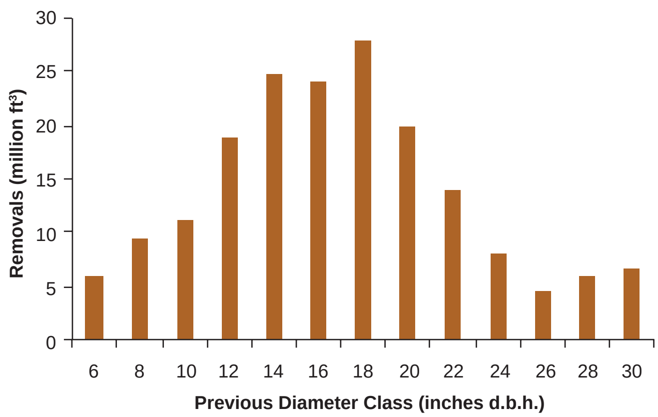


Figure 45.—Removals by previously measured diameter class on forest land, excluding removals due to forest land being diverted to nonforest uses, Ohio, 2006- 2011.

Statewide, the ratio of total growth to removals (G/R) averaged 2.2:1 from 2006 to 2011. If growth and removals due to land use change are excluded, this ratio is 2.1:1. Ratios were lower than the State average in the Southeastern and South-central Units (Fig. 46). G/R ratios were higher on publicly-owned forest land than on privately-owned forest land, 3.1:1 versus 2.6:1.

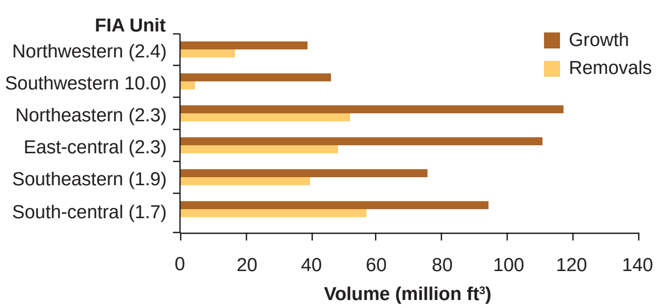
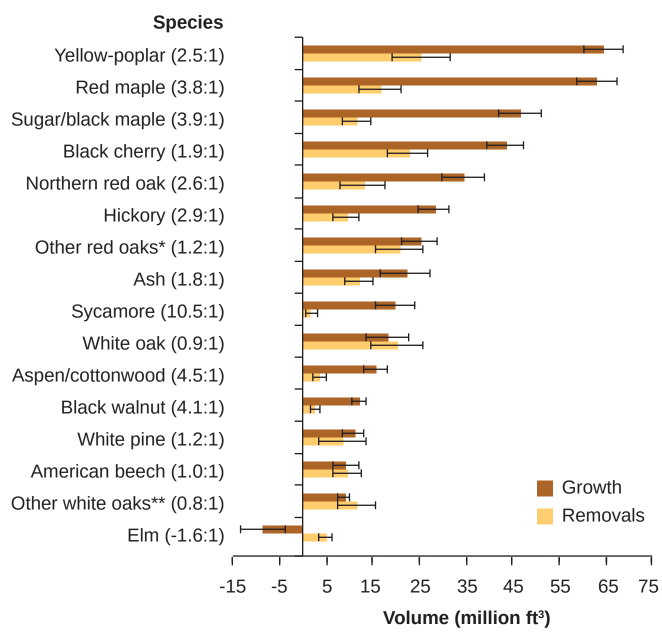


Figure 46.—Average annual growth and removals of net volume on forest land by FIA unit, Ohio, 2006 to 2011. Growth-to-removals ratio (G/R) listed beside unit name.

G/R ratios varied considerably between species (Fig. 47). Net growth exceeded removals for most major species, with the exceptions being white oak, elm, and the other white oaks group. Removals exceeded growth for these species for various reasons. Elm had negative growth because of high mortality and many of the oaks have low growth because of poor recruitment into the lower diameter classes discussed earlier. Yellow-poplar had the largest amount of growth followed by red maple and sugar maple. Yellow-poplar also accounted for the largest share of removals (12 percent), although growth still outpaced removals by a ratio of 2.5 to 1. Combined, the oaks represent 67 percent of removals and have a G/R ratio 1.3. Of the top 10 species by volume in Ohio, red maple and sugar maple had the largest G/R ratios, 3.8:1 and 3.9:1, respectively.



* Includes black, scarlet, pin, and shingle oak
**Includes chestnut, post, and overcup oak

Figure 47.—Average annual growth and removals of net volume on forest land by species, Ohio, 2006 to 2011. Growth-to-removals ratio (G/R) listed beside species name. Error bars represent 67-percent confidence intervals around the estimated mean.

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 2006, net growth has been twice that of removals, with the net change amounting to an annual increase of 1.6 percent in inventory volume. This finding implies that the current level of removals is sustainable and that increases in volume will continue at the State level as well as in each of the FIA units. The G/R ratios indicate that harvesting pressure is greatest in the South-central and Southeastern Units, and least in the Southwestern Unit. Currently oaks represent about two-thirds of removals, by volume, but only comprise about a fifth of total volume. The composition of the harvest will need to be adjusted over time to better reflect the composition of the changing resource.

Comparing the G/R ratios of individual species to the average ratio for all species (2.2:1) reveals which species are increasing in importance and which are decreasing. The high G/R ratios for red maple and sugar maple indicate these species will increase in importance in Ohio's forests. Removals exceeds growth for white oak, the other white oak group, and elm, where the G/R ratios were 0.9, 0.8, and -1.6, respectively, suggesting that these species will decrease in importance if current trends continue.

Mortality

Background

The volume of trees that die from natural causes, such as insects, diseases, fire, wind, and suppression by 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 from catastrophic events can indicate problems in forest health.

What we found

In Ohio, average annual mortality was 182 million cubic feet between 2006 and 2011, an annual rate of 1.1 percent of inventory volume. The mortality rate in Ohio is similar to that in the neighboring states of Indiana (1.1 percent), Kentucky (1.0 percent), Pennsylvania (0.9 percent) and West Virginia (0.9 percent). By FIA unit, rates were highest in the Northwestern Unit and lowest in the Southwestern Unit, 1.7 and 0.8 respectively (Fig. 48). Growing-stock trees had a lower mortality rate than cull trees at 1.0 percent, rough cull was 1.6 percent, and rotten cull was 5.7 percent. Mortality rates were higher for smaller diameter trees than for larger ones, although rates do rise in the largest diameter trees (Fig. 9). The mortality rate in the 6-inch class was 2.1 percent per year, which is nearly twice the average rate across all diameter classes, and the 16-inch diameter class had the lowest mortality rate at 0.6 percent. Trees less than 9.0 inches in diameter accounted for 21 percent of the total mortality, by volume, even though they represent only 13 percent of total volume.

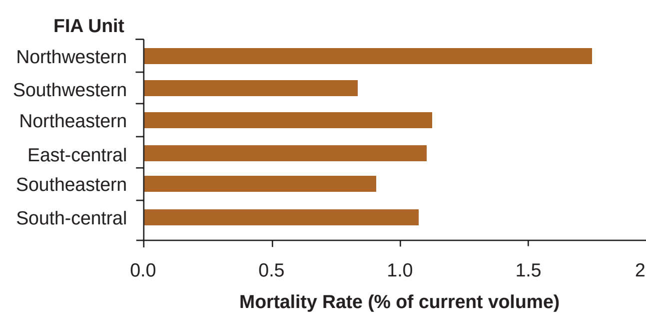


Figure 48—Average annual mortality rate by FIA unit, on forest land, Ohio, 2006- 2011.

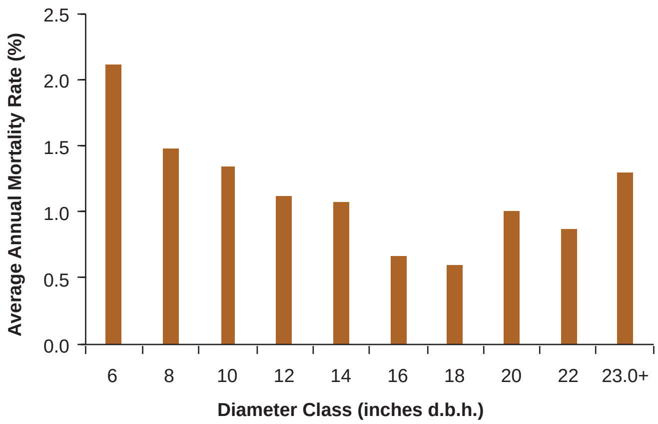
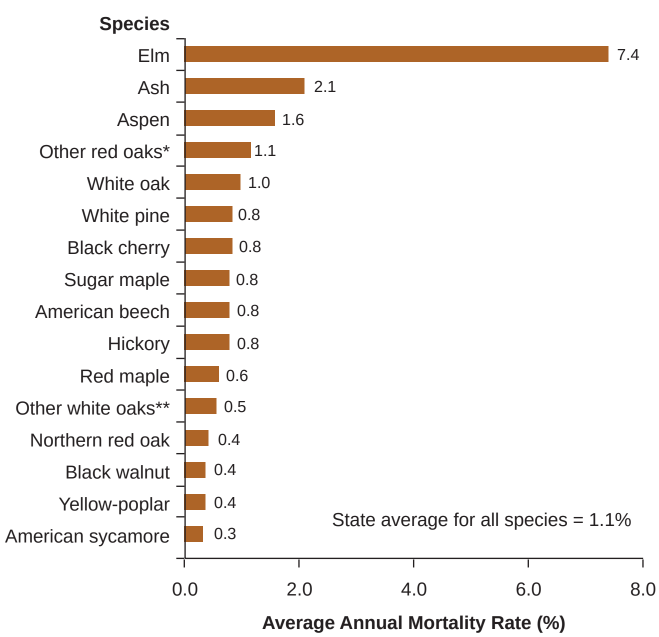


Figure 49.—Average annual mortality rate as a percent of current live trees volume on forest land by diameter class, Ohio, 2006- 2011.

Species groups with high annual mortality rates were elm, ash, and aspen at 7.4, 2.1, and 1.6 percent, respectively (Fig. 50). Yellow-poplar, the leading species in board-foot volume, had one of the lowest mortality rates (0.4 percent)—about a third of the State average for all species.



* Includes black, scarlet, pin, and shingle oak
**Includes chestnut, post, and overcup oak

Figure 50.—Average annual mortality rate as a percent of current live trees volume for major species, Ohio, 2006- 2011.

What this means

Since the tree mortality rates in Ohio are about the same as the surrounding states, they can be considered normal. Much of the mortality can be explained by stand dynamics or insects and diseases that target specific species. The maturing of Ohio's forests has resulted in 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 trees in the small-diameter classes. As discussed earlier, most trees less than 8.0 inches in diameter grow in the understory (Fig. 28), and one fifth of trees in the 6- and 8-inch diameter classes have live crowns less than 20 percent of their height—a sign of poor vigor in the smaller diameter classes (Fig. 29).

Elm and ash make up a large portion of the volume in the Northwestern Unit. High mortality in this unit is likely caused by Dutch elm disease and the emerald ash borer impacting these species. As the emerald ash borer infestation continues to spread, ash mortality will likely raise mortality rates in other units, especially in the Southwestern Unit where ash is the top species by volume.

Mortality rates vary between species with many species deviating substantially from the state average. Having a large diversity of species contributes to the resiliency of Ohio's forest to the impacts of insects and diseases that attack individual species.

Forest Indicators of Health and Sustainability

Shade River State Forest in Meigs County, in southeast Ohio. Photo by Ohio Department of Natural Resources, used with permission.

Tree Damage

Background

Tree damage is assessed for trees at least 5.0-inches in diameter. Up to two separate damages can be recorded on each tree. If more than two damage agents are observed, decisions about which two are recorded are based on the relative abundance of the damaging agents (U.S. For. Serv. 2010). The types of damage that are recorded include defoliation, foliage disease, cankers, decay, rot, fire, animal damage, weather, and logging damage.

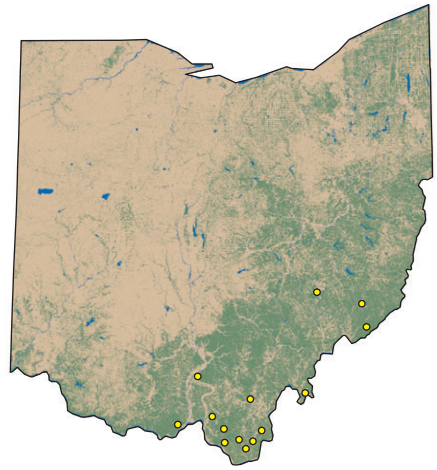


Figure 51.—Occurrence of insect defoliation on yellow-poplar, Ohio, 2011.

What We Found

Most of the damage on all species was decay, ranging from 7 percent on shagbark hickory to 33 percent for American beech (Table 3). Notably, 6 percent of yellow-poplar trees suffered damage from insect defoliation (Fig. 51). The occurrence of all other injury types was very low.

What This Means

Decay was the most commonly observed damage, predictable given that the majority of Ohio's forests are comprised of mature trees. American beech has the highest percentage of trees with decay, which is common to this species, but this will likely increase as beech bark disease continues to spread across the State.

Aerial damage surveys conducted within Ohio (U.S. For. Serv. 2013) revealed that the defoliation on yellow-poplar was most likely caused by a combination the yellow-poplar weevil (*Odontopus calceatus*) and tuliptree scale (*Toumeyella liriodendri*). These native insects are considered to be pests that can cause economic impacts in yellow-poplar if outbreaks occur over large areas.

Table 3.—Percent of trees with damage by species and damage type, Ohio, 2011

Damage Type	Red maple	Yellow-poplar	Sugar maple	Black cherry	White ash	White oak	Red oak	Shagbark hickory	American beech	Black oak
None	74	78	76	74	80	85	85	89	63	86
Insect defoliation	0	6	0	1	0	1	1	0	0	1
Bole insects	0	0	0	0	1	0	0	0	0	0
Foliage disease	0	0	0	0	0	0	0	0	0	0
Cankers	1	0	2	1	0	0	0	0	0	0
Decay	21	12	18	20	16	11	12	7	33	11
Root/butt rot	0	0	1	0	0	0	0	0	0	0
Fire	0	0	0	0	0	0	0	0	0	0
Animal	0	1	1	0	0	0	0	1	1	0
Weather	2	2	2	2	1	1	1	1	1	2
Logging/human	1	1	1	0	0	1	0	1	1	0

Crown Health

Background

The crown condition of trees is 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, or toxic pollutants. Biotic stressors include native or introduced insects, diseases, invasive plant species, and animals.

Seasonal or prolonged drought periods have long been a significant and historical stressor in Ohio. Significant drought has not occurred in the State since 1991, but moderate summer droughts occurred in 1999, 2002, and 2005, intermittent with some of the wettest summers on record in 2004 and 2011 (Fig. 52) (NCDC 2011). These periods of extreme precipitation can produce conditions that facilitate insect and/or disease outbreaks and can be even more devastating to trees previously stressed by pest damage or other agents.

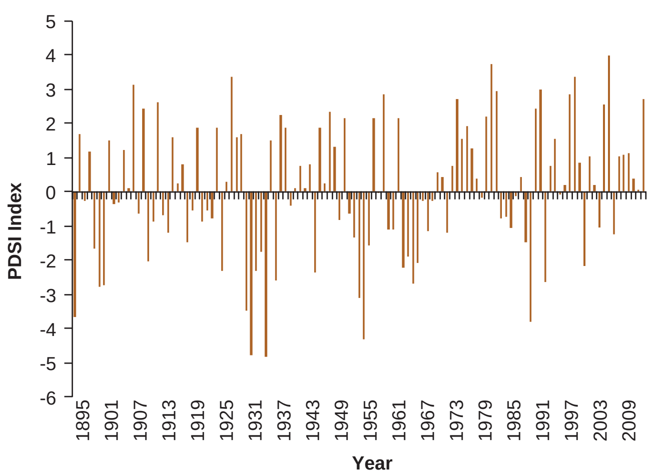


Figure 52.—Palmer Drought Severity Index (PDSI) 3-month average (June-August), Ohio, 1895-2011.

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 past century, Ohio's forests have suffered the effects of well-known exotic and invasive agents such as Dutch elm disease (*Ophiostoma ulmi*), chestnut blight (*Cryphonectria parasitica*), and European gypsy moth (*Lymantria dispar*). More recent invasions include beech bark disease complex and emerald ash borer (*Agrilus planipennis*). Tree-level crown measurements are collected on Phase 3 (P3) plots and include vigor class, crown ratio, light exposure, crown position, crown density, crown dieback, and foliage transparency (see Statistics, Methods, and Quality Assurance section of this report). Three of these factors were used to determine the condition of tree crowns: crown dieback, crown density, and foliage transparency.

Crown dieback is defined as recent mortality of branches with fine twigs and reflects the severity of recent stresses on a tree. Secondly, crown density is defined as the amount of crown branches, foliage, and reproductive structures that block light visibility through the crown and can serve as an indicator of expected growth in the near future. Finally, foliage transparency is the amount of skylight visible through the live, normally foliated portion of the crown. Changes in foliage transparency can also occur because of defoliation or from reduced foliage resulting from stresses during preceding years. A crown was labeled as 'poor' if crown dieback was greater than 20 percent, crown density was less than 35 percent, or foliage transparency was greater than 35 percent. These three thresholds were based on preliminary findings by Steinman (2000) that associated crown ratings with tree mortality. Crown dieback has been shown to be the best predictor of tree survival if crown variables are used individually (Morin et al. 2012).

Basal area is the cross sectional area of trees at d.b.h. This measure is used when comparing trees of different sizes. It gives more importance to larger diameter trees than smaller diameter trees. Crown health is presented here as a percentage of total live basal area by species.

What We Found

Mean dieback ranged from 0.5 percent for eastern white pine to 11.1 for elm species (Table 4). Black cherry had the second largest amount of dieback, averaging 8.0

percent. Observations of dieback in all other species were fairly low. In addition to having large amounts of dieback, elms also had the greatest proportion of trees with poor crowns, 24 percent (Table 5). Generally tree crown health was good for nearly all species across the State.

Table 4.—Mean crown dieback with statistics for live trees (>5 inches d.b.h.) on forest land by species or group, Ohio, 2011

Species	Trees	Mean	SE
	.... *number*	.... *percent*.......	
Elm spp.	71	11.1	3.0
Black cherry	151	8.0	1.5
White ash	65	6.8	1.8
Sassafras	37	6.6	2.7
White oak	69	6.3	2.1
Black locust	52	5.3	1.0
Black walnut	46	4.5	0.8
Black oak	42	3.7	0.9
Sugar maple	217	3.0	0.6
Red maple	229	3.0	0.7
American beech	22	2.7	0.9
Northern red oak	31	2.6	0.6
Red pine	23	2.0	0.5
Hickory spp.	115	1.9	0.6
Yellow-poplar	96	1.8	0.3
Green ash	21	1.4	0.7
Eastern white pine	37	0.5	0.3

Table 5.—Percent of live basal area with poor crowns by species, Ohio, 2006 and 2011.

	Percent of Basal Area with Poor Crowns	
Species	2006	2011
Elm spp.	16.3	24.9
Red maple	14.8	7.0
Black cherry	12.2	5.7
White ash	15.2	3.4
Sugar maple	6.5	2.7
White oak	4.0	2.1
Black oak	14.9	1.0
Yellow-poplar	6.6	0.9
Northern red oak	1.4	0.0
Shagbark hickory	0.1	0.0
American beech	0.1	0.0

The proportion of basal area with poor crowns has dropped for all species except elm since 2006. An analysis of the trees from the 2006 inventory that were remeasured in the 2011 inventory revealed that the proportion of the trees that died increased with crown dieback (Fig. 53).

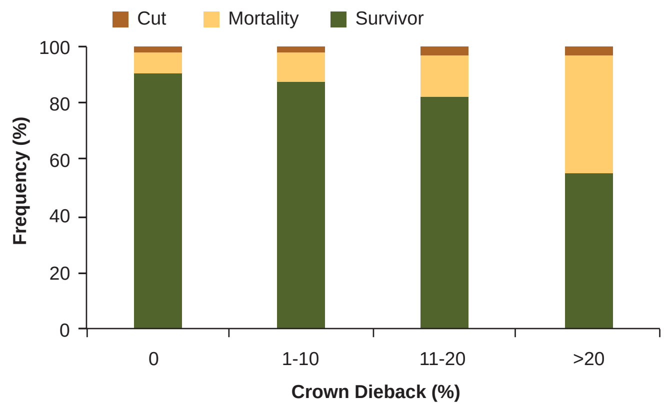


Figure 53.—Distribution of crown dieback (measured 2001-2006), by survival outcome (measured 2007-2011), Ohio.

What This Means

The elm species are widely distributed throughout Ohio's forests but are rarely a major overstory component. The cause of poor crown health in elms is due to the impacts of the exotic wilts *Ceratocystis ulmi* or Dutch elm disease in elm trees. Because of Dutch elm disease, elm species also have the highest mortality rate of all species in the State and are likely to remain a minor component of Ohio's forests. Unlike the elms, measures of crown health for ash trees do not coincide with the high mortality rate observed in this species group. This suggests that death may occur relatively quickly after emerald ash borer and other ash diseases cause observable dieback.

Ozone Bioindicator Plants

Background

Ozone (O_3) in the lower atmospheric is a byproduct of nitrogen oxide and volatile organic compound emissions (e.g., from power plants and motor vehicles). Ozone forms when nitrogen oxides and volatile organic compounds go through chemical transformation in the presence of sunlight (Brace et al. 1999). Ground-level ozone is known to have detrimental effects on forest ecosystems. Certain plant species exhibit visible, easily diagnosed foliar symptoms to ozone exposure. Ozone stress in a forest environment can be detected and monitored by using these plants as indicators. The FIA program uses these indicator plants to monitor changes in air quality across a region and to evaluate the relationship between them and ozone air quality.

The ozone-induced foliar injury on indicator plants is used to describe the risk of impact within the forest environment using a national system of sites (Smith et al. 2003, 2012). These sites are not co-located with FIA samples. Ozone plots are chosen for ease of access and optimal size, species, and plant counts. As such, the ozone plots do not have set boundaries and vary in size. At each plot, between 10 and 30 individual plants of three or more indicator species are evaluated for ozone injury. Each plant is rated for the proportion of leaves with ozone injury and the mean severity of symptoms using break points that correspond to the human eye's ability to distinguish differences. A biosite index is calculated based on amount and severity ratings where the average score (amount × severity) for each species is averaged across all species at each site and multiplied by 1,000 to allow risk to be defined by integers (Smith et al. 2007).

What We Found

Most of the indicator plants sampled were spreading dogbane (*Apocynum androsaemifolium*), white ash, milkweed (*Asclepias syriaca*), and blackberry (*Rubus*) (Table 6). The findings for Ohio indicate that risk of foliar injury due to ozone has dropped substantially since 2001 (Table 7 and Fig. 54). Ozone exposure levels have been trending downward since 1998 but inter-year variation is often important (Fig. 55, Fig. 56).

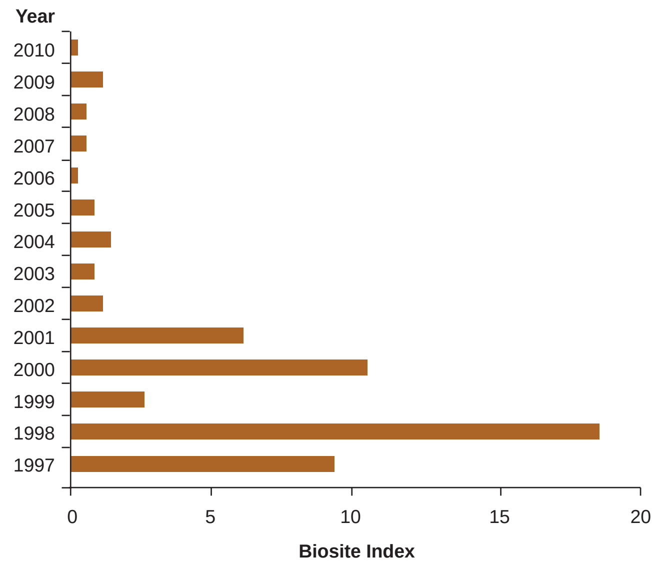


Figure 54.—Biosite index for risk of ozone injury, Ohio, 1997- 2010.

Table 6.—Number of plants sampled for ozone injury and percent exhibiting injury, by species, Ohio, 1997-2010

Species	Number	Percent
Spreading dogbane	8979	24.0
White ash	7696	20.6
Milkweed	5943	15.9
Blackberry	5907	15.8
Black cherry	3211	8.6
Sassafras	3101	8.3
Yellow-poplar	2045	5.5
Pin cherry	207	0.6
Unknown	141	0.4
Sweetgum	101	0.3
Big leaf aster	32	0.1
Total	37,363	100.0

Table 7.—Region-level summary statistics for ozone bioindicator program, Ohio, 1997-2010

Parameter	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Number of biosites evaluated	19	19	18	19	34	34	34	34	34	34	35	34	36	40
Number of biosites with injury	10	12	4	5	8	8	9	12	10	7	4	4	5	9
Average biosite index score	9.25	18.45	2.68	10.41	6.16	1.25	0.83	1.38	0.75	0.29	0.41	0.52	1.03	0.26
Number of plants evaluated	1,417	926	810	1,713	3,114	3,175	3,366	3,357	3,060	3,124	3,208	3,270	3,092	3,731
Number of plants injured	69	72	22	41	92	117	123	73	29	29	22	13	20	18
Maximum SUM06 value (ppm-hr)[a]	21.5	29.51	32.64	18.69	27.08	35.59	20.76	11.23	23.69	18.68	18.77	13.73	6.13	-

[a]Averaged from State values

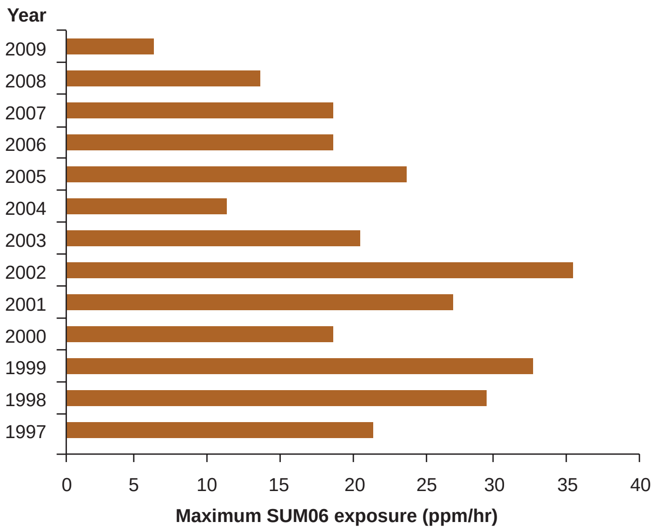


Figure 55.—Maximum SUM06 ozone exposure levels from Environmental Protection Agency ozone monitoring stations, Ohio, 1997- 2009.

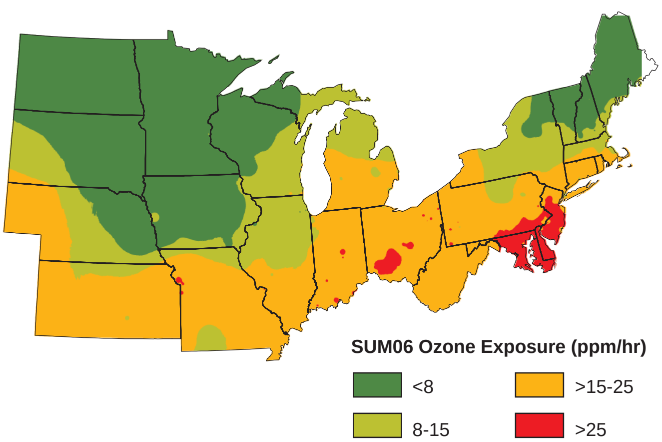


Figure 56.—Spatial interpolation of mean 3-month cumulative ozone exposure (SUM06), for 1994-2009.

What This Means

The risk of ozone damage on foliage in Ohio's forests has fallen since 2001, in spite of the fact that Ohio is located in areas of medium and high risk to ozone exposure (Coulston et al. 2003).

A typical summer O_3 exposure pattern for the northern United States is shown in Figure 56 (Smith et al. 2012). The term SUM06 is defined as the sum of all valid hourly O_3 concentrations that equal or exceed 0.06 ppm (U.S. EPA 2007). Controlled studies have found that high O_3 levels (shown in orange and red) can lead to measurable growth suppression in sensitive tree species (Chappelka and Samuelson 1998). Smith et al. (2003) reported that even when ambient O_3 exposures are high, the percentage of injured plants can be reduced sharply in dry years.

Down Woody Material

Background

Down woody materials, in the various forms of fallen trees and litter fall, fulfill a critical ecological niche in Ohio's forests. Down woody materials provide valuable wildlife habitat, stand structural diversity, and a store of carbon/biomass. Down woody material also contributes to forest fire hazards via surface woody fuels; measures of down woody materials can be useful in assessing the risk of wildfire.

What We Found

The fuel loadings of down woody materials (time-lag fuel classes) are not exceedingly high in Ohio (Fig. 57). When compared to the neighboring states of Pennsylvania and Indiana, Ohio's fuel loadings of various fuel classes are not substantially different (for fuel definitions see Woodall and Monleon 2008). Ohio's oak/hickory and maple/beech/birch forest-type groups contain the most of the coarse woody debris biomass, almost entirely within private ownership (Fig. 58). The detrital carbon stocks within Ohio's forests are dominated by the forest floor components of litter, duff, and coarse woody debris at approximately 41, 15, and 14 billion tons, respectively (Fig. 59). The top three forest-type groups in terms of volume per acre of coarse woody debris are maple/beech/birch, oak/hickory, and elm/ash/cottonwood (Fig. 60). The low volume but relatively high counts within the elm/ash/cottonwood forest-type group suggest a relatively small size of coarse woody debris within this forest type.

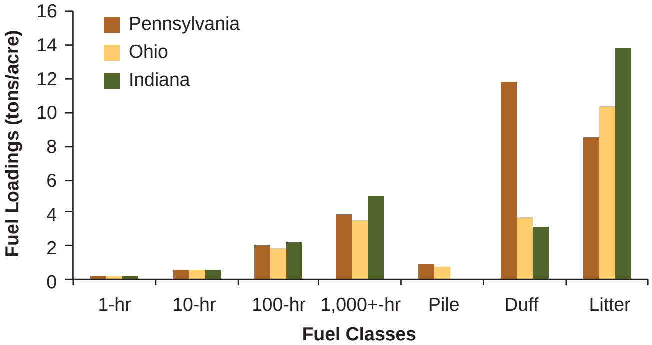


Figure 57.—Mean fuel loadings (tons/acre, time-lag fuel classes) by fuel type on forest land in Ohio and neighboring states, 2006-2010.

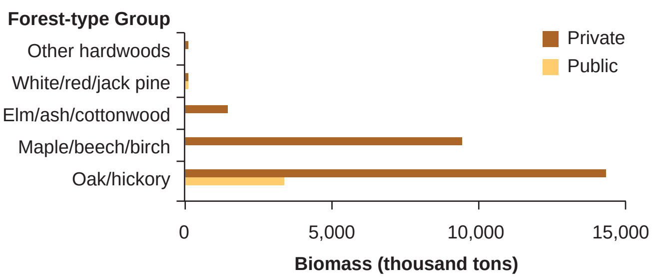


Figure 58.—Estimate of coarse woody biomass for top five forest-type groups by private and public ownership, Ohio, 2006-2010.

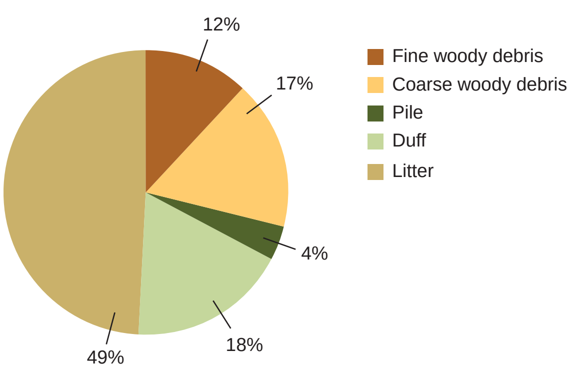


Figure 59.—Proportion of total carbon stocks by down woody material component, Ohio, 2006-2010.

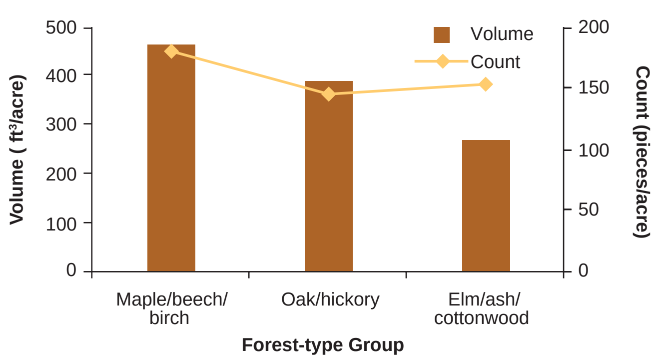


Figure 60.—Volume (ft^3/acre) and counts (pieces/acre) for coarse woody debris for the top three forest-type groups (by volume) in Ohio, 2006-2010.

What This Means

The down woody fuel loadings in Ohio's forests are not exceedingly different from those found in neighboring states. Therefore, only in times of extreme drought would these small amounts of fuels pose a hazard. Of all down woody components, litter had the largest fuel loadings related to the dominance of hardwood ecosystems across the State. In contrast, Pennsylvania with higher latitude forests had much greater duff tonnage. In Ohio, most of coarse woody debris biomass is found on private land which aligns with the general forest land ownership patterns across the State. Commensurate with estimates of fuel loadings, the forest floor component of litter dominates the proportion of detrital carbon stocks. Piles of coarse woody debris (i.e., harvest residue piles) were a minor component (≈ 4 percent) of down woody material across the State. The balance between the mean volume and counts of coarse woody debris among the top three forest-type groups suggests dominance of average-sized dead wood wildlife habitat. The exception is the elm/ash/cottonwood forest-type group which tends to have smaller-sized coarse woody debris. Generally, because fuel loadings are not exceedingly high, and larger fuels typically do not burn, the threat to Ohio's forests from wildfires is low and possible fire dangers may be outweighed by the down woody material benefits of wildlife habitat, biomass, and carbon sinks.

Vegetation Diversity

Background

Forest understory vegetation has many significant ecological roles. Within forests, vegetation helps to regulate the microclimate, mitigate erosion and runoff, sequester carbon, and provide habitat and forage for wildlife. Many plant species have cultural, aesthetic, medicinal, or culinary importance. The vegetation data gathered on forested P3 plots provide information on forest structure, diversity, abundance, and ecosystem health. Some plants have specific roles in the forested community and require very specific site characteristics. Within the plant community, they filter pollutants and can indicate air quality, nutrient availability, and provide species-specific habitat niches. Plant communities were sampled from 2007 to 2010 in Ohio on 85 P3 plots (approximately 6.3 percent of field plots).

What we found

FIA found 769 different plant species growing in Ohio's forest on the P3 plots measured between 2007 and 2010. This diverse array of species covers six growth habits (forb/herb, graminoid, shrub, subshrub, tree, and vine). The greatest number of species (404; Fig. 61) was in the forb/herb growth habit. The other 365 plant species consisted of 146 species of graminoids, 99 species of trees, 36 species of shrubs, 39 species of subshrubs, and 42 species of vines. Of these species, 632 (82 percent) were native to the United States, 125 species (16 percent) were introduced (nonnative), and 12 species (2 percent) were native and introduced, a category where in the classification of some subspecies are native and others are introduced (Fig. 62).

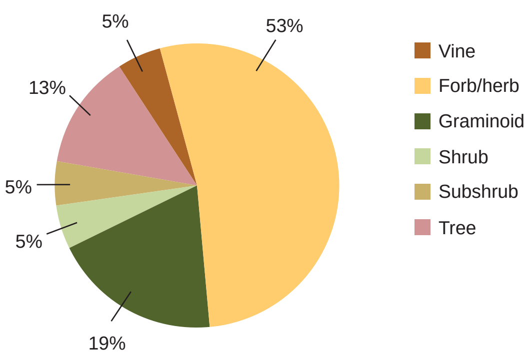


Figure 61.—Proportion of species on Ohio P3 plots, categorized by growth habit, (NRCS 2012), 2007-2010.

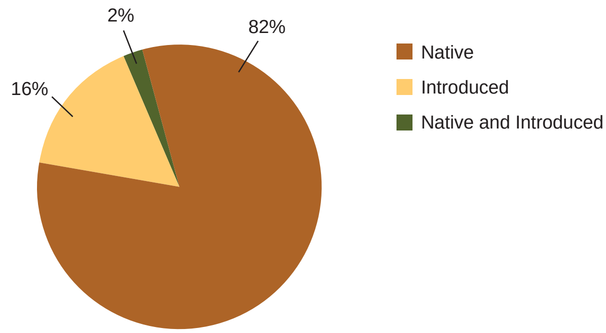


Figure 62.—Proportion of species on Ohio P3 plots by origin (NRCS 2012), 2007-2010.

The most frequently observed understory species was eastern poison ivy (*Toxicodendron radicans*), which occurred on 81 plots (95 percent of plots; Table 8), and was closely followed by Virginia creeper (*Parthenocissus quinquefolia*; 80 plots; 94 percent of plots). The most common tree species was black cherry (77 plots; 91 percent). Of the 35 most commonly observed species, two were introduced invasive plant species (multiflora rose [*Rosa multiflora*] and Japanese honeysuckle [*Lonicera japonica*]). A list of the 15 most commonly observed nonnative plant species is shown in Table 9 with multiflora rose being the most frequently recorded (77 plots; 91 percent).

What this means

A diverse mix of plant species is important to wildlife with some species requiring the presence of a specific plant for survival. The P3 data provide land managers with information to make informed decisions and show important baseline diversity, structure, and forest health trends at a statewide level. In the future, climate change may further increase the impacts from invasive plant species that already threaten native forest vegetation.

Table 8.—The 35 most commonly observed plant species on P3 plots, Ohio, 2007 to 2010

Species	Origin	Number of plots	Percentage of plots
Eastern poison ivy *(Toxicodendron radicans)*	Native	81	95
Virginia creeper *(Parthenocissus quinquefolia)*	Native	80	94
Black cherry *(Prunus serotina)*	Native	77	91
Multiflora rose *(Rosa multiflora)*	Introduced	77	91
White ash (*Fraxinus americana*)	Native	69	81
American elm (*Ulmus americana*)	Native	66	78
Red maple (*Acer rubrum*)	Native	62	73
Sugar maple (*Acer saccharum*)	Native	58	68
Common blue violet (*Viola sororia*)	Native	56	66
Northern red oak (*Quercus rubra*)	Native	55	65
White avens (*Geum canadense*)	Native	53	62
Flowering dogwood (*Cornus florida*)	Native	53	62
Northern spicebush (*Lindera benzoin*)	Native	50	59
Black raspberry (*Rubus occidentalis*)	Native	48	57
White snakeroot *(Ageratina altissima* var. *altissima)*	Native	47	55
Bitternut hickory *(Carya cordiformis)*	Native	47	55
American beech *(Fagus grandifolia)*	Native	46	54
Shagbark hickory *(Carya ovata)*	Native	45	53
Sassafras *(Sassafras albidum)*	Native	45	53
Christmas fern *(Polystichum acrostichoides)*	Native	44	52
Mayapple *(Podophyllum peltatum)*	Native	43	51
Jumpseed *(Polygonum virginianum)*	Native	43	51
Common cinquefoil *(Potentilla simplex)*	Native	42	49
White oak *(Quercus alba)*	Native	41	48
Stickywilly *(Galium aparine)*	Native	40	47
Black oak *(Quercus velutina)*	Native	39	46
Licorice bedstraw *(Galium circaezans)*	Native	38	45
American hornbeam *(Carpinus caroliniana)*	Native	38	45
Roundleaf greenbrier *(Smilax rotundifolia)*	Native	37	44
Black walnut *(Juglans nigra)*	Native	37	44
Hophornbeam *(Ostrya virginiana)*	Native	37	44
Yellow-poplar *(Liriodendron tulipifera)*	Native	36	42
Summer grape *(Vitis aestivalis)*	Native	36	42
Blackgum *(Nyssa sylvatica)*	Native	35	41
Japanese honeysuckle *(Lonicera japonica)*	Introduced	35	41

Table 9.—The 15 most commonly observed nonnative plant species found on P3 plots, Ohio, 2007-2010

Common Name	Number of plots	Percentage of plots
Multiflora rose *(Rosa multiflora)*	77	91
Japanese honeysuckle *(Lonicera japonica)*	35	41
Garlic mustard *(Alliaria petiolata)*	32	38
Common dandelion *(Taraxacum officinale)*	31	37
Ground ivy *(Glechoma hederacea)*	27	32
Spotted ladysthumb *(Polygonum persicaria)*	27	32
Canada bluegrass *(Poa compressa)*	25	29
European privet *(Ligustrum vulgare)*	23	27
Common yarrow *(Achillea millefolium)*	23	27
Nepalese browntop *(Microstegium vimineum)*	22	26
Amur honeysuckle *(Lonicera maackii)*	20	24
Queen Anne's lace *(Daucus carota)*	19	22
American red raspberry *(Rubus idaeus)*	19	22
Orchardgrass *(Dactylis glomerata)*	15	18
Common plantain *(Plantago major)*	15	18

Invasive Plant Species

Background

Invasive plant species (IPS) pose a significant threat to Ohio's ecosystems. IPS can be native or introduced and are highly competitive. In Ohio most IPS are nonnative. Many of these plants can readily grow from vegetative propagules (e.g., multiflora rose), produce an abundance of seed (e.g., tree-of-heaven), and/or leaf out before their native counterparts (e.g., common buckthorn [*Rhamnus cathartica*] and nonnative bush honeysuckles [*Lonicera* ssp.]). These species can displace native flora and fauna and disrupt ecological communities. Economically, these species are a concern as they increase management expenses. Pimentel et al. (2005) reported the estimated cost of controlling purple loosestrife, a prolific wetland invader, at $5 million per year.

IPS can also impact agricultural systems. Common barberry (*Berberis vulgaris*) is an alternate host for wheat stem rust which can cause the complete loss of some grain fields (Kurtz 2013). Common buckthorn is also a troublesome invader as it is one of the alternate hosts for the soybean aphid (*Aphis glycines*). After IPS establish in an area, some may alter the soil nutrient availability (e.g., common buckthorn) which can displace native species and promote their spread. There are an estimated 5,000 alien plant species established in the natural ecosystems of the United States. (Pimentel et al. 2005). To monitor the distribution and abundance of IPS, FIA has been collecting data on these plants on Ohio's forested Phase 2 (P2) Invasive plots. From 2007 through 2011, invasive species data were collected on 340 forested plots (approximately 20 percent of the P2 field plots).

What we found

The list of the 43 IPS and one undifferentiated genus (*Lonicera* spp.) that FIA monitors is shown in Table 10. Of this total, 14 were woody, 13 were herbaceous, 11 were trees, three were grasses, and three were vines. Thirty-two of the targeted invasive species from Table 10 were present on Ohio's 340 P2 Invasive plots (Table 11). Multiflora rose was the most commonly observed IPS, found on 291 plots (85.6 percent). Japanese honeysuckle and garlic mustard were the other two target IPS that were found on greater than 25 percent of the monitored plots. All of the invasive species monitored had an average subplot cover (average coverage is based on subplot data and is calculated only for the subplots where the species is present.) of less than 18 percent, except for common reed which had an average subplot cover of 52 percent but occurred on only three plots (Table 11). Figure 63 shows the number of IPS per plot, which ranged from zero to nine species. Like most IPS, multiflora rose was found on P2 Invasive plots throughout the State (Fig. 64, Table 11).

Table 10.—The list of 43 invasive plant species and one undifferentiated genera monitored by FIA on P2 Invasive plots, 2007-2011

Tree Species
Black locust *(Robinia pseudoacacia)*
Chinaberry *(Melia azedarach)*
Norway maple *(Acer platanoides)*
Russian olive *(Elaeagnus angustifolia)*
Princesstree *(Paulownia tomentosa)*
Punktree *(Melaleuca quinquenervia)*
Saltcedar *(Tamarix ramosissima)*
Siberian elm *(Ulmus pumila)*
Silktree *(Albizia julibrissin)*
Tallow tree *(Triadica sebifera)*
Tree-of-heaven *(Ailanthus altissima)*
Woody Species
Amur honeysuckle *(Lonicera maackii)*
Autumn olive *(Elaeagnus umbellata)*
Common barberry *(Berberis vulgaris)*
Common buckthorn *(Rhamnus cathartica)*
European cranberrybush *(Viburnum opulus)*
European privet *(Ligustrum vulgare)*
Glossy buckthorn *(Frangula alnus)*
Japanese barberry *(Berberis thunbergii)*
Japanese meadowsweet *(Spiraea japonica)*
Morrow's honeysuckle *(Lonicera morrowii)*
Multiflora rose *(Rosa multiflora)*
Nonnative bush honeysuckle *(Lonicera* spp.*)*
Showy fly honeysuckle *(Lonicera xbella)*
Tatarian honeysuckle *(Lonicera tatarica)*
Vine Species
English ivy *(Hedera helix)*
Japanese honeysuckle *(Lonicera japonica)*
Oriental bittersweet *(Celastrus orbiculatus)*

Herbaceous Species
Black swallow-wort *(Cynanchum louiseae)*
Bull thistle *(Cirsium vulgare)*
Canada thistle *(Cirsium arvense)*
Creeping jenny *(Lysimachia nummularia)*
Dames rocket *(Hesperis matronalis)*
European swallow-wort *(Cynanchum rossicum)*
Garlic mustard *(Alliaria petiolata)*
Giant knotweed *(Polygonum sachalinense)*
Japanese knotweed *(Polygonum cuspidatum)*
Leafy spurge *(Euphorbia esula)*
P. cuspidatum/P. sachalinense hybrid *(Polygonum xbohemicum)*
Purple loosestrife *(Lythrum salicaria)*
Spotted knapweed *(Centaurea stoebe* ssp. *micranthos)*

Grass Species
Common reed *(Phragmites australis)*
Nepalese browntop *(Microstegium vimineum)*
Reed canarygrass *(Phalaris arundinacea)*

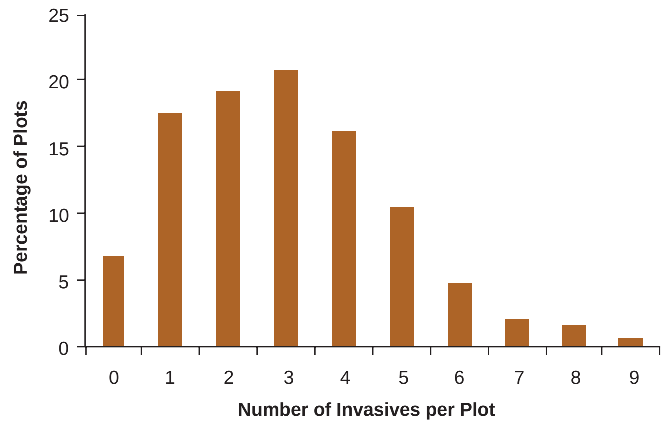


Figure 63.—Number of invasive plant species found on each P2 Invasive plot, Ohio, 2011. Note: Forty-four invasive plant species monitored from 2007-2011.

Table 11.—Invasive species observed on Ohio P2 Invasive plots, 2007-2011

Species	Number of plots	Percentage of plots	Average cover (%)
Multiflora rose *(Rosa multiflora)*	291	86	10
Japanese honeysuckle *(Lonicera japonica)*	110	32	13
Garlic mustard *(Alliaria petiolata)*	96	28	7
Black locust *(Robinia pseudoacacia)*	76	22	13
Amur honeysuckle *(Lonicera maackii)*	53	16	18
Autumn olive *(Elaeagnus umbellata)*	49	14	9
European privet *(Ligustrum vulgare)*	48	14	2
Nepalese browntop *(Microstegium vimineum)*	43	13	4
Japanese barberry *(Berberis thunbergii)*	42	12	3
Tree-of-heaven *(Ailanthus altissima)*	36	11	13
Creeping jenny *(Lysimachia nummularia)*	20	6	12
Oriental bittersweet *(Celastrus orbiculatus)*	20	6	4
Showy fly honeysuckle *(Lonicera xbella)*	19	6	17
Canada thistle *(Cirsium arvense)*	15	4	7
Morrow's honeysuckle *(Lonicera morrowii)*	14	4	7
Russian olive *(Elaeagnus angustifolia)*	11	3	6
Glossy buckthorn *(Frangula alnus)*	10	3	7
Nonnative bush honeysuckle *(Lonicera* spp.)	9	3	4
Tatarian honeysuckle *(Lonicera tatarica)*	6	2	3
Common buckthorn *(Rhamnus cathartica)*	5	2	4
Reed canarygrass *(Phalaris arundinacea)*	5	2	4
Dames rocket *(Hesperis matronalis)*	5	2	2
Common barberry *(Berberis vulgaris)*	4	1	1
Spotted knapweed *(Centaurea stoebe L.* ssp. *micranthos)*	4	1	1
Common reed *(Phragmites australis)*	3	1	52
Bull thistle *(Cirsium vulgare)*	3	1	1
European cranberrybush *(Viburnum opulus)*	2	1	9
Purple loosestrife *(Lythrum salicaria)*	2	1	1
Norway maple *(Acer platanoides)*	2	1	1
Princesstree *(Paulownia tomentosa)*	1	0	2
Giant knotweed *(Polygonum sachalinense)*	1	0	3
Japanese knotweed *(Polygonum cuspidatum)*	1	0	1

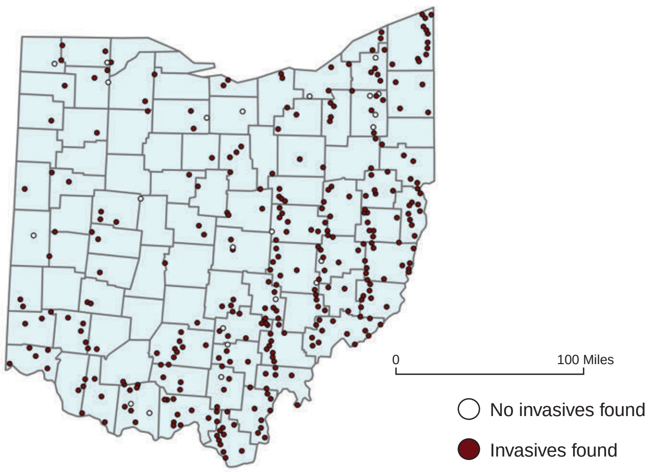


Figure 64.—Distribution of invasive plant species found on P2 Invasive plots, Ohio, 2011. Plot locations are approximate.

What this means

Ohio had a large number of IPS detected on the inventory plots with 93.2 percent of plots having invasives present. The data suggest that these plants are widespread throughout the State, which is worrisome as they have the potential to alter the forest community by inhibiting regeneration and changing forest structure, habitat quality, and hydrology. Continued collection of IPS data is important to help land managers understand the abundance, distribution, and spread of these species over time. Monitoring invasives in future inventories will enhance our understanding of how they impact the forest structure and help determine what site characteristics influence their presence. This will help managers minimize the impact of IPS within the forest.

Forest Habitats

Forests, woodlands, and savannas provide habitats for many species of Ohio birds (124), mammals (42), and amphibians or reptiles (53) (NatureServe 2011). Different forest types at different structural stages provide natural communities (habitats) at a "coarse filter" (landscape) scale of conservation. Rare, imperiled, or wide-ranging wildlife species may not be fully served at this scale, so a "fine filter" (local) approach is used to identify species-specific conservation needs. Representing an intermediate or "meso-filter" scale of conservation are specific habitat features (e.g., snags, riparian forest strips), which may serve particular habitat requirements for multiple species.

Like all states, Ohio has developed a Comprehensive Wildlife Conservation Strategy, commonly known as State Wildlife Action Plans (SWAP) (ODNR n.d.), based upon guidance provided by Congress, the U.S. Fish and Wildlife Service, and the International Association of Fish and Wildlife Agencies. Ohio's SWAPs program addresses all terrestrial wildlife and key habitats in the State. Of particular note for forest-associated wildlife, the SWAPs states, "Acreage in the brushy stage of forest succession, and the animal populations dependent on it, are declining as Ohio's forests mature." This section of the report focuses on key forest and woodland habitats at the coarse-filter scale (forest age/size structure) and meso-filter scale (standing dead trees). Additional characteristics important for wildlife habitat, like forest composition and forest fragmentation, are discussed elsewhere within this report.

Stand Structure, Age and Size, for Wildlife Habitat

Background

Some species of wildlife depend on early successional forests comprised of smaller, younger trees, while others require older, interior forests containing large trees and having a complex canopy structure. Yet other species inhabit the ecotone (edge) between different forest stages, and many require multiple structural stages of forests to meet different phases of their life history needs. Abundance and trends in these structural and successional stages serve as indicators of population carrying capacity for wildlife species (Hunter et al. 2001).

What we found

Total area of Ohio forest land has changed little in recent decades, showing a slight increase since 1979 (Fig. 2). The abundance of stands containing trees in the large-diameter stand-size class has increased steadily, from 43 percent of all forest land in 1979, to 66 percent in 2011. The acreage in the medium-diameter class has remained fairly stable at 21 to24 percent while the stands containing trees in the small-diameter class has decreased substantially, from 35 percent in 1979 to 11 percent in 2011 (Fig. 65). Since 1991, timberland area within the 41 to 100 year old stand-age classes has increased substantially. In contrast the area of younger forests (under 20 years) decreased dramatically between 1991 and 2011. Older forests of 100+ years comprised only about 3 percent of all forest land, a fraction that has remained stable over the past two decades (Fig. 66).

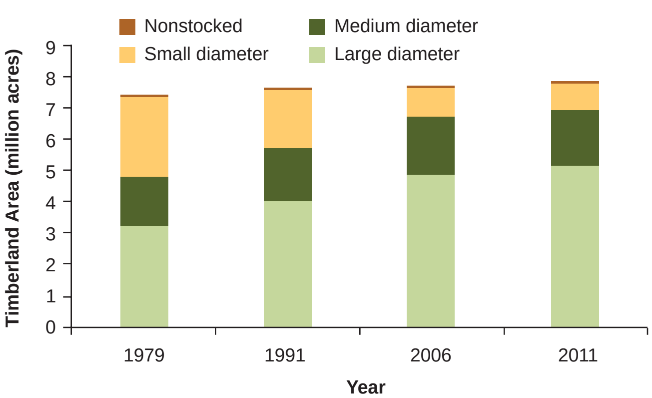


Figure 65—Area of timberland by stand-size class and inventory year, Ohio, 1979-2011.

Figure 66.—Area of timberland by stand-age class and inventory year, Ohio, 1991-2011.

In Ohio, all three stand-size classes occur in forests of multiple ages. As expected, small diameter forest is comprised predominately by young forests of 0 to 20 year age class, but also occurs in forests up to 60 years (Fig. 67). The medium stand-size class is comprised predominately by forests of 21 to 60 years of age, with lower abundances of both younger and older forest. Forests having 41 to 80 years of age comprise the largest proportion of stands within the large diameter stand-size class.

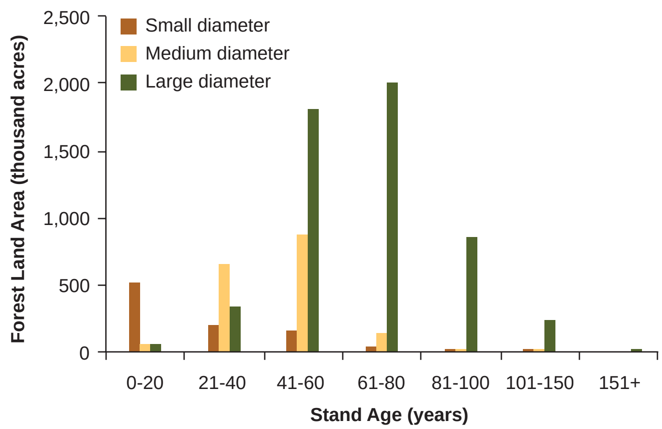


Figure 67.—Area of forest land by age class and stand-size class, Ohio, 2011.

What this means

The areas of Ohio timberland in the large diameter stand-size class increased by 60 percent while the area in small diameter class decreased by 65 percent during the past three decades. Similarly, the area of timberland over 60 years of age increased by 68 percent while the area of 0 to 20 year old timberland decreased by 78 percent since 1991. Stand-size class and stand-age class are indicators of the relationship between forest structural and the successional stage. It is interesting to see the presence of small-diameter stands in older stand-age classes and the occurrence of large-diameter forest in younger stand-age classes. These combinations can occur after selective harvesting operations when a stand can contain various mixtures of large residual trees and young regeneration. Such mixtures of different ages and sizes of trees provide a vertical diversity of vegetation structure that can enhance habitat conditions for wildlife species.

Across the landscape there is a need to maintain forest conditions in both smaller and larger structural stages in order to maintain both early and late successional habitats for all a range of forest-associated species. The trend of modest increasing forest land area is generally interpreted as a positive conservation outcome, but the composition and structure of additions to forest from nonforest areas reverting to forest can differ substantially from forest habitat lost due to forest being cleared for development. Managing for both forest and nonforest habitats across a variety of compositional and structural conditions will promote healthy wildlife populations in Ohio.

Standing Dead Trees

Background

Specific habitat features such as nesting cavities and standing dead trees provide critical habitat components for many forest-associated wildlife species. Standing dead trees that are large enough to meet habitat requirements for wildlife are referred to as ‘snags’. According to one definition, “…for wildlife habitat purposes, a snag is sometimes regarded as being at least 10 inches d.b.h. and at least 6 feet tall” (Helms 2008). Standing dead trees also serve as important indicators of past disturbance events and provide carbon storage. In addition, they serve as future sources of down woody material (discussed elsewhere in this report), which also provides additional habitat features for wildlife. The density, decay classes, species, and sizes of standing dead trees define an important wildlife habitat feature across Ohio forests.

What we found

FIA collects data on standing dead trees (at least 5 inches d.b.h.) by species, sizes and stage of decay. More than 100 million standing dead trees are present on Ohio forest land. This equates to an overall density of 12.5 standing dead trees per acre of forest land, with similar densities on public (12.8) and private (12.5) forest land. Fifteen species groups each contributed more than one million standing dead trees, with “other eastern soft hardwoods” exceeding 37 million as the top group (Fig. 68); American elm, within that group, lead all individual species with 13.6 million standing dead trees. Relative to the total number of live trees in each species group, seven species groups exceeded 10 standing dead trees per 100 live trees (of at least 5 inch d.b.h.), with “other eastern hard hardwoods” species group topping the list at over 39 standing dead trees per 100 live trees (Fig. 69). The “other eastern hard hardwoods group”, which is predominated by black locust, had the second highest density of standing dead trees per 100 live trees in Ohio. Eighty-one percent of standing dead trees were smaller than 11 inches d.b.h., with 43 percent being smaller than 7 inches d.b.h. (Fig. 70). Nearly 83 percent of standing dead trees showed intermediate levels of decay, a pattern which was consistent across diameter classes (Fig. 70).

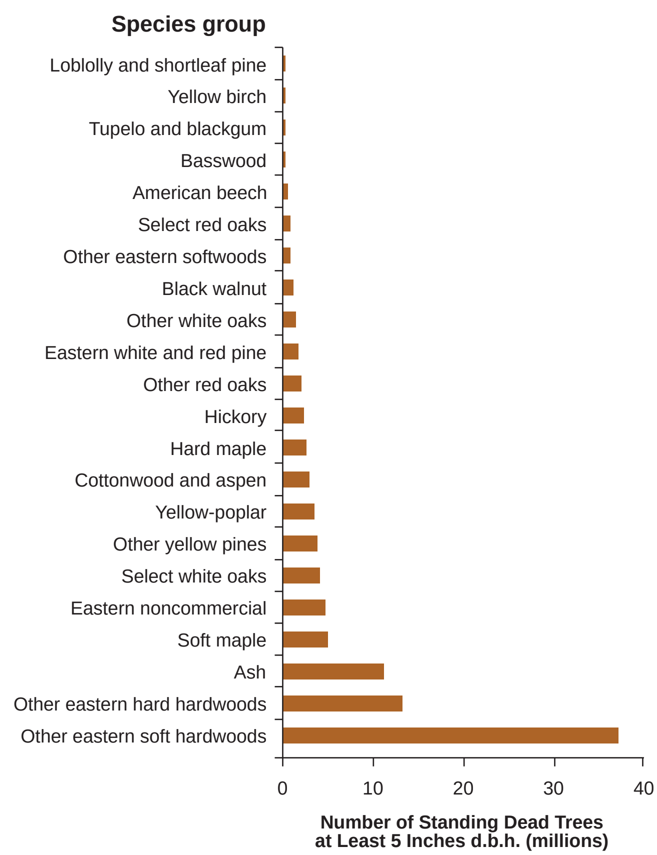


Figure 68.—Number of standing dead trees on forest land by species group, Ohio, 2011.

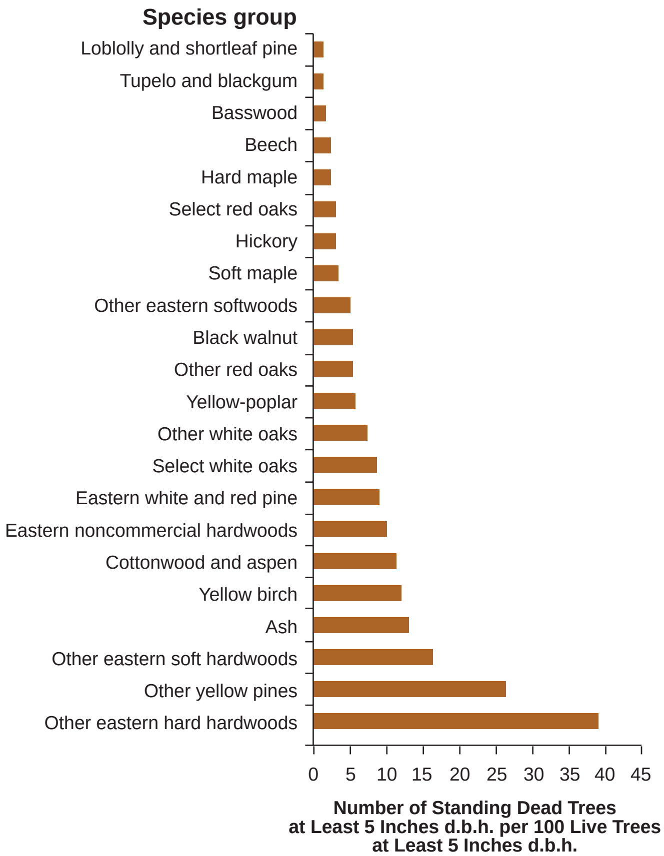


Figure 69.—Number of standing dead trees per 100 live trees on forest land by species group, Ohio, 2011.

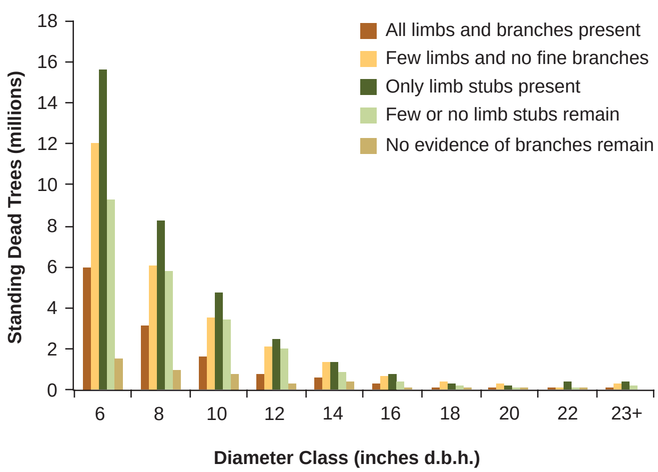


Figure 70.—Distribution of standing dead trees on forest land by diameter and decay classes for all dead trees, Ohio, 2011.

What this means

Snags and smaller standing dead trees result from a variety of potential causes, including competition, diseases and insects, weather damage, fire, flooding, drought, and other factors. The "other eastern soft hardwoods" species group contained the largest total number of standing dead trees; which included American elm was the predominant single species within that group. Compared to the number of live trees, the number of standing dead trees is relatively small, but they typically contain significantly more cavities per tree than occur in live trees (Fan et al. 2003). Standing dead trees provide locations for foraging, nesting, roosting, perching, and cavity excavation for wildlife, ranging from primary colonizers such as insects, bacteria, and fungi, to birds, mammals, and reptiles. Most cavity nesting birds are insectivores, which help to control insect populations. The availability of very large snags may be a limiting habitat feature for some species of wildlife, such as cavity nesting birds. Providing a variety of forest structural stages and retaining specific features like snags on both private and public lands are ways in which forest managers maintain the abundance and quality of habitat for forest-associated wildlife species in Ohio.

Tree Species of Concern in Ohio

Ash

Background

The emerald ash borer (EAB) is an exotic bark-boring beetle native to Asia that was discovered in Detroit, Michigan, in 2002 (Kovacs 2010). Initially detected in Ohio near Toledo in 2003, the pest has since spread to nearly all other parts of the State. EAB represents a major threat to the State's ash resource, killing host trees within 3 to 5 years of infestation. All ash species in Ohio (white, green, black, blue, and pumpkin), regardless of tree vigor, are at risk. EAB has already killed millions of ash trees in Ohio. Currently all counties in Ohio are under federal regulation for the EAB, which restricts the shipment of ash material to other states, although there are no longer quarantine regulations in place for the movement of ash material within the State.

What we found

Ash species are common on forest land throughout much of the State and are also widely planted in urban areas. Ash species represent 8 percent of the total volume of trees in Ohio's forests, and in some counties ash accounts for over 30 percent of the total volume (Fig 71). Ash reaches its highest volumes per acre in the Southwestern and Northwestern Units (Fig. 72). Between 2007 and 2011, ash mortality averaged 1.9 million trees (2 percent), 5-inches d.b.h. and larger, annually in Ohio's forests. Mortality rates for ash are highest in the Northwestern and Northeastern Units and lowest in the Southwestern Unit (Fig. 73).

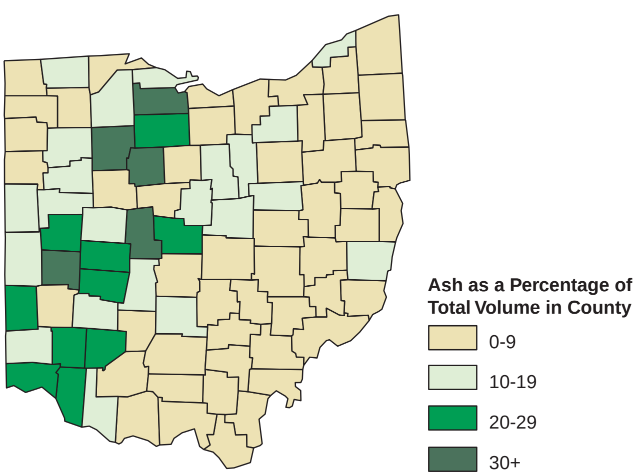


Figure 71.—Ash volume as a percentage of total tree volume, by county, Ohio, 2011.

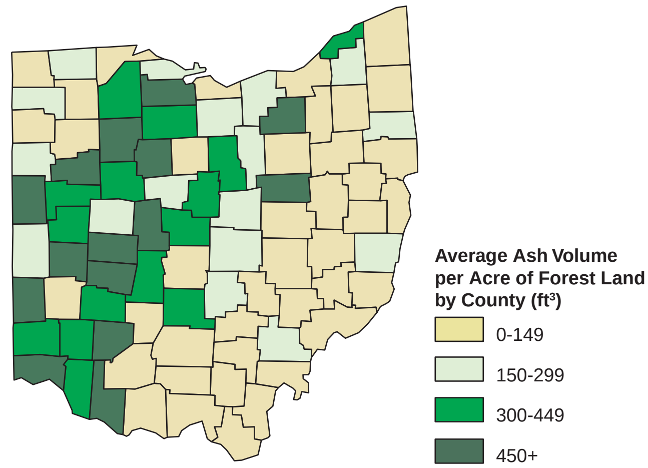


Figure 72.—Average ash volume per acre of forest land, by county, Ohio, 2011.

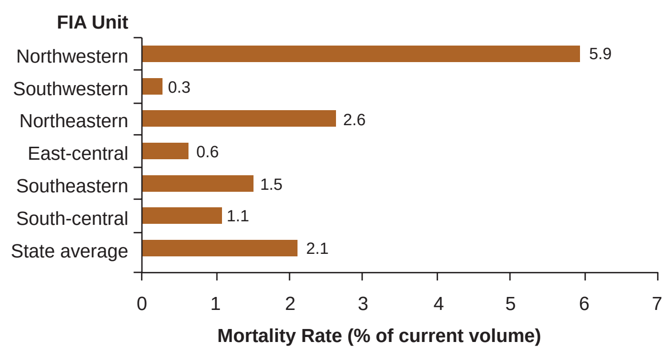


Figure 73.—Average annual ash mortality rate as a percentage of total volume, by FIA unit, Ohio, 2011.

What this means

Emerald ash borer is causing significant financial costs to municipalities, property owners, and the forest products industry. Although "ash yellows disease" (*Candidatus fraxinii*) is present in Ohio, EAB is likely to be the largest contributor to ash morality throughout the State. Currently Ohio's Southwestern Unit has high densities of ash and low mortality rates for ash. Ash mortality will likely rise significantly as EAB spreads throughout this unit. Statewide, the species composition and forest structure will likely change as ash gives way to more maple-dominated stand and likely facilitate establishment and expansion of invasive plant species. Annual forest inventories by FIA will monitor the ash resource at risk and how forests respond to its loss.

Black Walnut

Background

An emerging health issue for forests in the eastern United States, thousand cankers disease of black walnut and butternut, is caused by a recently identified fungus (*Geosmithia* spp.) and the walnut twig beetle (*Pityophthorus juglandis*) (USDA For. Serv. 2011). The walnut twig beetles carry fungal spores, and when they tunnel through the outer bark into the tree the fungus is transmitted. The fungus kills an area under the bark and the areas of dead tissue are called cankers. Thousand cankers disease has been causing black walnut dieback and mortality in many western states for over a decade, but it has now been discovered in several eastern states including Ohio, Pennsylvania, Tennessee, Virginia, and North Carolina.

What we found

In late 2012 the walnut twig beetle was detected in southwestern Ohio, followed by isolation of the thousand cankers disease fungus in walnut branch samples collected in the Butler County area. A quarantine is currently in effect to prevent the spread of walnut twig beetle and *Geosmithia* fungus in the State. It is believed that the spread of the fungus across the United States has been mainly due to the transportation of beetle-infested walnut logs and firewood. Black walnut makes up about 2 percent of both total volume and saw log volume in Ohio, and there are an estimated 86,000 acres in the walnut forest type. Walnut is most abundant in forests in the southwest part of the State (Fig. 74).

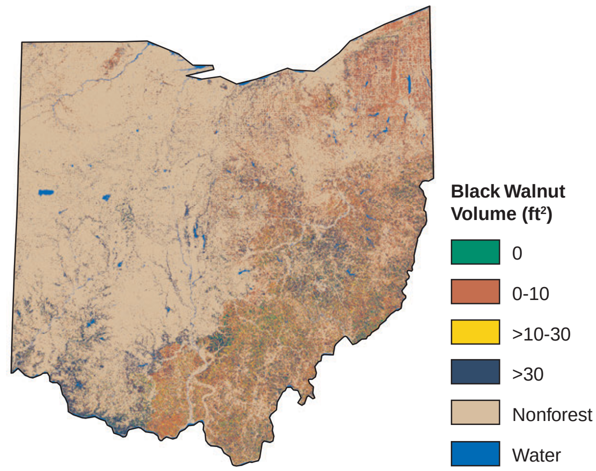


Figure 74.—Black walnut volume per acre on forest land, Ohio, 2011.

What this means

Although black walnut is a minor component of the forests in Ohio it is an extremely valuable species for lumber and veneer. Therefore, landowners and homeowners are encouraged to visually inspect their walnut trees for presence of thousand cankers disease. The earliest symptom is yellowing foliage that progresses rapidly to brown wilted foliage, and finally branch mortality. Other major symptoms of this disease are numerous small cankers on branches and the bole, and evidence of tiny bark beetles. Additional information about thousand cankers disease and quarantine restrictions in Ohio can be found at www.agri.ohio.gov/ and www.thousandcankers.com/.

Data Sources and Techniques

Logs from an Ohio logging operation. Photo by Ohio Department of Natural Resources, used with permission.

Forest Inventory

The FIA sampling design is based on a grid of hexagons superimposed on a map of the United States with each hexagon approximately 6,000 acres in size and at least one permanent plot established in each hexagon. In Phase 1 (P1) of FIA's multi-phase inventory, the population of interest is stratified and plots are assigned to each strata to increase the precision of estimates. During P2, tree and site attributes are measured for forested plots established in each hexagon. P2 plots consist of four 24-foot fixed-radius subplots on which standing trees are inventoried. During P3, forest health indicators are measured on a 1/16th subset of the entire FIA ground plot network so that each plot represents approximately 96,000 acres. The forest health indicators are tree crown condition, forest soils, vegetation diversity, and down woody material. The collection of data for lichen communities and ozone injury indicators has been discontinued.

A detailed set of tables, along with information on statistical reliability, are included in the Statistics, Methods, and Quality Assurance part of this report on the DVD attached to the inside back cover. Tools to access data, previous reports, and additional information are available at: www.nrs.fs.fed.us/fia.

National Woodland Owner Survey

The National Woodland Owner survey (www.fia.fs.fed.us/nwos) is conducted periodically by the Forest Service to increase our understanding of private woodland owners—the critical link between society and forests. Questionnaires are mailed to individuals and private groups who own the woodlands where FIA has established inventory plots (Butler 2008). About 6,000 owners are contacted each year. Results in Ohio, included in this report, are based on 225 responses received during the 2002-2006 survey.

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This report summarizes the second full cycle of annual inventories, 2007-2011, of Ohio's forests by the Forest Inventory and Analysis unit of the Northern Research Station in cooperation with the Ohio Department of Natural Resources, Division of Forestry. Since 2006, forest land increased by 2.1 percent and currently totals 8.1 million acres. Net volume of live trees on forest land increased by 7 percent totaling 15.9 billion cubic feet. Most stands are dominated by large trees, 66 percent are in sawtimber-size stands, although most stands are less than fully stocked with growing-stock trees. Annual growth outpaced removals by a ratio of 2.2:1. This report includes additional information on forest attributes, land-use change, carbon, and forest health. The included DVD contains 1) descriptive information on methods, statistics, and quality assurance of data collection, 2) a glossary of terms, 3) tables that summarize quality assurance, 4) a core set of tabular estimates for a variety of forest resources, and 5) a Microsoft Access database that represents an archive of data used in this report, with tools that allow users to produce customized estimates.

KEY WORDS: inventory, forest statistics, forest land, volume, biomass, carbon, growth, removals, mortality, forest health, Illinois, emerald ash borer

A black oak in an Ohio forest. Photo by Ohio Department of Natural Resources, used with permission.

DVD Contents

Ohio's Forests 2011 (PDF)

Ohio's Forests: Statistics, Methods, and Quality Assurance (PDF)

Ohio's Forests 2006 (PDF)

Ohio Inventory Database (CSV file)

Ohio Inventory Database (Access file)

Field guides that describe inventory procedures (PDF)

Database User Guides (PDF)

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