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Abstract

This report constitutes the third full report of annualized inventory on Ohio forest land and summarizes field data collected from 2011 through 2016. Ohio has 8.0 million acres of forest land containing 103 tree species and 50 forest types. Net cubic-foot and sawtimber volumes continued to increase, as did the area occupied by large diameter stands. Growing-stock volume remained stable overall, though it decreased 3 percent on private land since 2006. The net-growth-to-harvest-removals ratio dropped from 2.3:1 in 2011 to 1.6:1 in 2016. Invasive insects have had a substantial impact on Ohio's forests, particularly for ash species. Additional information on land-use change, fragmentation, ownership, forest composition, structure, age, carbon stocks, regeneration, invasive plants, insect pests, and the possible future of Ohio's forests is also presented. Sets of supplemental tables are available online at https://doi.org/10.2737/NRS-RB-118 and contain: 1) tables that summarize quality assurance and 2) a core set of tabular estimates for a variety of forest resources.

Acknowledgments

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Cover: Vinton County scene. Photo by Ohio Department of Natural Resources, used with permission.

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Foreword

The forests of Ohio are critically important to the ecology and economy of the State, and to the health of its people. They are incredibly biodiverse, providing habitat for hundreds of species of plants and terrestrial wildlife. These areas also provide many recreational opportunities, improve water and air quality, and serve as a natural retreat for people, benefiting mental and physical health. The forests of Ohio also support a thriving forest products industry, which contributed over $26 billion to the State's economy and employed 122,000 people in 2015. Forests are clearly important for Ohio, and the data generated by the USDA Forest Service's Forest Inventory and Analysis program provide the basis for understanding how they are changing and how we can sustain them for future generations.

This and previous reports show that the proportion of Ohio in forest cover has remained at 30 percent since 1991, after increasing steadily since the low point of about 10 percent forest cover in 1910. Eighty-five percent of the forest land in Ohio is privately owned, meaning private landowners are critical to the continued health of our forests. While only 12 percent of landowners owning 10 or more acres have management plans for their forests and fewer than 20 percent have received forest management advice, these figures have improved significantly from previous reports. Additional encouraging findings from this report include the increase in the area of mature forests containing large trees and improvement in the quality of sawtimber.

While Ohio's forests provide us with a wealth of ecological and economic services, they are faced with some key challenges, including fragmentation, reduced oak regeneration, and invasive species. New home production is increasing at a rate 4.5 times that of the population growth. Much of this construction is encroaching on forest land, fragmenting areas of continuous forest cover. The consequences of forest fragmentation are many, including greater invasive species colonization, reduction in wildlife habitat quality, and reduced opportunities for solitude. While oaks make up a large proportion of the overstory trees, they are a small proportion of the seedlings, suggesting a future shift in overstory tree species composition. Invasive species such as the emerald ash borer (EAB) can wreak havoc on native forest ecosystems. Several counties have lost more than 95 percent of their ash trees to EAB since its arrival.

The Ohio Division of Forestry is striving to address these issues and many others. This report, and those that follow, will allow us to evaluate our impacts, successes, and failures in managing Ohio's forest resource, and help us move toward a balance between wise use and protection of our forests for the benefit of all.

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

Contents

Highlights

On the Plus Side

- The extent of forest land in Ohio remains relatively stable at 8.0 million acres, or 30 percent of the State's total area, allowing for the continued provision of timber products and valuable ecosystem services such as wildlife habitat, mitigation of air and water pollution, carbon sequestration, and outdoor recreation.
- The species composition of Ohio's forests is among the most diverse in the region with 103 tree species and 50 forest types identified on Forest Inventory and Analysis plots.
- Large diameter (sawtimber) stands continue to increase in area, covering 68 percent of timberland.
- Net volume on timberland continues to increase, totaling 15.8 billion cubic feet.
- Sawtimber volume increased 8 percent since 2006 to 51 billion board feet, averaging 6,686 board feet per acre.
- The quality of available sawtimber volume, as indicated by tree grade, has continued to increase with 29 percent of sawtimber volume in grade 1 trees.

Issues to Watch

- Development and urbanization remain a concern; conversion to developed land uses accounts for about half of the forest land that is lost.
- Eighty-five percent of forest land is privately owned, but only 12 percent of private landowners with 10 or more acres have management plans and fewer than 20 percent have received forest management advice.
- Upcoming changes in ownership of family forest land are likely, given the average owner age of 63 years, and may result in greater parcelization of forest tracts.
- Growing-stock stocking levels have shifted into lower stocking classes since 2006. Increased disparities between stocking of live trees and growing-stock trees represent opportunities for stand improvement activities.
- Growing-stock volume increased only 0.3 percent over the past 10 years and decreased by 3 percent on private timberland.

- The net-growth-to-harvest removals ratio fell from 2.3:1 in 2011 to 1.6:1 in 2016.
- White oak has decreased 9 percent in net volume, 11 percent in growing-stock volume, 7 percent in sawtimber volume, and 14 percent in the number of trees 5 inches or greater in diameter.
- Oak regeneration remains a challenge.
- Emerald ash borer has had substantial effects on the ash resource in Ohio and will continue to do so given the prevalence of ash in Ohio.
- Invasive plant species were found on 96 percent of monitored plots.

Background

Sugar maple atop a rock wall in Vinton County. Photo by Ohio Department of Natural Resources, used with permission.

An Overview of Forest Inventory

What is FIA?

The USDA Forest Service's Forest Inventory and Analysis program, commonly referred to as FIA, is the Nation's forest census. It was established by the U.S. Congress to "make and keep current a comprehensive survey and analysis of the present and prospective conditions of and requirements for the renewable resources of the forest and range lands of the United States" (Forest and Rangeland Renewable Resources Planning Act of 1974; 16 USC 1601 [note]). FIA has been collecting, analyzing, and reporting on the Nation's forest resources for more than 80 years. The first FIA inventory of Ohio's forests was completed in 1952. Information is collected on the status, trends, extent, composition, structure, health, and ownership of the forests. This information is used by policy makers, resource managers, researchers, and the public to better understand forest resources and to make more informed decisions about their future.

What is this report?

This report is a summary of the findings from the seventh survey of the forest resources of Ohio conducted by FIA. This report uses data from the second and third cycle of plot measurement using the annualized inventory of plots. Data for this survey were collected between 2011 and 2016, referred to throughout this report as the inventory year 2016. Previous periodic forest inventories of Ohio were completed in 1952 (Hutchison and Morgan 1956), 1968 (Kingsley and Mayer 1970), 1979 (Dennis and Birch 1981), and 1991 (Griffith et al. 1993); full cycle annualized reports were published for 2006 (Widmann et al. 2009) and 2011 (Widmann et al. 2014).

The results of the survey are divided into sections on such topics as forest features, attributes, and health. Definitions for FIA terms commonly used in the 5-year reports are available at https://www.nrs.fs.fed.us/fia/data-tools/state-reports/glossary/. Supplemental tables summarizing the reported results can be found online at https://doi.org/10.2737/NRS-RB-118.

A Guide to Forest Inventory

What is a tree?

Trees are perennial woody plants with central stems and distinct crowns. FIA defines a tree as any perennial woody plant species that can attain a height of 15 feet at maturity. A complete list of the tree species measured in Ohio during this inventory is included in Appendix 1. Throughout this report, the size of a tree is usually expressed as diameter at breast height (d.b.h.), in inches. This is the diameter, outside the bark, at a point 4.5 feet above the ground.

What is a forest?

A forest is a collection of trees and most people would agree on what a forest is. But in order for statistics to be reliable and comparable, a definition must be created to avoid ambiguity.

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. Generally, the minimum area for classification as a forest is 1 acre in size and 120 feet in width. There are more specific criteria for defining forest land near streams, rights-of-way, and shelterbelt strips (USDA Forest Service 2015).

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

FIA defines three types of forest land:

Timberland is 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 at least 20 cubic feet per acre of industrial wood (equivalent to the solid wood content of about ¼ cord) per year. Inaccessible and inoperable areas can be included.

Reserved forest land is all forest land withdrawn from timber utilization through statute without regard to productive status (e.g., state parks, natural areas, national parks, and Federal wilderness areas). All reserved forest land is in public ownerships.

Other forest land consists of forest land that is not capable of growing 20 cubic feet per acre 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.

Since 2001, the annual inventory design has allowed for reporting volumes on all forest land in Ohio. As a result, there is now one set of remeasured plots across all forest land with associated estimates of growth, removals, and mortality. Before the 2001-2006 inventory cycle (referred to as the 2006 inventory) in Ohio, for most attributes, FIA included only data collected on timberland plots. Therefore, trend analyses that use data prior to 2001 are limited to timberland for many attributes.

A word of caution on suitability and availability

FIA does not attempt to identify those lands suitable or available for timber harvesting, particularly since such suitability and availability is subject to changing laws, economic and market constraints, physical conditions, adjacency to human populations, and ownership objectives. The classification of land as timberland does not necessarily mean it is suitable or available for timber production. Forest inventory data alone are inadequate for determining the area of forest land available for timber production. Additional factors, such as those listed, need to be considered when estimating the timber base, and these factors may change over time.

How do we estimate a tree’s volume?

To estimate a live tree’s volume, FIA uses volume equations developed for each tree species group found within the northeastern United States. Individual tree volumes are based on species, diameter, and height. FIA reports volume in cubic feet and board feet (International ¼-inch rule). Board-foot volume measurements are applicable only for sawtimber-size trees. Some wood products are often 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 are bark and air.

How is forest biomass estimated?

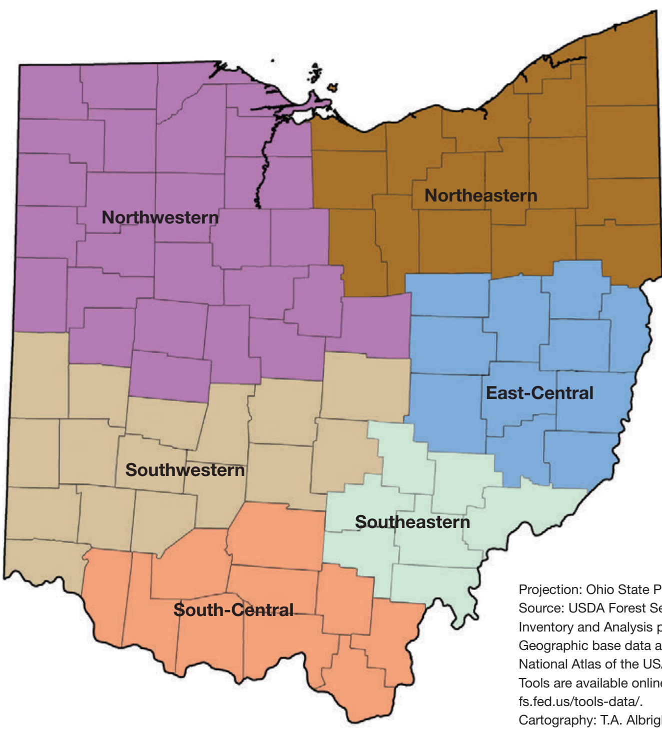
The USDA Forest Service has developed estimates of specific gravity for many tree species (Miles and Smith 2009). These specific gravities are applied to estimates of tree volume to estimate the biomass of merchantable trees (weight of the bole). Estimates of total aboveground tree biomass are calculated by adding top, limb, and stump biomass to bole biomass (Woodall et al. 2011). 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. Oven-dry weight is the weight of a tree with no moisture content; oven-dry weight is used to report biomass in this report. On average, 1.9 tons (2,000 pounds/ton) of green biomass equals 1 ton of oven-dry biomass.

How do we estimate all the forest carbon pools?

FIA does not directly measure the carbon in standing trees; it estimates forest carbon pools by assuming that half the biomass in standing live and dead trees consists of carbon. Additional carbon pools (e.g., soil, understory vegetation, belowground biomass) are modeled based on stand and site characteristics (e.g., stand age and forest type).

Regional analysis

Throughout this report, references are made to regions of Ohio (Fig. 1). These are synonymous with FIA survey units and reflect the diverse landscape of the State to facilitate meaningful analysis on a more local scale.



Projection: Ohio State Plane North, NAD83. Source: USDA Forest Service, Forest Inventory and Analysis program, 2017. Geographic base data are provided by the National Atlas of the USA®. FIA data and Tools are available online at https://www.fia.fs.fed.us/tools-data/. Cartography: T.A. Albright, USDA Forest Service, January 2018.

Figure 1.—Forest Inventory and Analysis survey units (regions) of Ohio, 2016.

Forest inventory sample design

FIA has established a set of permanent inventory plots across the United States that are periodically revisited. Each plot consists of four 24-foot radius subplots for a total area of about one-sixth of an acre. All plots (i.e., forested and nonforest) are randomly located within a hexagon that is about 6,000 acres in size. Therefore, each plot represents about 6,000 acres of land and can be used to generate unbiased estimates with associated sampling errors for attributes such as total forest land area. Full details of sample design and estimation procedures are available in Bechtold and Patterson (2005).

Understanding FIA data

Before 2000, 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 are easier to identify because a subset of observations (about 14 percent) are made every year. It is still necessary to look over long time periods because many trends such as forest succession can be difficult to discern in short timespans. 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 geographic areas will contain more plots and thus produce more reliable estimates. For example, there may not be a sufficient number of plots within a county or single forest type from which to derive reliable estimates. It is also important to consider the degree to which a variable can be measured precisely. For instance, a stand variable, such as age, is not as precise as forest type; and a tree variable, such as crown dieback, is not as precise as diameter. Location and ownership are similarly important considerations when analyzing the status and trends of forests. Forest resources vary by geographic unit and ownership group.

Some definitions and procedures have changed between inventories. Because of these changes, some comparisons and estimates should be made with caution.

Since the beginning of the Ohio annual inventory in 2001, varying cycle lengths have been used for data collection. A 7-year cycle was used for the first 4 years from 2001 to 2005, during which 14.3 percent of all plots were selected for measurement each year. In 2006, Ohio inventory changed to a 5-year cycle length, with 20 percent of all plots selected for measurement annually. Also in 2006, the remainder of the first full cycle was completed. The 5-year cycle length continued through 2013 with the completion of the second full cycle and first remeasurement of annual plots completed in 2011. Ohio returned to a 7-year cycle length in 2014 with the third cycle scheduled for completion in 2018. Regardless of cycle length, FIA maintains a 5-year reporting period with each report encompassing a full cycle of data. 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 2011 through 2016 are collectively labeled the 2016 inventory and were used to produce this 2016 report. The 2006 inventory was the first annual inventory to include the complete cycle of annual inventory plots (Widmann et al. 2009) and the 2011 inventory was the first annual inventory to include a complete remeasurement of plots (Widmann et al. 2014).

In Ohio, 4,542 plot locations were selected for measurement during the 2016 inventory cycle. Of these, 1,660 contained forest land, 2,623 were nonforest, and 259 were not sampled due to access constraints. All estimates of current forest area, composition, volume, and other forest statistics are based on 4,283 sampled plots. To get reliable estimates of change (e.g., forest area change, growth, mortality, and removals), FIA uses only those plots sampled during both the 2016 cycle and the previous cycle. Because 152 plots were not sampled during the previous cycle, 4,131 plots form the basis for estimates of change in 2016.

To improve the consistency, efficiency, and reliability of the inventory, procedures and definitions have been updated over time. Major changes occurred with the annual inventory begun in 1999. For the sake of consistency, a new, national plot design was implemented by FIA throughout the United States in 1999 (Gormanson et al. 2018). Estimates for the 2016 inventory use the most recent updated protocols.

What is P2+?

In 2012 Northern Research Station FIA began implementation of the Phase 2 Plus (P2+) protocol (USDA Forest Service 2016). This 12.5 percent subset of all plots is sampled during the leaf-on portion of the field season (May through September). The suite of additional measurements consists of an advanced tree seedling regeneration (ATSR) survey, vegetation profile (Veg), invasive plant species (Invasives) survey, down woody materials (DWM) tally, and additional tree crown variables (Crowns). Half of P2+ plots (6.25 percent of all plots) are selected for soils measurements and laboratory analysis during the summer window.

What is the National Woodland Owner Survey?

The National Woodland Owner survey is conducted periodically by the Forest Service (NWOS; https://www.fia.fs.fed.us/nwos). It is aimed at increasing our understanding of woodland owners, who are the critical link between forests and society (Butler et al. 2016). The most recent survey was conducted from 2011 through 2013. Questionnaires were mailed to individuals and private groups who own the woodlands where FIA has an established inventory plot. Results from Ohio, included in this report, are based on responses from 205 family forest owners in the most recent survey (Butler et al. 2016).

Where can I find additional information?

Details about data collection, estimation procedures, and statistical reliability can be found in Gormanson et al. (2018), available at https://doi.org/10.2737/NRS-GTR-178. Most data used in this report can be downloaded from the FIA Web site (https://www.nrs.fs.fed.us/fia) and are also accessible by using the online Web tools Forest Inventory Data Online (FIDO) and EVALIDator (Miles 2018). These tools allow public access to all FIA databases. This enables anyone to generate tables and maps of forest statistics through a Web browser without having to understand the underlying data structures. These programs are available at https://www.fia.fs.fed.us/tools-data/. 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. More categories may be found in online summary tables and custom tables created with FIDO and EVALIDator. Definitions of tables and fields are available in the database users manual (Woudenberg et al. 2010). Other FIA resources for Ohio's forest inventories are available at https://www.nrs.fs.fed.us/fia/data-tools/state-reports/OH/default.asp.

Forest Features

Black cherry canopy. Photo by Thomas Albright, USDA Forest Service.

Area and Land Use

Background

One of the most basic aspects of forest inventory programs is producing an estimate of the extent of forest land. Forest land area is estimated from all measured plots within the given inventory cycle. These estimates are most useful in identifying larger-scale changes in the area of forest land over time. Land-use change estimates use only plots visited in successive inventory cycles. Current land use at a given location is compared to the land use at the previous visit. These estimates of change can differ from estimates that use all sample locations.

FIA characterizes land area by using several broad land use categories: forest, rangeland, agriculture, water, developed, and other land (wetlands, undeveloped beaches, nonvegetated lands, persisting snow and ice). Forest land is broken down into three categories based on reserve status and productivity: timberland, reserved forest land, and other forest land.

The conversion of forest land to nonforest and water uses is referred to as gross forest loss (or diversion), and the conversion of nonforest land and water to forest is known as gross forest gain (or reversion). The magnitude of the difference between gross loss and gross gain defines net forest change. By comparing the land uses on current Ohio inventory plots (2011-2016) with the land uses recorded for the same plots measured during the previous inventory (2005-2011), hereafter referred to as 2016 and 2011, respectively, we can characterize forest land-use change dynamics. Although the total area of forest land in Ohio remained relatively stable between inventories, some areas of the State experienced forest loss, whereas other areas saw increases in forest land. To better understand Ohio's forest land dynamics, it is important to explore the underlying land-use changes occurring in the State. Understanding land-use change dynamics is essential for monitoring the sustainability of Ohio's forest resources and helps land managers make informed policy decisions.

What we found

The 2016 estimate for forest land in Ohio was 8.0 million acres, covering 30 percent of the State. This represents about a 1 percent decrease from the estimate of 8.1 million acres in 2011. Timberland is 96 percent (7.6 million acres) of all forest land. Less than 300,000 acres (4 percent) of forest land is reserved and less than 1 percent (62,000 acres) is other forest land. Decades of steady expansion in forest land brought the total forest land area from 5.4 million acres in 1952 to 7.8 million acres in 1991 (Fig. 2). The extent of forest land has remained relatively stable in the State since that time. Small fluctuations in forest land acreage have occurred since 1991; the highest estimate was 8.2 million acres in 2013.

Total forest land estimates produced from individual inventory cycles do not tell the full story. A more complete picture of land-use change is produced by comparing land use at the plot level on those plots that were measured at both the latest and previous cycles. Analysis of land-use change shows that between 2011 and 2016, most of the land in Ohio either remained forested (29.2 percent) or stayed in a nonforest land use (68.9 percent) (Fig. 3). Forest change plots—defined as those remeasured plots having forest gain or loss of at least 25 percent of plot area—were concentrated in the eastern and southern portions of the State (Fig. 4).

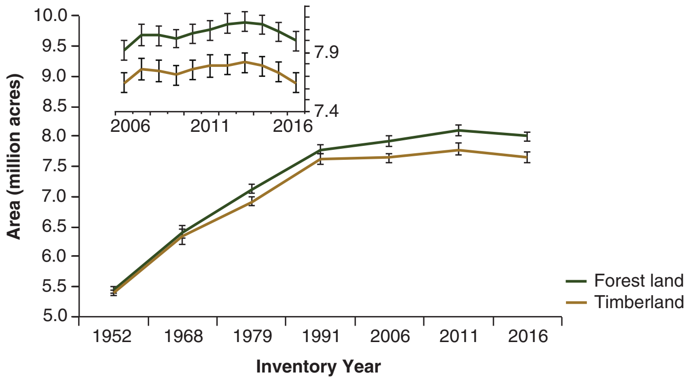


Figure 2.—Forest land and timberland area by inventory year, Ohio. Error bars represent a 68 percent confidence interval.

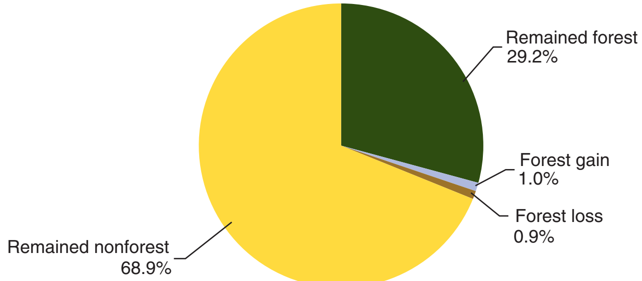


Figure 3.—Land-use dynamics showing percentage of unchanged land, forest loss, and forest gain, Ohio, 2011 to 2016.

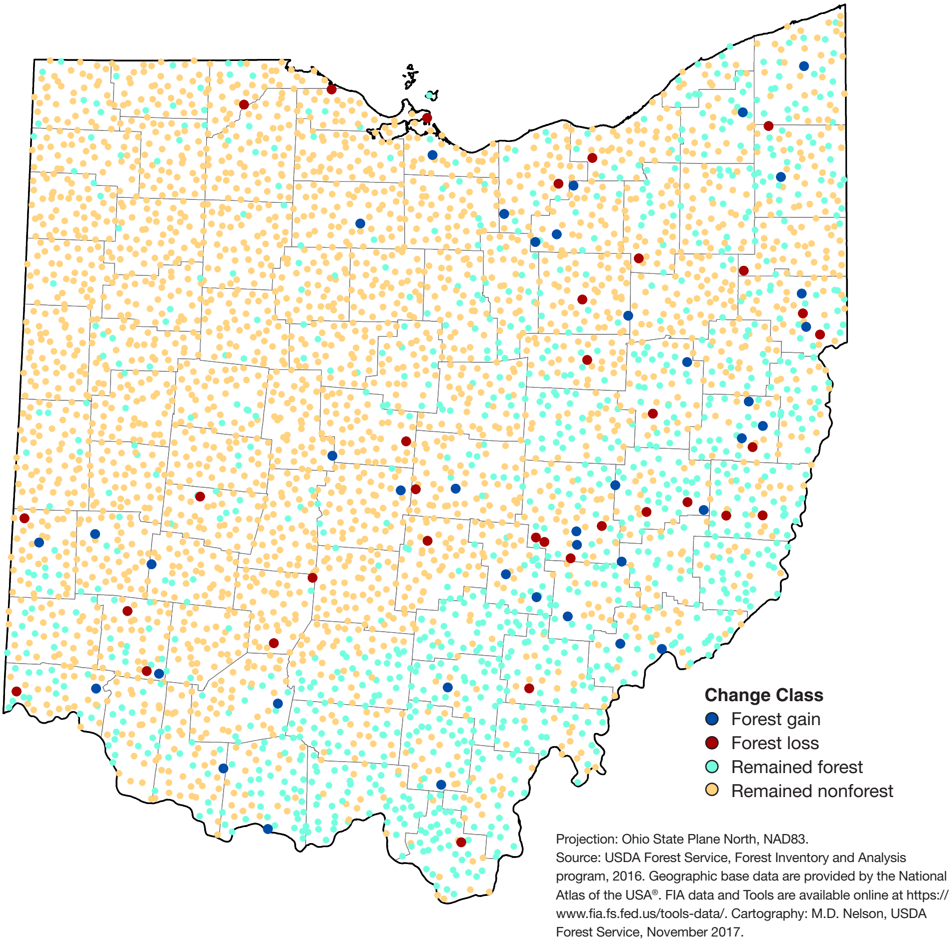


Figure 4.—Approximate locations of remeasured Forest Inventory and Analysis plots showing forest gain, forest loss, persisting forest, and persisting nonforest, Ohio, 2011 to 2016.

On the 1.9 percent of surface area where land use changed between the 2011 and 2016 inventories, the amount of nonforest that reverted to new forest land (258,000 acres) slightly exceeded the amount diverted from forest to nonforest (246,000 acres), leading to little net change in forest land (Fig. 5). Twenty-seven percent of the gross forest loss was due to diversion to agricultural land uses including cropland (9 percent), pasture (7 percent), and agricultural land grouped with idle farmland (11 percent) (Fig. 6). The other 73 percent of forest loss was forest land converted to developed land (49 percent), rights-of-way (9 percent), water or marsh (4 percent), or other land uses (11 percent). Forty-seven percent of forest gain in Ohio was previously agricultural land, primarily cropland (25 percent), pasture (10 percent), and agricultural land grouped with idle farmland (12 percent) converting to forest. Other land use sources for new forest land included developed land (14 percent) and rights-of-way (7 percent).

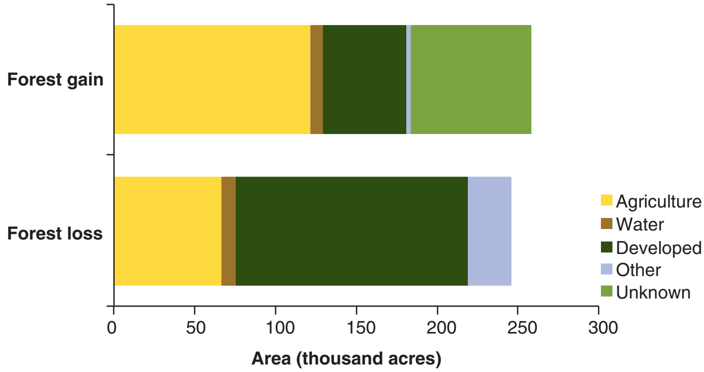


Figure 5.—Gross area of forest loss and forest gain by land-use category, Ohio, 2011 to 2016. Reversions to forest from nonforest plots previously measured in 2005 and 2006 are reported as of "unknown" origin because nonforest land classes were not recorded before 2007.

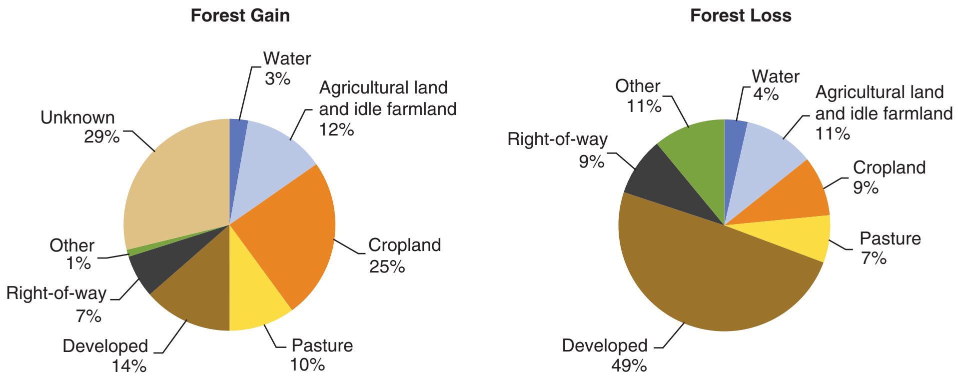


Figure 6.—Forest gain from previous land use and forest loss to current land use, Ohio, 2011 to 2016. Reversions to forest from nonforest plots previously measured in 2005 and 2006 are reported as of "unknown" origin because nonforest land classes were not recorded before 2007.

Although gains offset gross losses in forest land, thus resulting in little net change, the composition and structure of reverting and diverting forests differ. Though "new" forest land is gained through natural succession (seedling to sapling to tree) from lands no longer maintained for nonforest uses, small changes in maintenance patterns can cause treed areas previously not meeting size requirements to qualify as forest land. Thus, these "new" forests can be any size class. We can characterize the nature of forest loss and forest gain by looking at the stand-size classes associated with these changes. Ohio's forests are dominated by stands in the large diameter size class (68 percent), followed by medium diameter (21 percent) and small diameter and nonstocked (11 percent) size classes. A larger percentage of large diameter stands was in forest land lost (44 percent) compared to gained (39 percent), but for small diameter stands a larger percentage was gained (39 percent) than lost (30 percent).

Nonstocked forest is about 1 percent of Ohio forest land, but contributes about 3 percent of forest land gain and 2 percent of forest land loss (Fig. 7).

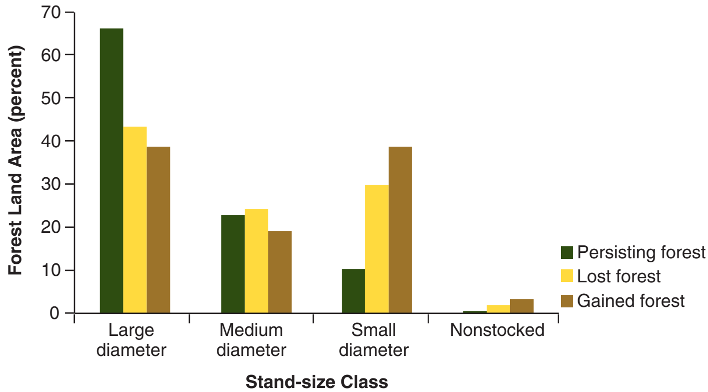


Figure 7.—Percentage of forest land use by stand-size class for persisting forest, forest lost from previous size class, and forest gained to current size class, Ohio, 2011 to 2016.

What this means

Gains and losses from multiple causes drive land-use change dynamics in the State. Some of the diversion and reversion of forest land in Ohio is probably the result of marginal forest land moving into and out of the forest land base, as suggested by the higher rate of change within nonstocked forest. This movement between forest and nonforest classifications may be a result of land meeting or not meeting FIA's definition of forest land due to small changes in understory disturbance, forest extent, or forest cover. Such changes are generally not permanent and may be more prevalent in stands of small diameter trees (small stand-size class). Similar rates of forest gain occur in both small and large diameter class; losses as a percentage of forest land area are greatest in the large diameter class. The combined total of 58 percent of gained forest classified as either large or medium diameter stands indicates that the majority of "new" forest land is the result of smaller-scale changes in maintenance rather than reversion of large tracts of nonforest land.

Although the extent of forest land has increased slightly over the past three decades, the amount of forest land reported in this inventory is nearly equal to the 2011 estimate, with a difference of only 92,000 acres. Analysis of land-use changes at the plot level shows only 12,000 more acres of forest land was gained than was lost to other land uses. The lack of a clear trend in land-use change suggests that the area of forest land across Ohio remains stable relative to 2011. Small fluctuations in the annual estimate of forest land are evident since 2006, but estimates from 2014, 2015, and 2016 have shown consecutive losses totaling 166,000 acres compared to the 2013 estimated high of 8.2 million acres. The recent downturn is worth watching into the future as it is unclear whether it is the beginning of a downward trend or simply a continuation of past fluctuations.

Urbanization and Fragmentation of Forest Land

Background

The expansion of urban lands that accompanies human population growth often results in the fragmentation and urbanization of remaining natural habitat (Wilcox and Murphy 1985). Continuing fragmentation, parcelization, and urbanization can be barriers to stewardship if they result in forest tracts that are too small or too isolated for effective management (Shifley and Moser 2016). Forest fragmentation can also affect forest ecosystem processes through changes in microclimate conditions, limiting the ability of tree species to move in response to climate change (Iverson and Prasad 1998). An intact functioning forest also is critical in protecting both the quantity and quality of surface and groundwater resources (McMahon and Cuffney 2000, Riva-Murray et al. 2010), and can enhance the ability of forest systems to adapt to changes in growing-season length, temperatures, rainfall patterns, and phenology associated with climate change.

Forest fragmentation and habitat loss diminish biodiversity and are recognized as a major threat to animal populations worldwide (Honnay et al. 2005, Rosenberg et al. 1999). This threat is particularly acute for species that require interior forest conditions for all or part of their life cycle (Donovan and Lamberson 2001). Fragmentation and loss also affect animal species that have large ranges, move slowly, or have lower reproductive rates (Charry and McCollough 2007, Forman et al. 2003). Changes in the size of remaining forest patches, connectivity, surrounding forest cover, and the amount of forest-nonforest edge all directly affect the amount and quality of interior forest. The same factors may also affect the ease with which exotic, invasive, or generalist species can gain a foothold and spread across the landscape. Landscape pattern metrics help quantify these characteristics of fragmentation, and the addition of spatial census data contributes information on types and levels of urbanization.

To summarize the spatial distribution of forest land in Ohio, we adapted a spatial integrity index (SII) developed by Kapos et al. (2002) for the 2000 Global Forest Resources Assessment (FRA2000). The SII integrates three facets of fragmentation affecting some aspect of forest ecosystem functioning—patch size, local forest density, and patch connectivity to core forest areas—to create a single metric. The SII ranges in value from 1, which indicates highly fragmented area, to 10, which represents the highest forest spatial integrity.

Values for any fragmentation measure are sensitive to the resolution of the land cover data source used (Moody and Woodcock 1995), similar to the way animal species utilize the landscape very differently depending on the scale at which they operate. For example, the same patch that supplies interior forest conditions for one species may be an unsuitable fragment for another species that requires higher quality or a larger area. Furthermore, important forest ecosystem processes operate at different scales. Consequently, we calculated spatial integrity using two reliable and widely available datasets of differing scale: the 2006 National Land Cover Database (NLCD) at a 30 m scale (Fry et al. 2011) and 2009 FIA forest cover at a 250 m scale (Wilson et al. 2012). Both scales fall within the range of 10 to 1,000 km^2 (2,500 to 250,000 acres), at which pattern process linkages are often of greatest management interest (Forman and Godron 1986).

In the SII calculation, core forest is defined by a minimum patch size and minimum local forest density within a defined local neighborhood (Table 1). A forest fragment (unconnected area) is defined by a maximum patch size, maximum local forest density, and minimum distance to core forest. The spatial integrity of remaining forest land is scaled between fragmented and core forests (low, medium, and high integrity). At the 250 m scale, core forest requires a minimum forest patch size greater than 1,544 acres and patches less than 30 acres are fragments. At the 30 m scale, the analogous minimum and maximum areas are 22 acres and 2.5 acres for core and fragmented forest, respectively. Local forest density is calculated within a radius of 0.78 mile (1,200 acres) for the 250 m scale and within a radius of 0.09 mile (16 acres) for the 30 m scale. Core forest requires a minimum 90 percent forest density within each local neighborhood at each scale. Fragments can have a maximum 10 percent local forest density.[1] These scales capture a relatively broad range of definitions for core forest and spatial integrity that could be used to bracket the scales appropriate for understanding impacts on a wide range of wildlife species and ecosystem processes affected by forest fragmentation.

Table 1.—Spatial integrity index (SII) parameters used in calculations at each scale

	Scale	
Definition of Core	**250 m**	**30 m**
patch size	>1,544 acres	>22 acres
local forest density	≥90%	≥90%
neighborhood radius (area)	0.78 mile (1,200 acres)	0.09 mile (16 acres)
Definition of Unconnected Fragment	**250 m**	**30 m**
patch size	<30 acres	< 2.5 acres
local forest density	≤10%	≤10%
neighborhood radius	0.78 mile	0.09 mile
distance to core	>4.2 miles	>0.5 mile

[1] Riemann, R. 2014. Adaptation of a spatial integrity index to 30 m and 250 m scales and its application across the northeastern United States. Unpublished paper on file at: USDA Forest Service, Northern Research Station, Forest Inventory and Analysis Program, Troy, NY.

Because SII does not consider underlying housing density or proximity to roads, it does not represent completely intact forest conditions. The wildland-urban interface (WUI) is the zone where human development meets or intermingles with undeveloped wildland vegetation (Radeloff et al. 2005). It is associated with a variety of human-environment conflicts. Radeloff et al. (2005) have defined this area by housing density ("intermix" areas, which have a minimum of 16 houses per square mile), proximity to developed areas ("interface" areas), and percentage of vegetation coverage (minimum 50 percent). We intersected WUI intermix areas (U.S. Census Bureau 2011) with forest land from the 2011 NLCD to examine changes in forest land area by WUI housing density. In addition, we identified areas where SII core forest (based on forest canopy) and WUI intermix overlapped.

Neither SII nor WUI captures the full impact of roads on forest land. Roads can have a variety of effects: direct hydrological, chemical, and sediment impacts; anthropogenic impacts; invasive species spread; habitat fragmentation; and wildlife mortality. Actual impacts will vary depending on road width, use, construction, level of maintenance, and hydrologic and wildlife accommodations (e.g., Charry and McCollough [2007], Forman et al. [2003]). We determined the amount of forest land (2001 NLCD; Homer et al. 2007) within 650 and 1,310 feet from a road (U.S. Census Bureau 2000). In general, when more than 60 percent of a region is within 1,310 feet of a road, cumulative ecological impacts from roads are an important consideration for managers (Riitters and Wickham 2003).

What we found

The 2011 NLCD (Jin et al. 2013) shows land cover varying considerably across Ohio, ranging from the heavily forested Southeastern unit (70 percent forest) to the heavily agricultural Northwestern unit (77 percent agriculture), and a landscape approximately evenly divided among urban, agriculture, and forest (25, 39, and 30 percent, respectively) in the Northeastern unit.

Considering SII at the 250 m scale, 32 percent of the forest land in Ohio is core forest, 29 percent has high integrity, 11 percent has medium integrity, 1 percent has low spatial integrity, and 27 percent of the forest is in unconnected fragments. At the 30 m scale, with 22 acres or greater considered core forest, 48 percent of the forest land in Ohio is core forest, 25 percent has high spatial integrity, 9 percent has medium or low integrity, and 18 percent of the forest is in unconnected fragments (Table 2). Forest connectivity is highest in the Southeastern unit, and lowest in the Northwestern unit of Ohio (Fig. 8); note how the remaining large areas of relatively continuous forest clearly stand out. At the 30 m scale, the lower threshold of 22 acres for defining core forest means that more forest patches are considered core

(Fig. 9), particularly in areas more densely populated, such as northeastern Ohio. It is important to note that the SII is depicting tree cover only and may not incorporate the presence of local development associated with or underlying this tree cover. Addressing this requires the use of census-derived house density information.

Table 2.—Spatial integrity index (SII), by inventory unit, scale, and with and without wildland-urban interface (WUI) as core forest, Ohio

30 m Spatial integrity class						
	Forest fragment	Low SII	Medium SII	High SII	Core forest	Core forest if WUI removed
Unit			*percent*			
Northwestern	66	1	6	15	12	10
Northeastern	24	1	11	30	34	17
Southwestern	43	1	10	20	25	11
East-Central	6	1	8	28	57	41
South-Central	8	1	7	25	59	37
Southeastern	3	1	5	23	69	47
State total	18	1	8	25	48	31
State total after removing WUI areas	18	2	9	40	31	
250 m Spatial integrity class						
	Forest fragment	Low SII	Medium SII	High SII	Core forest	Core forest if WUI removed
Unit			*percent*			
Northwestern	92	1	3	3	1	1
Northeastern	65	3	16	12	4	3
Southwestern	76	1	4	12	8	3
East-Central	9	2	18	41	29	23
South-Central	10	1	8	32	49	32
Southeastern	2	1	6	35	56	40
State total	27	1	11	29	32	23
State total after removing WUI areas	27	4	12	35	23	

Between 2000 and 2010, the population of Ohio increased by 1.6 percent, to 11.5 million. During that same time period the number of housing units grew by 7.2 percent (U.S. Census Bureau 2011), increasing at a pace 4.5 times the rate of population growth, a trend not unique to Ohio. In recent decades this housing growth has occurred not only in increasing suburban rings around urban areas but also in rural areas. Lepczyk et al. (2007), Theobald (2005), and Hammer et al. (2004)

observed that among the areas facing particularly rapid increases in housing density currently and into the future are amenity-rich rural areas around lakes and other forest recreation areas. Although the overall number of second homes in Ohio is relatively small, their 24 percent increase from 2000 to 2010 could be a partial reflection of this trend (U.S. Census Bureau 2011). This can put additional pressure on forested areas even above the general increases in population density and housing density.

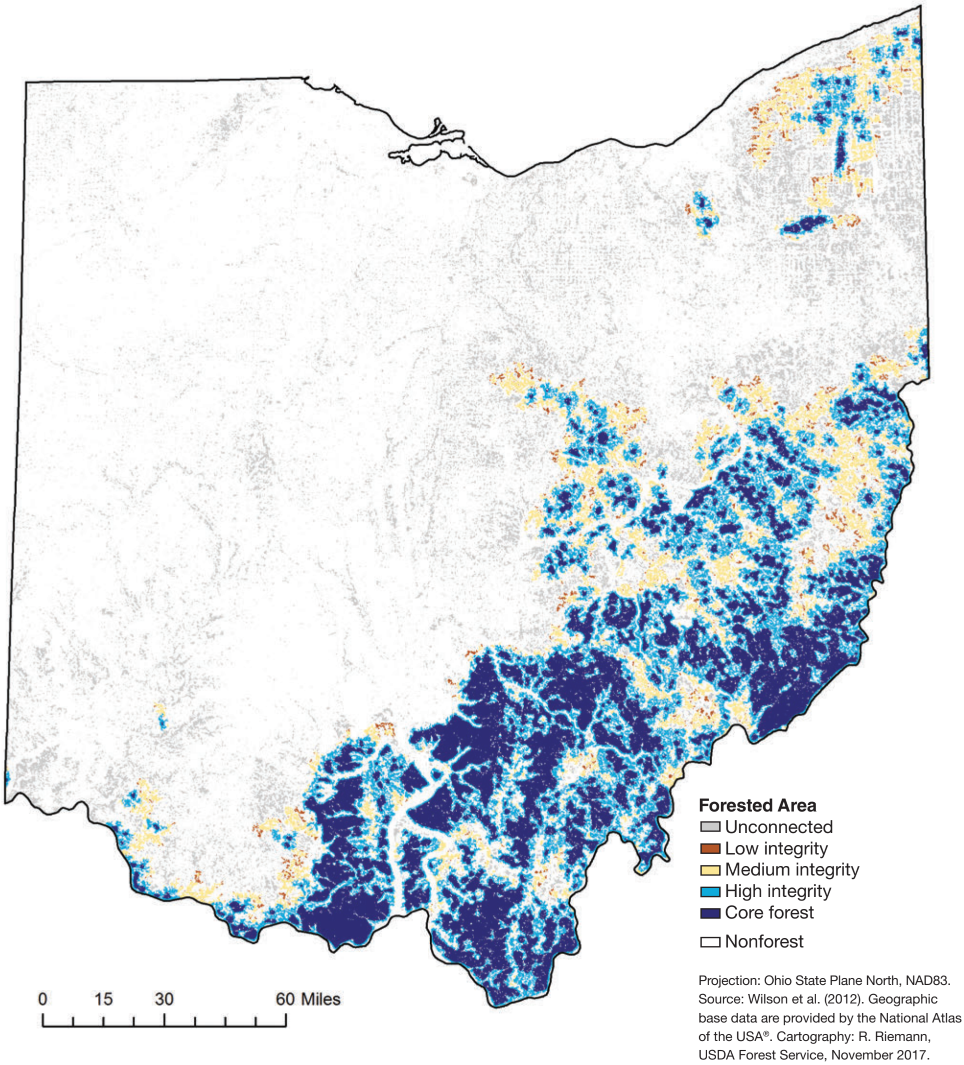


Figure 8.—Distribution of forest land by spatial integrity class at the 250 m scale, Ohio, 2009.

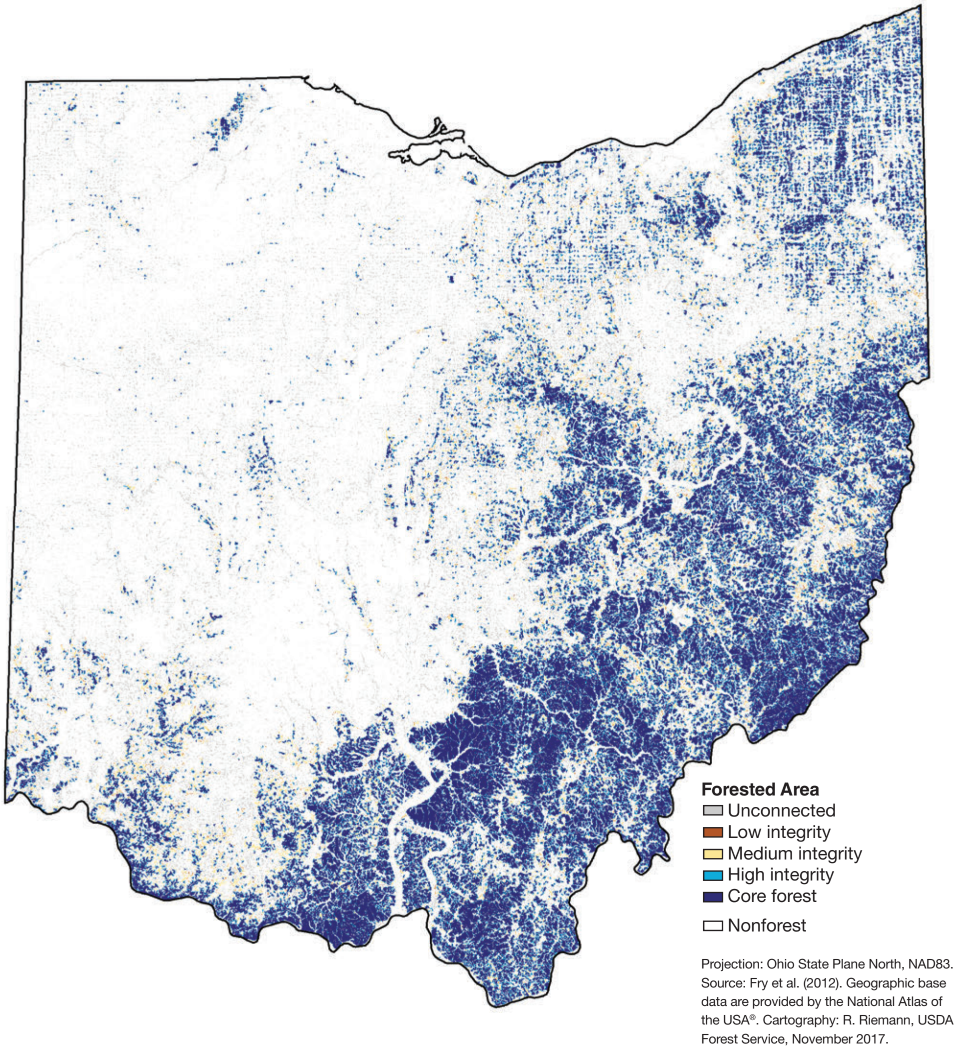


Figure 9.—Distribution of forest land by spatial integrity class at the 30 m scale, Ohio, 2009.

Forest land with sufficient underlying housing density to qualify as WUI has been slowly but steadily increasing, with WUI concentrated around population centers (Fig. 10). In 1990, 26 percent of Ohio's forest land was in low and medium density WUI. This increased to 30 percent of the forest land in 2000, and 34 percent in 2010 statewide, although there is substantial local variation. The three most heavily forested units in Ohio experienced the greatest increases in the proportion of forest in WUI. The Southeastern, South-Central, and East-Central units experienced increases in the proportion of forest in WUI of 13, 11, and 8 percentage points, respectively, between

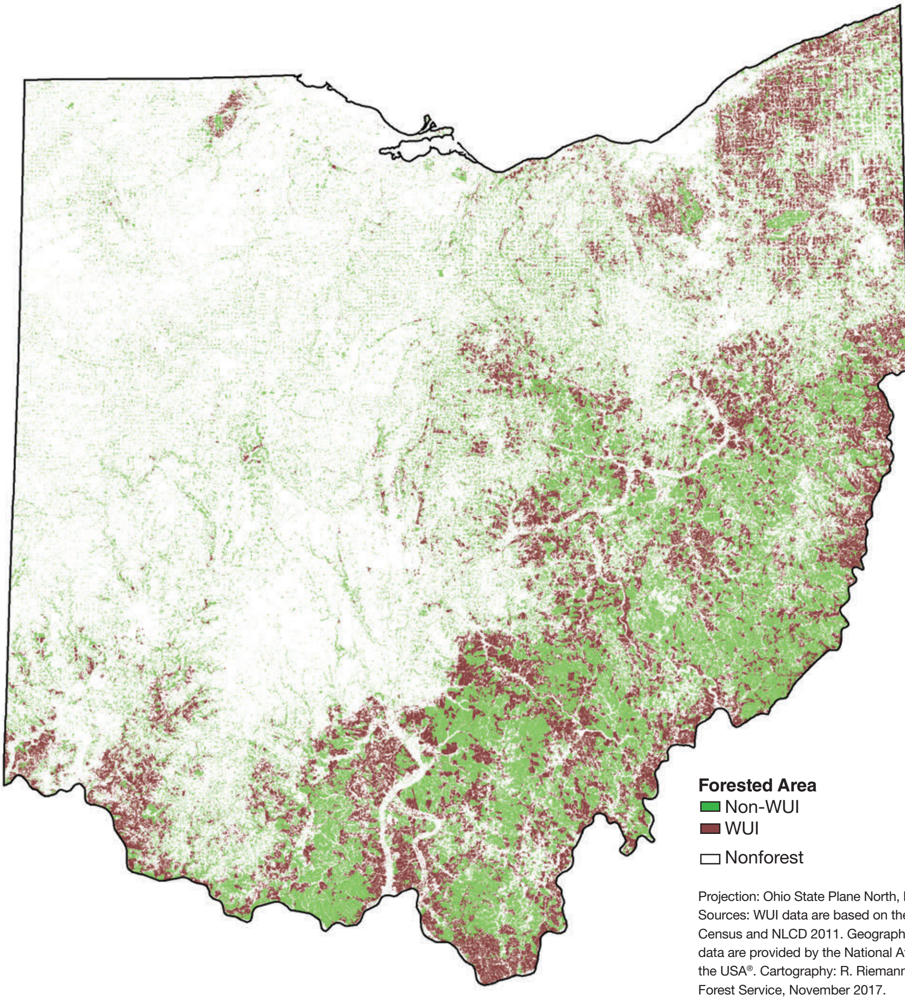


Figure 10.—Distribution of forest land by wildland-urban interface (WUI) status, Ohio, 2010 Census (restricted to forest as defined in the 2011 National Land Cover Database).

1990 and 2010 (Table 3); individual counties within each unit showed considerable variation. Thirty-three counties experienced no change or negative change, indicating either no additional WUI in forested areas, or previously WUI forest land that was converted to nonforest land. By integrating WUI with SII results at the 250 m scale, core forest drops from 32 to 23 percent statewide. At the 30 m scale, core forest drops from 48 to 31 percent of forest land when WUI areas are accounted for (Table 2). This represents a substantial impact on core forest land from underlying or nearby house densities, as can be seen in southern Ohio when WUI status is incorporated at the 30 m scale (Fig. 11).

Table 3.—Change in the percentage of forest occurring within the wildland-urban interface (WUI) between 1990 and 2010, by inventory unit, Ohio (based on forest as defined in the 2011 National Land Cover Database and not forested wetland)

	Percentage of forest in WUI					
Unit	1990	2000	2010	Difference (%), 1990 to 2000	Difference (%), 2000 to 2010	Difference (%), 1990 to 2010
Northwestern	6	8	9	2	1	3
Northeastern	37	39	42	2	3	5
Southwestern	25	26	31	1	5	6
East-Central	23	27	31	4	4	8
South-Central	30	37	41	7	4	11
Southeastern	22	31	35	9	4	13
State total	26	30	34	4	4	8

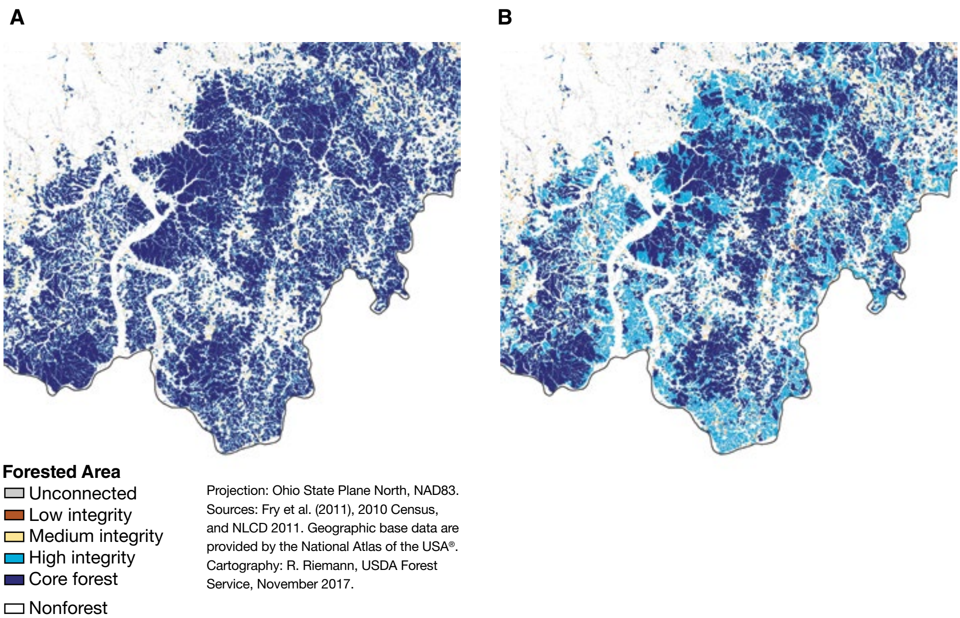


Figure 11.—Forest land by Spatial Integrity Index (SII) at the 30 m scale, without (A) and with (B) incorporation of wildland-urban interface status into SII, in southern Ohio, 2009 forest (2010 Census).

Ohio has an extensive system of roads, often hidden from aerial view throughout large areas of continuous canopy. Even as of 2000, 77 percent of Ohio's forest land was within 1,310 feet of a road, and 44 percent was within 650 feet, with relatively little variation in those numbers within each of the units (Table 4, Fig. 12). Much of this area—but not all—may coincide with WUI housing development.

Table 4.—Distribution of forest land with respect to urbanization and fragmentation factors, by inventory unit, Ohio

Unit	Forest land[a] as a percentage of total land in each unit	Percentage of forest land in wildland-urban intermix[b]	Percentage of forest land <650 feet from a road[c]
Northwestern	9	9	36
Northeastern	30	41	44
Southwestern	15	30	47
East-Central	59	31	48
South-Central	54	41	42
Southeastern	70	32	46
State total	32	34	44

[a] Based on the 2011 National Land Cover Database, including forested wetland. Values are generally higher than estimates from FIA plot data.

[b] Approximating the forest land potentially affected by underlying or nearby development. Data source: U.S. Census Bureau (2010).

[c] Approximating the forest land potentially affected by roads (road data from U.S. Census Bureau [2000]).

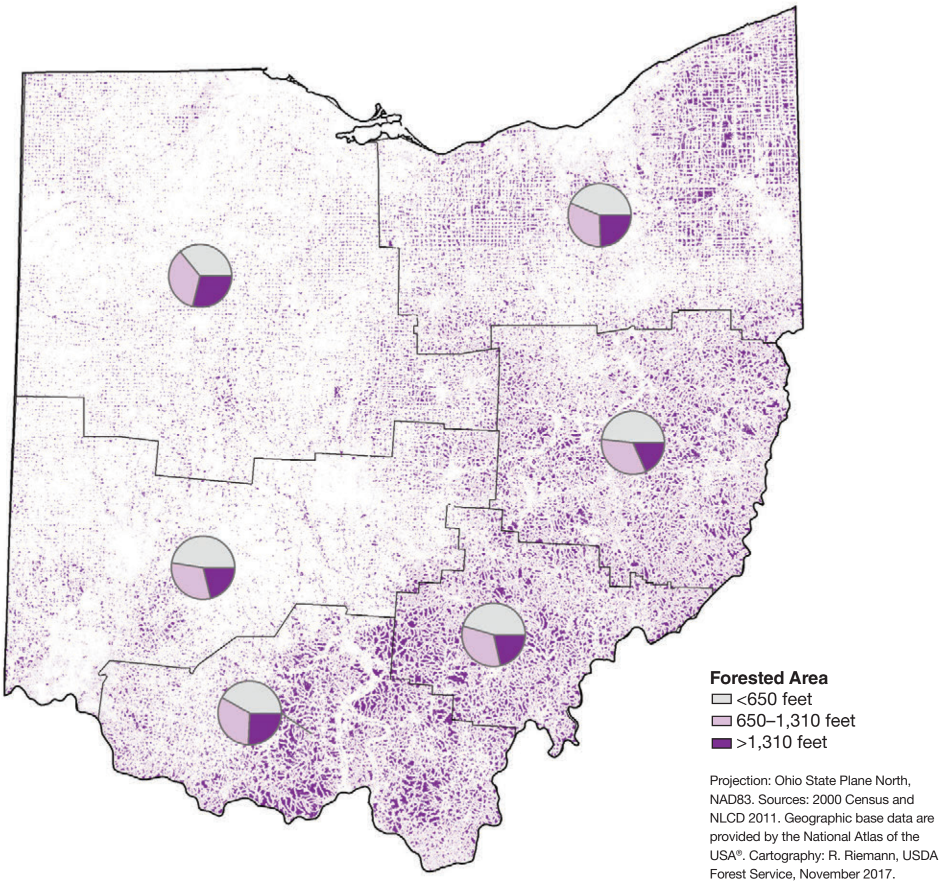


Figure 12.—Forest land by distance from the nearest road, Ohio, 2000 roads (restricted to 2001 forest).

What this means

Urbanization places people, development, and other anthropogenic pressures closer to natural habitats. Both urbanization and forest fragmentation change the way in which humans use forest land, frequently decreasing the likelihood that it will be managed for forest products and potentially increasing its use for outdoor recreation, although urbanization has also been observed to increase the incidence of "posting" forested land, which decreases outdoor recreation opportunities and alters local cultural use of forest land (Butler 2008, Kline et al. 2004, Wear et al. 1999).

Between 32 and 48 percent of Ohio's forest land is core forest and 19 to 28 percent is in unconnected fragments or has low spatial integrity, depending on SII scale. Statewide, core forest drops 9 to 17 percentage points upon removing WUI areas. Accounting for roads further reduces integrity in some areas.

Fragmentation and urbanization continue to change how Ohio's forests function, affecting forest health and sustainability, and their ability to supply forest products and ecosystem services. As housing development continues to sprawl into rural areas, fragmentation is a growing concern to land managers because forest stewardship becomes increasingly difficult on smaller ownerships. Factors that increase fragmentation, such as development incursions into core and high integrity forest areas, may become the focus of conservation and planning activities. Steps to help decrease forest fragmentation, such as maintaining or even creating connectivity between forest patches, could also be considered. In addition, managers may need to consider impacts on the resilience of forests when maintaining and developing roads.

Ownership

Background

How land is managed is primarily the owner's decision. Therefore, to a large extent, landowners determine the availability and quality of forest resources, including recreational opportunities, timber, and wildlife habitat. By understanding the priorities of forest landowners, the forest conservation community can better help owners meet their needs, and in so doing, help conserve the State's forests for future generations. The National Woodland Owner Survey (NWOS; www.fia.fs.fed.us/nwos), conducted by the USDA Forest Service Forest Inventory and Analysis program, studies private forest landowners' attitudes, management objectives, and concerns. It focuses on the diverse and dynamic group of owners that is the least understood—families, individuals, and other unincorporated groups, collectively referred to as "family forest owners." The

NWOS data reported here focus on owners of at least 10 acres and are based on the responses from 205 such family forest owners who own 10 or more acres of woodlands and participated between 2011 and 2013 (Butler et al. 2016).

What we found

An estimated 85 percent of the forest land of Ohio is privately owned. The vast majority of this private land, an estimated 5.6 million acres, is owned by family forest owners (Fig. 13). Corporations own an estimated 974,000 acres, and other private owners, including conservation organizations and unincorporated clubs and partnerships, own an estimated 204,000 acres.

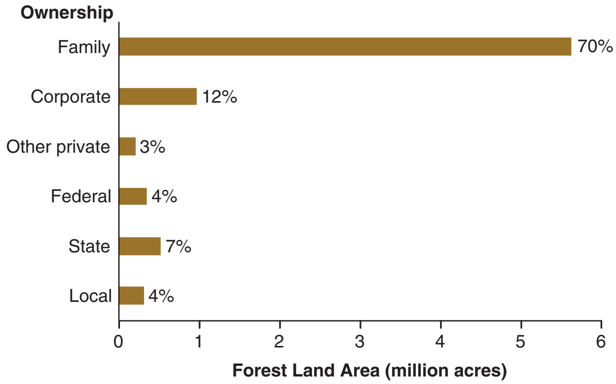


Figure 13.—Area of forest land by ownership class, and percentage of total forest land area, Ohio, 2016.

Public owners control 15 percent of Ohio's forest land. The Federal government manages an estimated 352,000 acres of forest land, much of it in the Wayne National Forest. State forest, park, and wildlife agencies are stewards of another 528,000 acres of forest land. Local government agencies, primarily at the county level, control an estimated 313,000 acres of forest land in the State.

According to the latest NWOS data, there are an estimated 145,000 family forest ownerships across Ohio that each own at least 10 acres of forest land, a collective 5.0 million acres. The average forest holding size of this group is 34 acres; 81 percent of these family forest ownerships own less than 50 acres of forest land, but 55 percent of the family forest land is in holdings of at least 50 acres (Fig. 14). The primary reasons for owning forest land are related to beauty, wildlife, and nature (Fig. 15). The most common activities on this land are personal recreation, such as hunting and hiking, and cutting trees for personal use, such as for firewood (Fig. 16). Most family forest ownerships have not participated in traditional forestry management and assistance programs in the past 5 years (Fig. 17). The most common form of assistance is management advice, but fewer than 20 percent of the ownerships reported receiving such advice. Only 12 percent of the ownerships have a management plan for their forest land. The average age of family forest owners in Ohio is 63 years; 41 percent of the family forest land is owned by people who are at least 65 years of age and only 4 percent is owned by people under the age of 45 (Fig. 18).

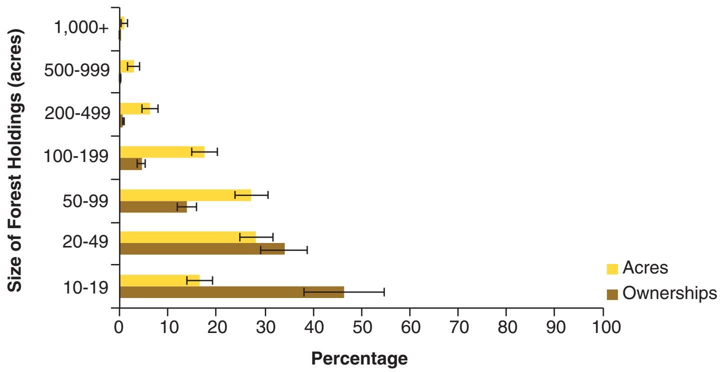


Figure 14.—Percentage of family forest ownerships and area of forest land by size of forest land holdings, Ohio, 2013. Error bars represent a 68 percent confidence interval.

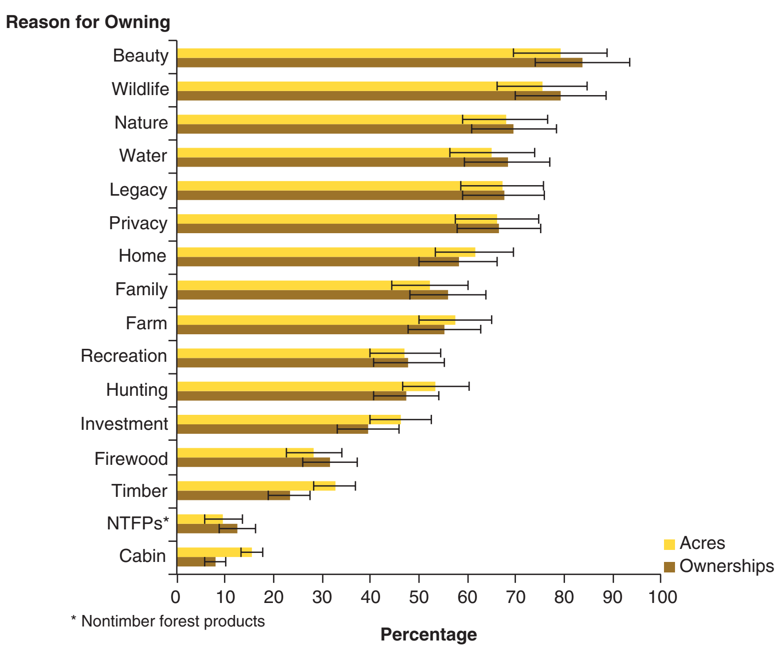


Figure 15.—Percentage of family forest ownerships and area of forest land by reasons given for owning forest land ranked as very important or important, Ohio, 2013. Categories are not exclusive. Error bars represent a 68 percent confidence interval.

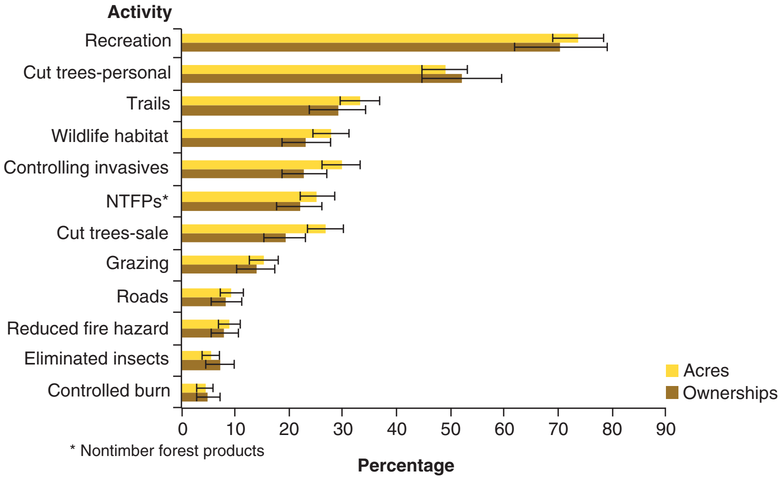


Figure 16.—Percentage of family forest ownerships and area of forest land by activities in the past 5 years, Ohio, 2013. Categories are not exclusive. Error bars represent a 68 percent confidence interval.

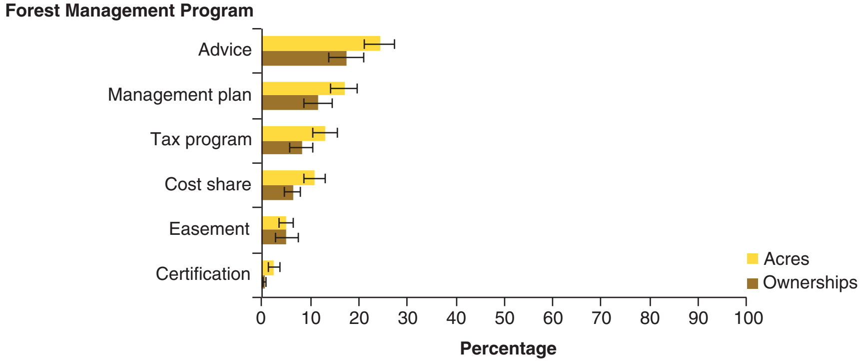


Figure 17.—Percentage of family forest ownerships and area of forest land by participation in forest management programs, Ohio, 2013. Categories are not exclusive. Error bars represent a 68 percent confidence interval.

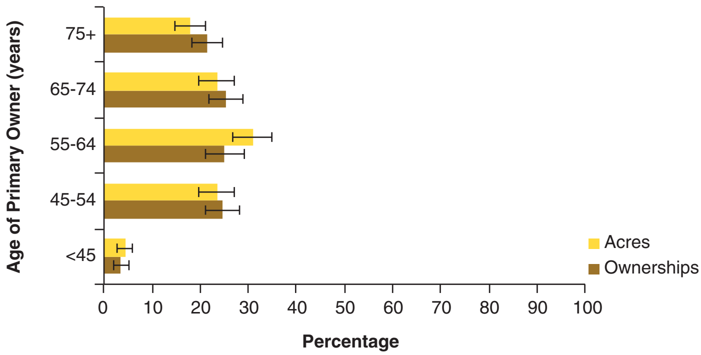


Figure 18.—Percentage of family forest ownerships and area of forest land by age of primary owner, Ohio, 2013. Error bars represent a 68 percent confidence interval.

What this means

The fate of the forests lies primarily in the hands of those who own and control the land. It is therefore critical to understand the needs and goals of forest owners and to identify the policies and programs that can help them conserve the forests for current and future generations. Family forest owners are the least understood ownership group, yet their land arguably has the most uncertain fate. They own their land primarily for amenity reasons, and many actively use it for recreation. Most do not have a forest management plan, however, and most have not participated in any other traditional forest management planning or assistance programs. The community of foresters, educators, loggers, researchers, and others has a responsibility to use the great opportunities available to help these owners increase their engagement and stewardship of their lands.

The Ohio Division of Forestry maintains several programs to assist landowners with forest management. Service foresters can provide technical assistance for management, information on timber harvesting, and assistance with tax and cost-share programs. The Ohio Tree Farm Program is a community of landowners united in responsible management of their forest tracts. The Northwest Ohio Windbreak Program is a multi-agency cooperative effort with the goal of helping farmers reduce soil erosion through planting trees. Finally, the Ohio Forest Legacy Program is designed to help landowners manage and conserve their forests for future generations. See http://forestry.ohiodnr.gov/landownerassistance for more information on these programs available to Ohio landowners. Additional programs such as Tools for Engaging Landowners Effectively (http://www.engaginglandowners.org) can help the conservation community develop and implement programs more effectively and efficiently.

Another important trend to watch is the increasing age of family forest owners. Many acres of land are expected to be passed on to the next generation in the not too distant future. This transfer carries the additional risk of increased parcelization as land is split among heirs. Programs such as Your Land Your Legacy (http://masswoods.net/monthly-update/your-land-your-legacy-deciding-future-your-land) and Ties to the Land (http://tiestotheland.org) are being implemented to help owners meet their bequest goals, but it is uncertain who the future forest owners will be and what they will do with their land.

Forest Resource Attributes

Group selection harvest in Ross County. Photo by Ohio Department of Natural Resources, used with permission.

Forest Composition

Background

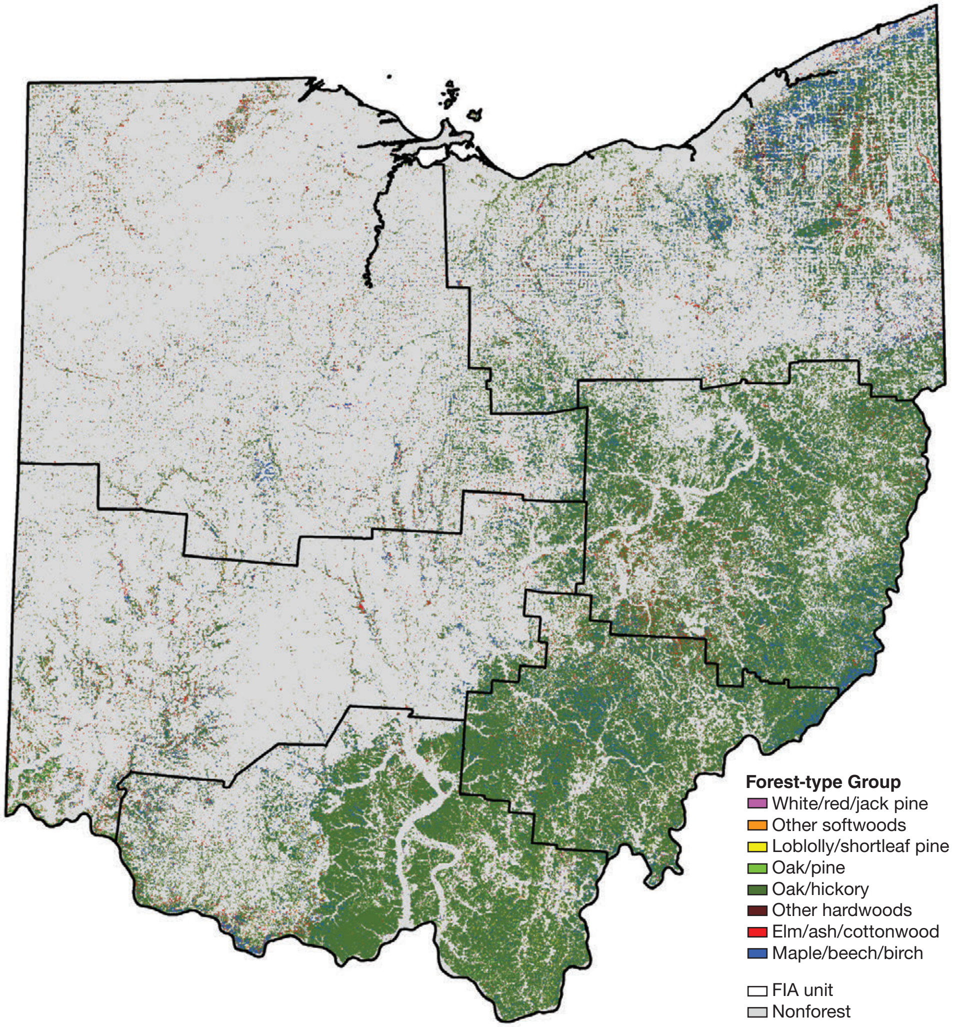
A multitude of factors interact to affect the species composition of a forest. Forest disturbances, such as timber harvesting, insect and disease outbreaks, weather events, and fires, as well as the lack thereof, influence site characteristics. Soil attributes, climate, and competition among species also have an effect on composition. Stands recovering from substantial disturbances tend to be populated by species of low shade tolerance, whereas mature forests favor shade-tolerant tree species. Forest management can be used to intervene in natural processes, thereby further influencing forest composition.

One way that FIA characterizes the forest resources of an area is by forest types and forest-type groups. Tree species that generally coexist together in a stand are described as forest types, and similar forest types are known collectively as forest-type groups. Forest types and forest-type groups categorize the overstory of the forest. The number of trees by species and size can also be used to evaluate the composition of forests.

What we found

The FIA inventory of Ohio for 2016 tallied 103 tree species at least 1 inch in diameter (Appendix 1) throughout the State. Fifty different forest types in 12 forest-type groups were identified. Hardwoods dominate the forests of Ohio (Fig. 19) with 7.7 million acres of forest land (96 percent) in hardwood forest-type groups. The oak/hickory forest-type group was the largest by far, covering 5 million acres (Fig. 20), or 63 percent of forest land. An additional 1.6 million acres (21 percent) were covered by forests in the maple/beech/birch forest-type group. The single most common forest type was white oak/red oak/hickory with 2 million acres of forest land.

Regional differences in composition are evident when area by forest-type group is compared across inventory units. The oak/hickory forest-type group makes up nearly 70 percent of the forest land in the South-Central, Southeastern, and East-Central units (Fig. 21), and the maple/beech/birch forest-type group composes an additional 17, 18, and 19 percent, respectively. The proportion of oak/hickory falls to less than half of forest land (48 percent) in the Southwestern unit, where maple/beech/birch and elm/ash/cottonwood compose 23 and 25 percent of forest land, respectively. The Northwestern unit is 61 percent oak/hickory, 21 percent maple/beech/birch, and 15 percent elm/ash/cottonwood. Softwood forest-type groups reach their highest proportion of regional forest land at 5 percent in the South-Central unit.



Projection: Ohio State Plane North, NAD83. Source: USDA Forest Service, Forest Inventory and Analysis program, 2009. Geographic base data are provided by the National Atlas of the USA®. FIA data and Tools are available online at https://www.fia.fs.fed.us/tools-data/. Cartography: T.A. Albright, USDA Forest Service, January 2018.

Figure 19.—Major forest-type groups, Ohio, 2009.

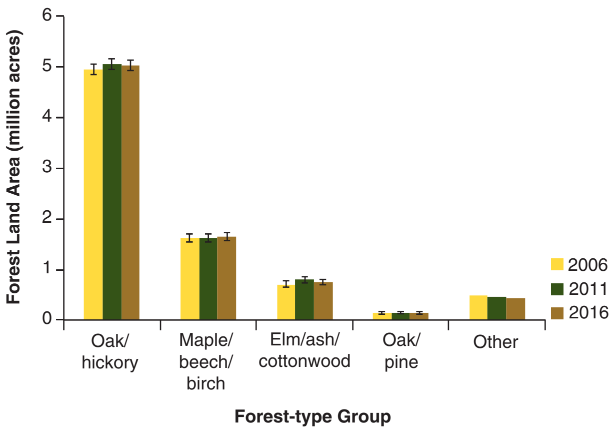


Figure 20.—Forest land area by forest-type group and inventory year, Ohio. Error bars represent a 68 percent confidence interval and are unavailable for the aggregated "Other" group.

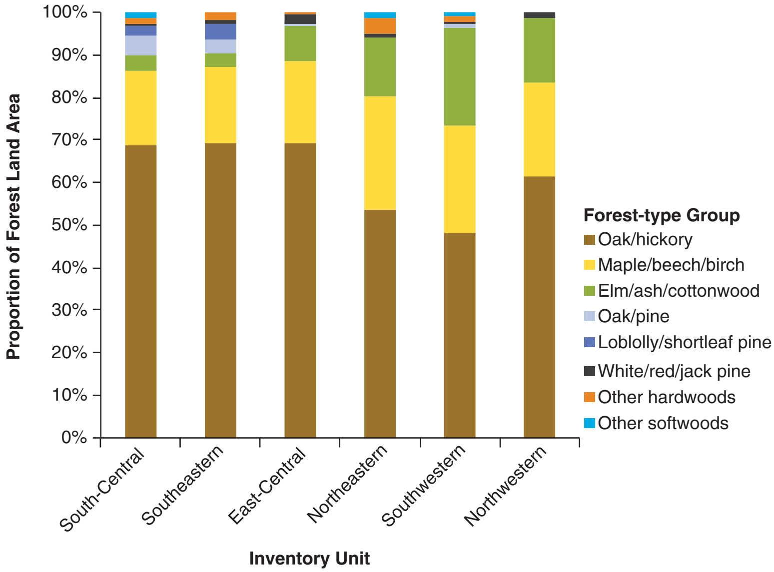


Figure 21.—Percentage of forest land area, by forest-type group and inventory unit, Ohio, 2016.

Ohio's forests contain an estimated 1.1 billion trees having a diameter at breast height (d.b.h.) of at least 5 inches, a 2.7 percent increase over the 2006 estimate. Thirteen species each accounted for at least 2 percent of total tree numbers (Fig. 22), and the most numerous species was red maple with 141 million trees, or 13 percent of all trees greater than or equal to 5 inches d.b.h. The 13 species with the most trees remained unchanged since 2006, but some species lost or gained positions. White ash dropped one spot to the sixth most numerous tree. Its 17 percent decrease in tree numbers from the 2006 estimate was mostly due to emerald ash borer (*Agrilus planipennis*) (see Tree Pests and Diseases of Special Concern on p. 92). White oak also lost 14 percent of its trees 5 inches or greater. Black walnut replaced black locust in the number 10 spot due to a 10 percent decrease in the number of black locust trees and a 24 percent increase for black walnut. The 13 most numerous species account for 65 percent of all trees, and 16 additional species have at least 1 percent of the total tree estimate.

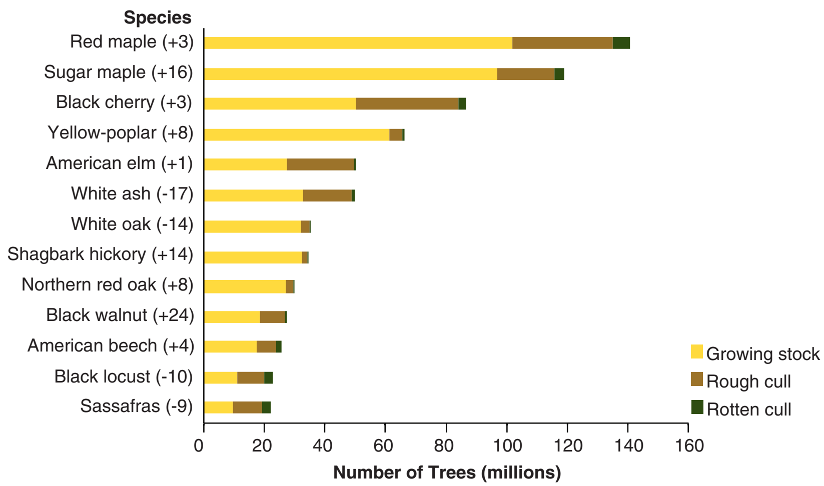


Figure 22.—Number of trees at least 5 inches in diameter on forest land for species composing at least 2 percent of total number of trees, by species and tree class, with percentage change between 2006 and 2016 in parentheses, Ohio, 2016.

FIA considers any tree with d.b.h. between 1.0 and 4.9 inches a sapling. The estimate of the total number of saplings decreased 4 percent from 2006 to 2.9 billion in 2016, but the 10 species with the most saplings did not change. Sugar maple remained the most numerous sapling with 411 million saplings (Fig. 23), down 4 percent from 2006. The number of red maple saplings decreased by 15 percent, but this species again had the second highest number of saplings with 320 million. Yellow-poplar moved from the eighth to the fourth spot due to a 25 percent increase in sapling numbers with a total of 128 million. Flowering dogwood went down two spots to the ninth position with 95 million saplings, a 19 percent decrease since 2006. American beech moved up one spot to the eighth most numerous sapling due to a 20 percent increase in number to 104 million in 2016. Seven of the leading 10 species had substantial decreases in number between 2006 and 2016, including American elm (-9 percent), black cherry (-21 percent), hawthorn (-22 percent), and white ash (-13 percent).

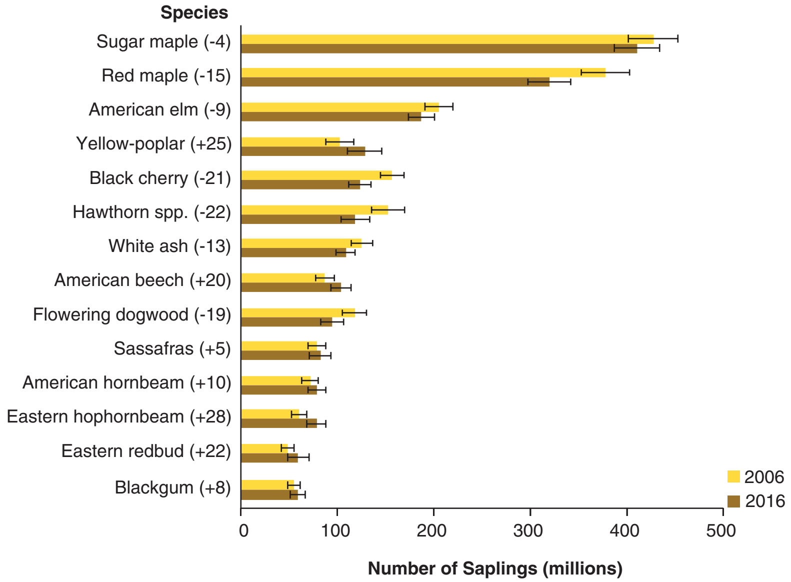


Figure 23.—Number of saplings (1.0 to 4.9 inch d.b.h.) for species composing at least 2 percent of total sapling numbers, by species and inventory year, with percentage change between 2006 and 2016 in parentheses, Ohio. Error bars represent a 68 percent confidence interval.

Tree species with d.b.h. less than 1.0 inch and length of at least 12 inches in hardwoods or 6 inches in conifers are tallied as seedlings. The total seedling estimate decreased 1 percent between 2006 and 2016 to 17.9 billion seedlings. White ash and sugar maple remained the most numerous species (Fig. 24) with white ash seedling numbers increasing 38 percent and sugar maple dropping 24 percent from 2006. Red maple, green ash, black cherry, and sassafras had substantial decreases of 29, 21, 39, and 37 percent, respectively. Notable increases were observed in pawpaw (64 percent) and slippery elm (61 percent). Hawthorn moved out of the 10 species with the most seedlings, based on a 39 percent decrease in seedlings. The increase in numbers of pawpaw moved it to the 4th spot, up from 11th in 2006.

Differences in composition by diameter class and species are evident. In 2006, oaks accounted for 22 percent of all trees with d.b.h. 11 inches or greater, but composed only 5 percent of total sapling numbers and 7 percent of seedlings. The proportion of trees 11 inches or greater in d.b.h. that were oaks dropped below 20 percent in 2016, with fewer than 6 percent of all saplings and 8 percent of seedlings. Oaks dominated the larger diameter classes across Ohio, having 30 percent of all trees 17 inches or greater in diameter, but only 12 percent of trees 5 inches or greater. Species of maple have increased as a proportion of all trees at least 5 inches since 2006. Collectively, red maple and sugar maple made up 24 percent of trees at least 5 inches and 21 percent of trees at least 11 inches in diameter, but only 17 percent of trees 17 inches and greater.

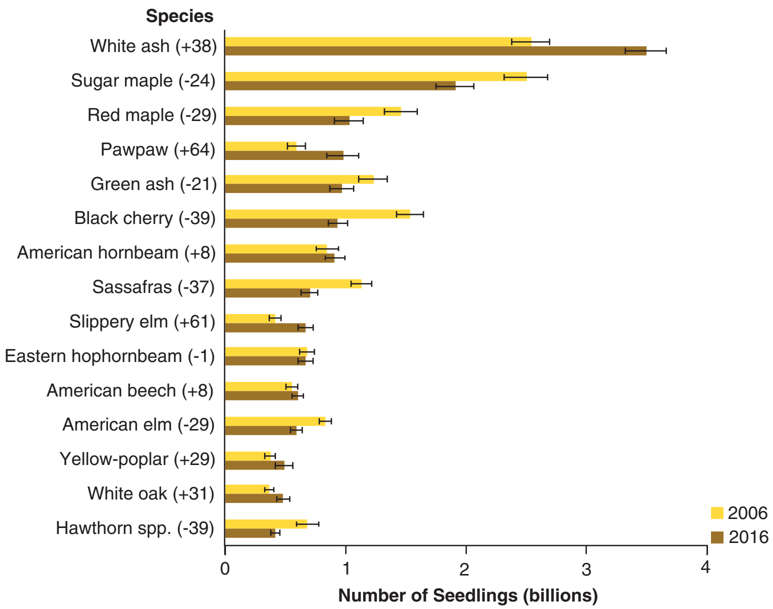


Figure 24.—Number of seedlings for species composing at least 2 percent of total seedling numbers, by species and inventory year, with percentage change between 2006 and 2016 in parentheses, Ohio. Error bars represent a 68 percent confidence interval.

What this means

The variety of species and forest types in Ohio shows a diverse population within the State's forests. A diversity of species and communities provides for a wealth of goods and services and makes a forest more resilient to insect and disease outbreaks that adversely affect any one species or species group. Little change has occurred since 2006 in the acreage of the major forest-type groups, suggesting a stability in the forest resource in terms of community types.

Decreasing numbers of seedlings and saplings are most likely the result of the stand dynamics at play in Ohio's maturing forests. Seedlings and saplings growing under a mature canopy receive scant resources on which to thrive. Therefore, many will not survive to maturity without the creation of canopy gaps to grow into. A resource that continues maturing, with a greater proportion of trees in larger diameter classes, leaves less opportunity for a proliferation of regeneration, particularly of shade-intolerant species.

Observations about the number of species composing at least 1 percent of total abundance in each of the three major tree-size classifications (seedlings, saplings, trees with d.b.h. 5 inches or greater) may indicate a decreasing diversity of species in future forests in Ohio. Twenty-nine species have at least 1 percent of the total number of trees at least 5 inches in diameter, and most of those (26) are capable of reaching dominant or codominant positions in the forest canopy. For saplings, 26 species make up at least 1 percent of the total sapling estimate. Six of those species, including the invasive species ailanthus, contribute to the 15 percent of total sapling abundance that is in noncommercial species. Twenty-seven species each make up at least 1 percent of total seedling numbers, six of which again are noncommercial species and together represent 17 percent of total seedling abundance. Maintaining a diversity of canopy species, as well as forest products and services, will require regeneration strategies to promote desirable species and limit the proliferation of those that are less desirable.

The past stability in forest communities does not, however, mean that changes will not occur in the future. The differences noted in the composition of the overstory versus those species of growing number in the smaller diameter classes may be an indication of changes to come. Oaks are a high proportion of the larger diameter classes, with each of five species having at least 1 percent of total tree (diameter 5 inches or greater) numbers; these species together make up 10 percent of all trees. Four species of oak compose at least 1 percent of seedling abundance, for a combined 7 percent of all seedlings. But only three species of oak have at least 1 percent of saplings, for a total of 4 percent of all saplings. These estimates suggest that seedlings, though lower than the proportion of oaks in the overstory, are able to become established but do not survive to sapling status. It is likely that they succumb to a combination of stressors such as browsing by ungulates (e.g., white-tailed deer [*Odocoileus virginianus*]) and competition from more shade-tolerant species in the understory.

Red and sugar maple combine for almost 24 percent of all trees and more than 25 percent of all saplings. Yet for seedling abundance, their share is only 14 percent, a proportion that has dropped substantially over the past 10 years. Maples, with a high proportion of trees in the smaller diameter classes, may be well situated to replace oak species in the larger diameter classes as those oaks are removed or suffer mortality. The long-term status of maples within Ohio's forests, however, will largely depend on future regeneration trends.

Forest Structure

Background

In addition to species composition, the size and age of trees and their density are important descriptors of any forest. FIA categorizes stand size based on the size of the trees occupying a majority of a stand and reports them as one of three classes: large diameter (minimum 11.0 inch d.b.h. for hardwoods and 9.0 inch d.b.h. for softwoods), medium diameter (5.0 to 10.9 inch d.b.h. for hardwoods and 5.0 to 8.9 inch d.b.h. for softwoods), and small diameter (less than 5.0 inch d.b.h.). These classes can be referred to as sawtimber, poletimber, and seedling/sapling, respectively, and indicate the developmental stage of the forest.

Forest stand age is analogous to successional stage. Young, vigorous forests exemplify early successional habitat valuable to some wildlife species. A diversity of timberland by successional stage is vital in ensuring the long-term availability of forest products and values. Stand age is determined by tree cores of dominant and codominant trees representing the plurality of trees within the forest condition and reported here in 20-year class intervals.

Relative stocking is a measure of the area occupancy of trees in a forest stand. Understanding stocking is critical to gaining a perspective on stand dynamics, especially competition between individuals, growth rates of individual trees, and light distribution. FIA classifies stocking into five categories: overstocked (more than 100 percent), full (60-100 percent), moderate (35-59 percent), poor (10-34 percent), and nonstocked (0-9 percent). Overstocked stands are exceedingly dense, resulting in crowded trees that compete for limited resources at the expense of health and growth. Increased mortality and lack of regeneration, especially of shade-intolerant species, are characteristic of overstocked stands. Fully stocked stands are of sufficient density to effectively utilize the resources available on the site. Moderately stocked stands have ample room for ingrowth while also leaving gaps in the canopy through which light can reach the forest floor. Poorly stocked stands have sparse canopy cover and are open to colonization by invasive and undesirable species. Nonstocked stands are typically found after a harvest or severe disturbance.

FIA evaluates stocking in two ways: using growing-stock trees and using all-live trees. Growing-stock trees are commercial species with less than two-thirds rough and rotten cull. Live-tree stocking includes trees of noncommercial species and cull trees. These occupy space in the forest that could be used to grow trees of higher commercial value. But they also add critical value to a forest as food and habitat sources for wildlife and provide the diversity necessary for a healthy forest. By comparing growing-stock stocking and all-live stocking, we can gain some insight into the relative proportions of merchantable tree species and cull trees. This difference can also highlight opportunities where forest management interventions may be useful or necessary.

What we found

Ohio's timberland continues to shift into larger size-classes. An estimated 5.2 million acres of timberland were classified as large diameter stands in 2016 (Fig. 25), or 68 percent of total timberland area. This represents a substantial increase from the estimates of 53 percent in 1991 and 63 percent in 2006. Poletimber area decreased slightly from 23 percent in 1991 to 21 percent in 2016, covering 1.6 million acres. The small diameter class had a higher loss of acreage, dropping nearing 1 million acres of timberland from 1.8 million acres in 1991 (24 percent of timberland) to 821,000 acres in 2016 (11 percent of timberland). A higher percentage of public timberland was in large diameter stands (73 percent) compared to 67 percent of private timberland. As a proportion of total public timberland acreage, the distribution across stand-size classes remained relatively stable (Fig. 26), even while increases in public acreage estimates occurred. Private timberland trends generally mirror the statewide changes with increases in the proportion of timberland comprising large diameter timber and decreases in the proportion of small diameter stands.

Eighty-five percent of large diameter stands fell into the fully or moderately stocked classes (Fig. 27). Only 4 percent of large diameter stands are overstocked, with the overstocked class having its highest percentage in small diameter stands (15 percent).

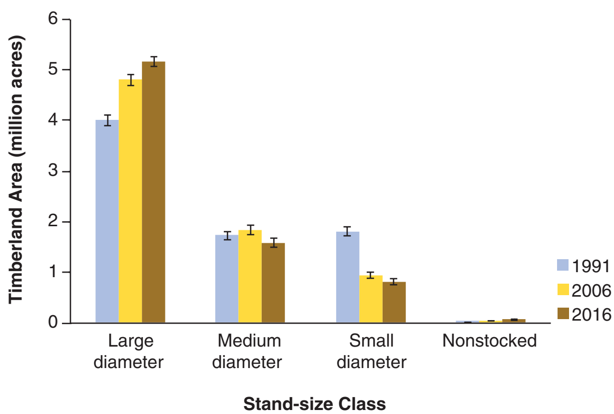


Figure 25.—Area of timberland by stand-size class and inventory year, Ohio. Error bars represent a 68 percent confidence interval.

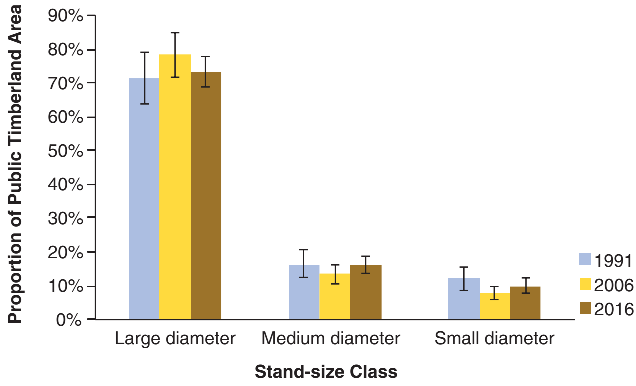


Figure 26.—Percentage of public timberland area by stand-size class and inventory year, Ohio. Error bars represent a 68 percent confidence interval.

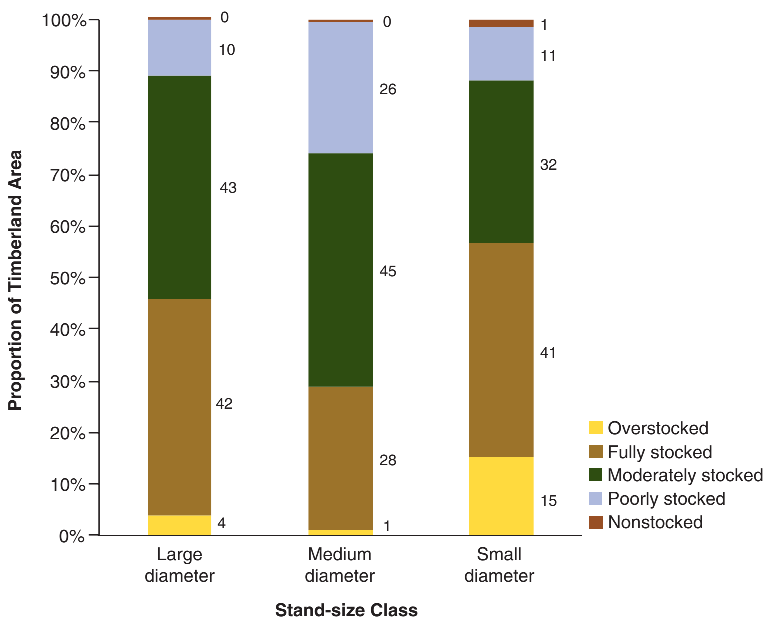


Figure 27.—Percentage of timberland area by live-tree stocking class and stand-size class, Ohio, 2016.

The Northwestern unit had the highest percentage of timberland in large diameter stands at 75 percent, and the lowest proportion of poletimber (15 percent) and small diameter timberland (9 percent) (Fig. 28). East-Central Ohio has the most acreage in sawtimber stands at 1.2 million acres, or 67 percent of total timberland in the unit. The area in small diameter stands was highest in the South-Central unit at 229,000 acres (13 percent of the unit).

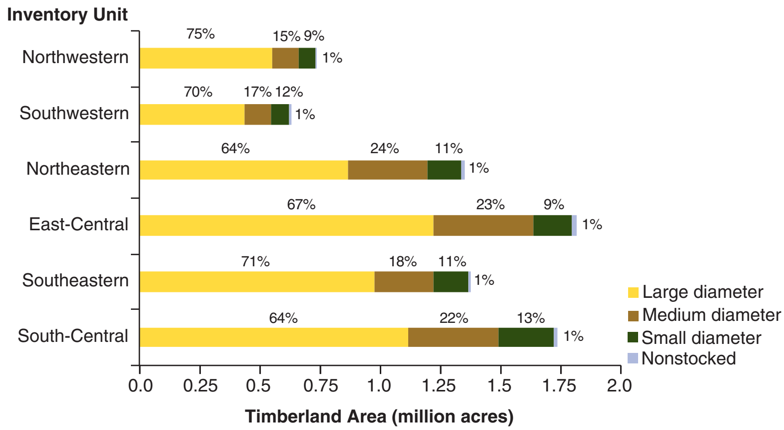


Figure 28.—Timberland area by inventory unit and stand-size class, Ohio, 2016.

Ohio timberland has shown a clear trend of aging forests. In 2006, an estimated 65 percent of timberland was less than or equal to 60 years of age, with the bulk of that (36 percent) in the 41- to 60-year age class (Fig. 29). This proportion dropped to 52 percent in 2016, with the largest drop occurring in the 21- to 40-year class, falling from 19 percent of timberland to just 11 percent, a loss of more than 600,000 acres (Fig. 30). Timberland 40 years of age or less decreased by more than 650,000 acres, from 28 percent of timberland in 2006 to 19 percent in 2016. Over the same time period, the proportion of timberland over 60 years old increased from 35 to 47 percent (Fig. 29).

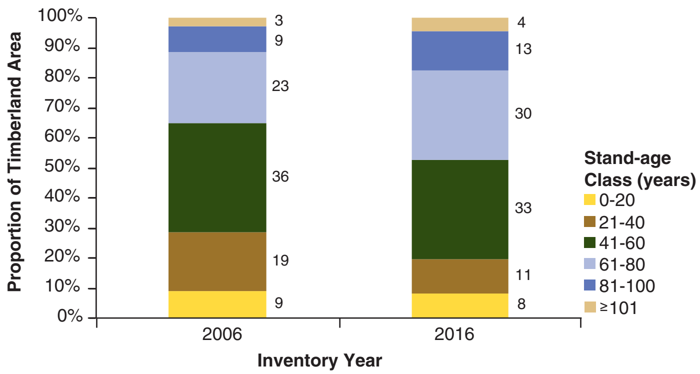


Figure 29.—Percentage of timberland area by stand-age class and inventory year, Ohio.

Distinct differences were apparent in the distribution of timberland age classes when we consider major ownership groups. Over half (54 percent) of private timberland was 60 years old or younger in 2016, down from 67 percent in 2006 (Fig. 31). On private land, the two age classes from 41 to 80 years combined made up 65 percent of the total, or 4.4 million acres, in 2016. Public timberland had a more even distribution of acreage across the age classes. No single class accounted for more than 27 percent of public land, though with 58 percent of public timberland being over 60 years of age it tends to be older than private timberland.

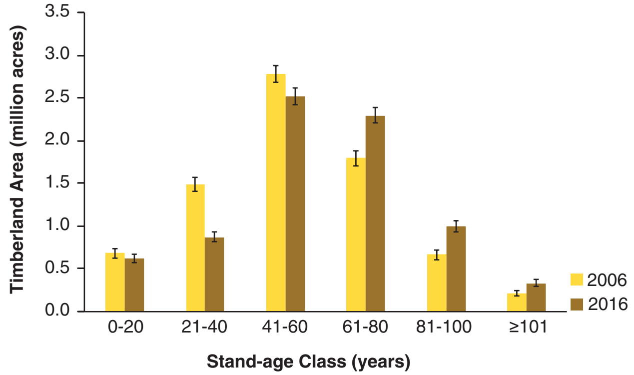


Figure 30.—Timberland area by stand-age class and inventory year, Ohio. Error bars represent a 68 percent confidence interval.

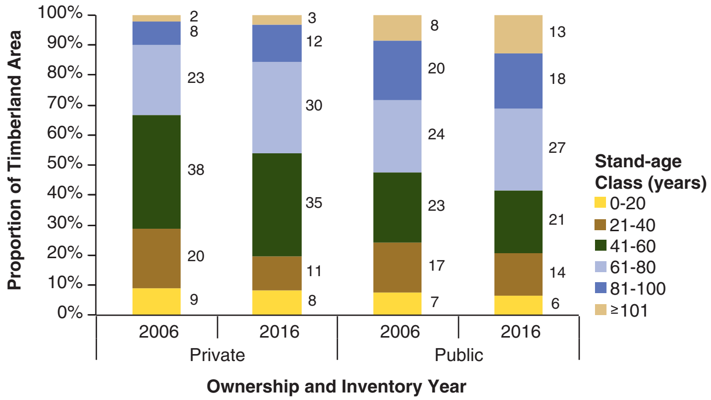


Figure 31.—Percentage of timberland area by stand-age class, major ownership group, and inventory year, Ohio.

As of 2016, 81 percent of Ohio timberland was either fully (39 percent) or moderately stocked (42 percent) with live trees (Fig. 32). The distribution of timberland across live-tree stocking classes showed little change between 2006 and 2016. The largest changes were a 3 point increase in the percentage of fully stocked timberland and a 3 point decrease in moderately stocked timberland. In terms of growing-stock stocking, 66 percent of timberland is either fully (26 percent) or moderately stocked (40 percent). The nonstocked and poorly stocked classes represent 32 percent of timberland statewide. The proportion of timberland in each growing-stock stocking class showed slightly more change than live-tree stocking, having lost 1, 2, and 4 percentage points in the overstocked, fully stocked, and moderately stocked classes, respectively. The acreage poorly stocked with growing-stock trees increased from 22 percent of timberland in 2006 to 27 percent in 2016 and the growing-stock nonstocked class grew from 3 percent to 5 percent of timberland.

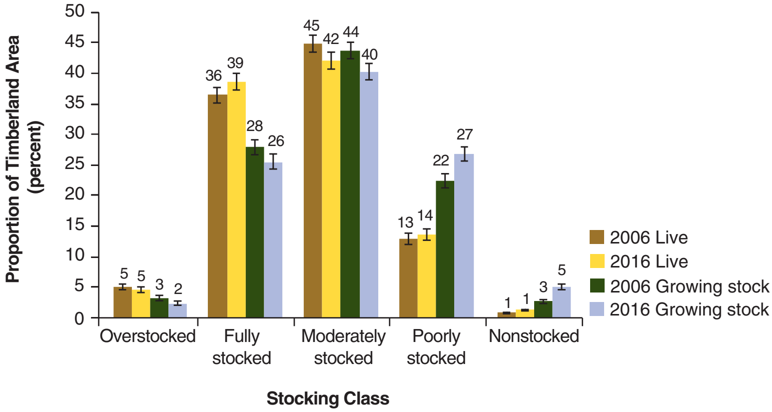


Figure 32.—Percentage of timberland area by live-tree and growing-stock stocking class and inventory year, Ohio. Error bars represent a 68 percent confidence interval.

Regional differences in the stocking classes composing total timberland acreage are evident (Fig. 33). For live-tree stocking statewide, a combined 44 percent of timberland was in the overstocked (5 percent) and fully stocked (39 percent) classes. This number ranges from 33 percent in the East-Central unit to 52 percent in both the Northeastern and Northwestern units. Poorly stocked and nonstocked classes combined for 15 percent of timberland across the State, ranging from 11 percent in the Southeastern unit to 19 percent in the East-Central unit. Growing-stock stocking percentages also stand out for the East-Central unit. Forty-two percent of the timberland in the East-Central unit was either nonstocked or poorly stocked with growing-stock trees, 10 points higher than the statewide estimate and 23 points higher than the estimate for live-tree stocking in the nonstocked and poorly stocked classes.

Growing-stock trees are a subset of all live trees, so growing-stock stocking is a subset of live-tree stocking. Therefore, acreage in any given live-tree stocking class will also fall into the same or lower growing-stock stocking classes. For example, an area fully stocked with live trees can be fully, moderately, poorly, or nonstocked with growing-stock trees. By comparing live-tree and growing-stock stocking at the same location, and the trends over time, we can gain some insight into the site occupancy relative to merchantable trees. This method of analysis revealed some notable changes.

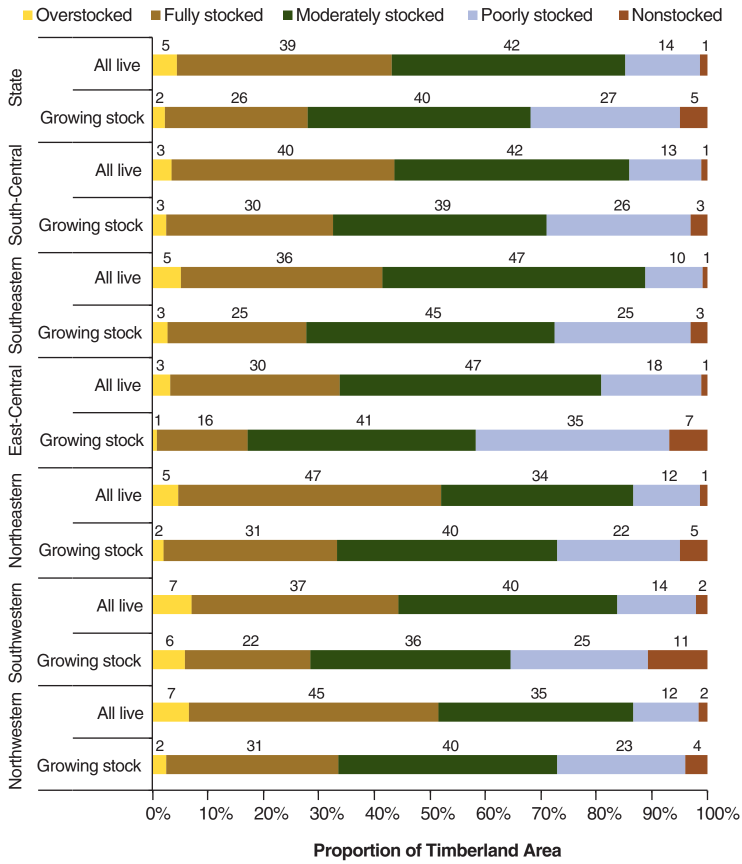


Figure 33.—Percentage of timberland, by live-tree and growing-stock stocking class and inventory unit, Ohio, 2016.

In 2006, 89 percent of timberland that was overstocked with live trees was either overstocked or fully stocked with growing-stock trees (Fig. 34). That proportion dropped to 87 percent in 2016. Seventy-three percent of timberland area that was fully stocked with live trees in 2006 was also fully stocked with growing-stock trees; in 2016, however, that proportion was 62 percent, representing a loss of 200,000 acres. That acreage shifted into lower growing-stock stocking classes as the moderate class increased from 25 percent to 32 percent of the area fully stocked with live trees and the poorly stocked class increased from 2 percent to 5 percent. For timberland in the moderately stocked live-tree stocking class, the proportion that was also moderately stocked with growing-stock trees decreased by 11 points (from 77 percent to 66 percent) and the percentage that was poorly stocked increased from 22 percent to 32 percent. Acreage nonstocked with growing-stock trees also increased from 1 percent to 2 percent of the moderately stocked live-tree class. The proportion of the area of timberland poorly stocked with live trees and nonstocked with growing-stock trees doubled from 9 percent in 2006 to 18 percent in 2016.

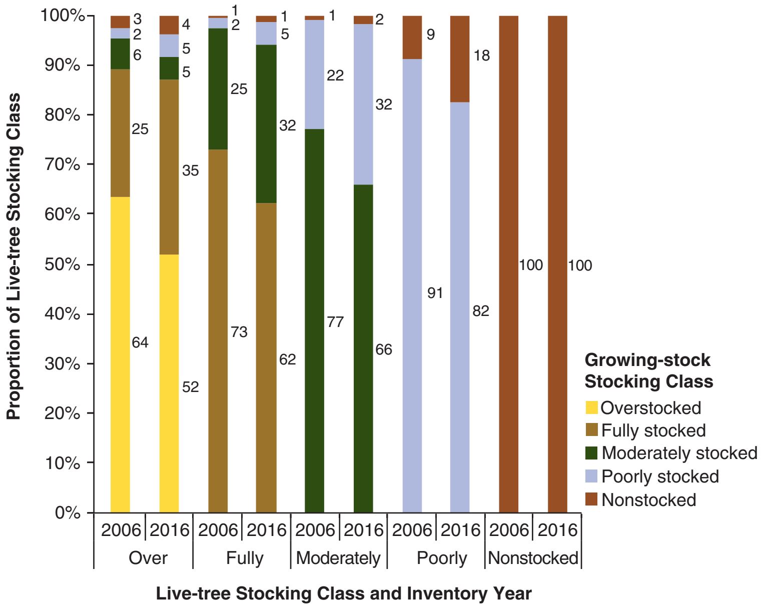


Figure 34.—Percentage of live-tree stocking class, by growing-stock stocking class and inventory year, Ohio.

What this means

The growing proportion of Ohio timberland dominated by large diameter timber and the increasing percentage of timberland over 60 years old indicate a largely mature resource. There is a dearth of young and small diameter forests available to replace the aging forest. The rich diversity of tree species found throughout the State supports a variety of wildlife, but the relative lack of diversity in age and size structure can leave some species that rely on early successional stages unsupported. Furthermore, like species diversity, a diversity of ages and sizes can better prepare a resource to tolerate significant disturbances such as insect and disease outbreaks.

Ohio's decreasing proportion of timberland in the lowest size and age classes suggests a lack of harvesting and disturbance sufficient to cause stands to revert to early successional stages. With the majority of large diameter stands in higher stocking classes, opportunities abound for stand improvement activities to be funded by a removal of a portion of available sawtimber in fully and overstocked stands.

As a healthy mature resource with a diverse population of tree species, the forests of Ohio have a variety of species and tree forms that enhance values other than commercial timber. Those trees that do not meet commercial timber specifications contribute to live-tree stocking but not growing-stock stocking. Evaluating the stocking structure of growing-stock trees in relation to all live trees shows a rising disparity between growing-stock and live-tree stocking. The area of timberland in the moderately and fully stocked classes for live trees remained stable at 6.2 million acres, 81 percent of all timberland. Of that acreage, 1.3 million acres, over 20 percent, were either poorly or nonstocked with growing-stock trees, an increase of more than 400,000 acres between 2006 and 2016. This growing disparity indicates that an increasing proportion of timberland is occupied by noncommercial trees.

A legacy of less than ideal management techniques very likely contributed to the conditions of the present. Generally, harvesting practices that maximize short-term economic gain do not prioritize the value of the residual stand. Harvesting only trees of higher value and leaving noncommercial trees decreases the proportion of growing-stock trees left after harvest, thereby degrading the overall quality of the future forest. Thinning noncommercial species and cull trees in fully stocked stands can increase the availability of resources for the remaining growing-stock trees and create canopy gaps to encourage the regeneration of less shade-tolerant species, while maintaining forest values for future generations.

The National Woodland Owner Survey has shown that the owners of less than 25 percent of Ohio family forest land received management advice for their land, and management plans are in place for only 17 percent of family forest land. The limited use of professional forest management resources suggests that important opportunities for outreach promoting responsible forest management exist throughout Ohio.

Volume on Timberland

Background

Estimates of tree volume, and the associated trends, quantify the changes in the wood resource available for use. Several measures of volume are available for evaluation: sound and net volume of live trees and growing-stock trees in cubic feet, and sawtimber volume in board feet (International ¼-inch rule). The different measures are useful in quantifying various portions of the wood resource.

All volume calculations are based on trees at least 5 inches in diameter. Sound volume is the volume of a tree with deductions taken for rotten and missing wood. Net sound volume, or net volume, is the sound volume of a tree with more deductions taken for form defects, such as sweep, crook, and forks. Estimates of net volume can be further restricted by including growing-stock trees only. Growing-stock trees are those of a commercial species having less than two-thirds of their volume in sound or rotten cull. Qualifying portions (free of sound or rotten cull) of trees not meeting the definition of growing stock are also calculated. Rough cull refers to trees not of a commercial species or that have more than two-thirds of their volume in mostly sound cull. Rotten cull trees are those that are at least two-thirds cull, the majority of which is unsound. Sawtimber volume is a calculation of the volume in the saw log portion of trees of a certain minimum size. Hardwood species must have a d.b.h. of at least 11 inches to be considered sawtimber, and the minimum top diameter of a saw log is 9 inches. Softwood species must be at least 9 inches in diameter and the minimum top diameter is 7 inches.

What we found

The estimate of sound volume on timberland in Ohio was 18.3 billion cubic feet in 2016. An additional 106 million cubic feet on other forest land and 800 million cubic feet on reserved forest land made the total forest land estimate 19.3 billion cubic feet, a 10 percent increase from 2006. Net volume on timberland totaled 15.8 billion cubic feet, up 7 percent from 2006. Growing-stock volume was 86 percent of total net volume at 13.6 billion cubic feet (Fig. 35), an increase of only 0.3 percent. Most of the increase in timberland net volume occurred in rough cull, which rose to 2.0 billion cubic feet, a gain of 82 percent over the 2006 estimate. Rough cull represented 12 percent of timberland net volume. Rotten cull accounted for the remaining 273 million cubic feet. Notably, growing-stock volume in 2006 was 91 percent of total net volume on timberland and rough cull was 7 percent.

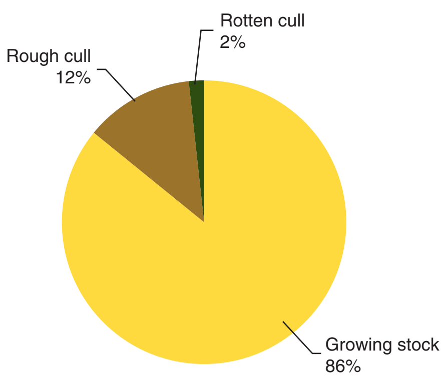


Figure 35.—Percentage of net volume on timberland by tree class, Ohio, 2016.

A total of 24 species each contribute at least 1 percent of total net volume (Fig. 36). The 10 species with the highest net volume collectively made up 62 percent of all volume and gained 8 percent over 2006, though at varying rates. Red maple continued to have the most net volume on timberland of any species with 1.7 billion cubic feet, a gain of 14 percent over the 2006 estimate and nearly 11 percent of all species combined. Yellow-poplar was a close second; it trailed red maple by only 38 million cubic feet and increased in net volume by 16 percent. Shagbark hickory net volume increased 24 percent over the previous 10 years while net volume of sugar maple and northern red oak each went up 19 percent. Black cherry and black oak net volume increased 8 percent and 1 percent, respectively. Losses were observed in both white oak and white ash, with decreases of 9 percent and 20 percent, respectively.

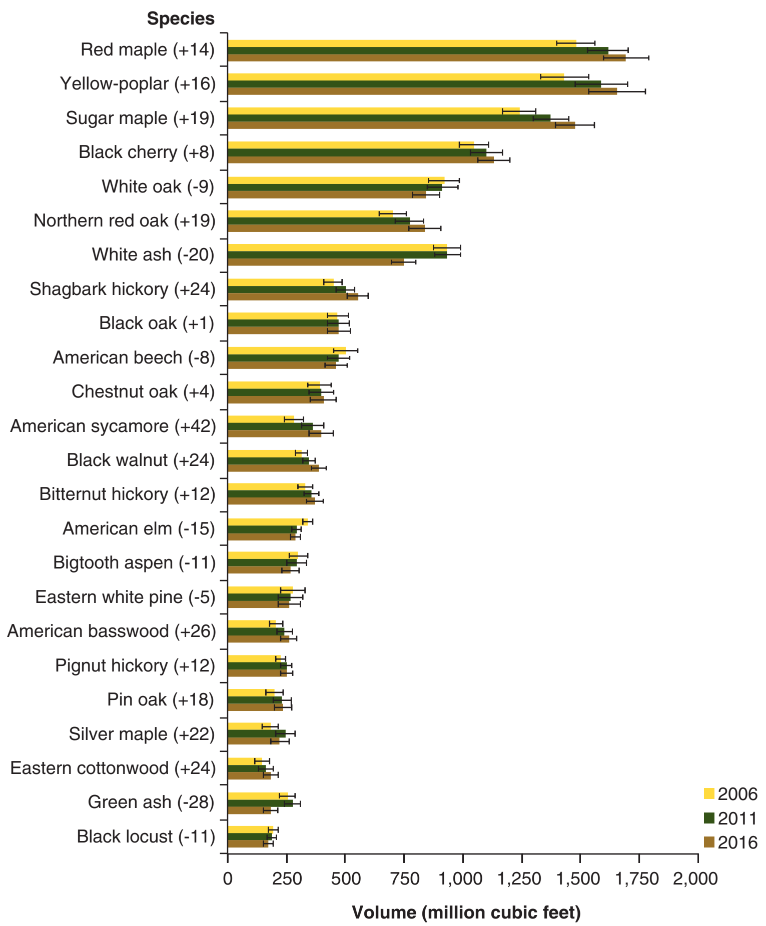


Figure 36.—Net volume on timberland for species composing at least 1 percent of total net volume, by species and inventory year, with percentage change between 2006 and 2016 in parentheses, Ohio. Error bars represent a 68 percent confidence interval.

Net volume increases were concentrated in the diameter classes of 16 inches and larger (Fig. 37). All diameter classes below 16 inches (trees 5.0 to 14.9 inches) lost net volume between 2006 and 2016. Collectively, net volume in the lower diameter classes decreased 4 percent. Increases in net volume for trees 15 inches and larger were 20 percent between 2006 and 2016.

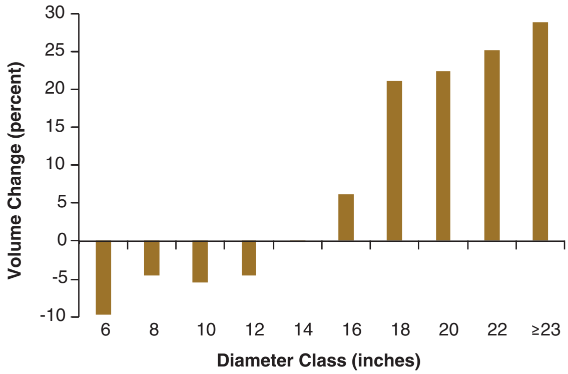


Figure 37.—Percentage change in net volume, by diameter class on timberland, Ohio, 2006 to 2016.

Volume per acre of timberland was an estimated 2,072 cubic feet in 2016, 7 percent higher than the 2006 estimate. Per acre volume was highest on State-owned land with 2,455 cubic feet per acre (Fig. 38), though this was only 3 percent higher than in 2006. Increases in net volume per acre were highest on county and municipal government land (10 percent) as well as on national forest property (9 percent). When we look at volume per acre by age class (Fig. 39), decreases from 2006 estimates were observed in age classes 0-20 years (-3 percent), 21-40 years (-9 percent), and 41-60 years (-5 percent). All older classes exhibited higher per acre net volumes relative to 2006: 3 percent for 61-80 years, 1 percent for 81-100 years, and 15 percent for 101-150 years.

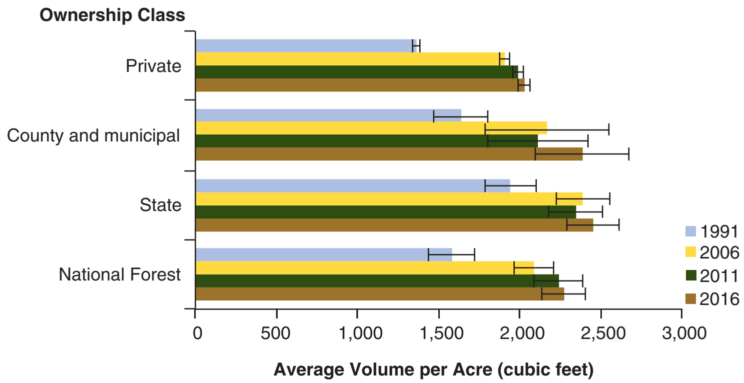


Figure 38.—Average net volume per acre of timberland, by select ownership class and inventory year, Ohio. Error bars represent a 68 percent confidence interval.

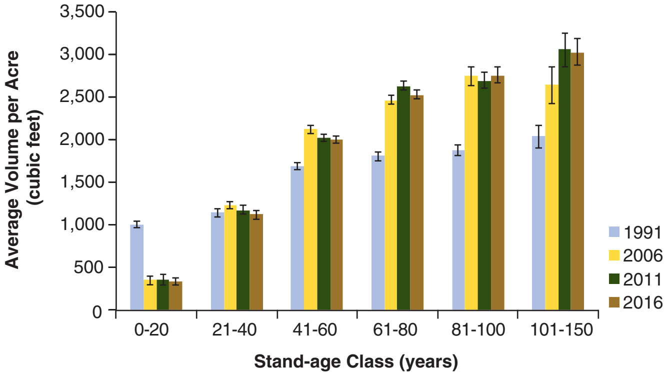


Figure 39.—Average net volume per acre of timberland, by stand-age class and inventory year, Ohio. Error bars represent a 68 percent confidence interval.

All regions of Ohio showed per acre increases in net volume from 2006 to 2016 (Fig. 40). Gains were highest in the Northeastern unit, where the net volume of 2,245 cubic feet per acre represented an 11 percent increase from 2006. The Northwestern unit had the highest per acre volume at 2,246 cubic feet per acre, but exhibited the smallest percentage growth over 2006 at less than 2 percent. Per acre net volume was the lowest in the East-Central unit at 1,950 cubic feet per acre, though it did increase 9 percent from 2006.

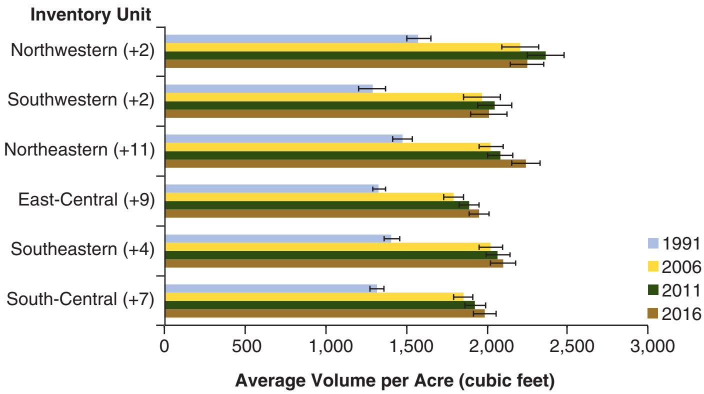


Figure 40.—Average net volume per acre of timberland, by inventory unit and year, with percentage change between 2006 and 2016 in parentheses, Ohio. Error bars represent a 68 percent confidence interval.

Regional differences in net volume by species, as well as rate of volume change for those species since 2006, were apparent. The 10 species with the greatest volume vary across the units (Table 5), but collectively represent between 61 and 70 percent of the total for each unit. Red maple, sugar maple, northern red oak, white ash, and black cherry were among the 10 highest-volume species in all regions, though they composed varying proportions of regional volume. Yellow-poplar was the leading species by net volume in both the South-Central and Southeastern units, gaining 23 percent and 16 percent, respectively, since 2006. Sugar maple had the most volume of all species in the Northwestern and Southwestern units, and was the second most voluminous species in the Northeastern, Southeastern, and South-Central units; gains ranged from 39 percent in the Northwestern unit to 12 percent in the South-Central unit. Red maple's share of regional volume ranged between 4 percent in the Southwestern unit and 20 percent in the Northeastern unit, the highest proportion of regional volume of any species in any unit. White oak was among the 10 leading species by net volume in 3 of the 6 units; this species had volume declines of 23 percent in the Southeastern unit and 4 percent in the South-Central unit, and a 21 percent increase in the East-Central unit. White ash remained 1 of the 10 most voluminous species across all units despite volume decreases ranging from 71 percent in the Northwestern unit to 6 percent in the Southeastern unit. It did, however, increase in net volume in two units, the South-Central and East-Central units, gaining 8 percent and 6 percent, respectively.

Table 5.—Net volume on timberland for the 10 species with the most volume (ranked by 2016 volume), by inventory unit, with percentage of regional volume, and percentage change in net volume between 2006 and 2016, Ohio

Region	Species	Volume in region, 2016 (million ft^3)	Volume as a percentage of total regional volume	Percentage change in volume, 2006 to 2016
South-Central	Yellow-poplar	510	15	23.0
	Sugar maple	356	10	12.1
	White oak	291	8	-4.1
	Red maple	270	8	31.1
	Chestnut oak	241	7	0.5
	White ash	159	5	7.8
	Black oak	121	4	-5.9
	Northern red oak	119	3	8.5
	Pignut hickory	119	3	8.7
	Black cherry	116	3	14.8
	Regional total	3,453	100	9.2
Southeastern	Yellow-poplar	528	18	16.4
	Sugar maple	304	11	20.6
	Red maple	237	8	11.6
	White oak	222	8	-23.3
	Northern red oak	167	6	32.8
	Chestnut oak	118	4	13.2
	Shagbark hickory	113	4	37.1
	White ash	109	4	-6.1
	Black oak	108	4	1.0
	Black cherry	105	4	4.2
	Regional total	2,885	100	6.1

(Table 5 continued on next page.)

(Table 5 continued)

Region	Species	Volume in region, 2016 (million ft^3)	Volume as a percentage of total regional volume	Percentage change in volume, 2006 to 2016
East-Central	Black cherry	484	14	13.7
	Red maple	420	12	21.9
	Yellow-poplar	412	12	2.5
	Sugar maple	222	6	15.4
	Northern red oak	189	5	22.8
	White oak	170	5	21.1
	White ash	144	4	5.9
	Black oak	135	4	13.4
	Eastern white pine	107	3	-6.8
	American sycamore	101	3	18.0
	Regional total	3,539	100	6.4
Northeastern	Red maple	604	20	7.1
	Sugar maple	281	9	23.2
	Black cherry	259	9	-7.2
	Northern red oak	190	6	12.3
	Pin oak	160	5	11.0
	Yellow-poplar	137	5	41.6
	White ash	137	4	-19.7
	American beech	123	4	5.1
	Bitternut hickory	109	4	15.4
	Shagbark hickory	96	3	17.7
	Regional total	3,037	100	7.1
Southwestern	Sugar maple	153	12	14.2
	White ash	142	11	-13.4
	Black cherry	87	7	17.2
	American sycamore	70	6	51.5
	Hackberry	62	5	40.3
	Northern red oak	60	5	-6.4
	Black walnut	57	4	8.9
	Red maple	54	4	-8.7
	Yellow-poplar	52	4	16.3
	American elm	39	3	-8.8
	Regional total	1,266	100	2.8
Northwestern	Sugar maple	161	10	38.7
	Shagbark hickory	147	9	10.4
	Black walnut	116	7	68.0
	Northern red oak	115	7	40.6
	American basswood	114	7	44.5
	Red maple	109	7	13.4
	Black cherry	82	5	22.8
	Bur oak	64	4	32.9
	White ash	57	3	-71.1
	Silver maple	57	3	152.3
	Regional total	1,658	100	6.8

Growing-stock net volume was an estimated 13.6 billion cubic feet, a 0.3 percent increase since 2006, though the gains were primarily between 2006 and 2011. Estimates of growing-stock net volume in 2011 and 2016 were virtually the same, increasing by only 4 million cubic feet. Collectively, the species having at least 1 percent of total growing-stock net volume increased 1.6 percent from 2006 to 2016. Nearly half of those 24 leading species decreased in growing-stock net volume during the previous 10 years (Fig. 41). Green ash, American elm, and white ash had the highest percentage losses, decreasing 34, 31, and 28 percent, respectively. Black cherry was the only species among the five most voluminous to lose volume, dropping 7 percent between 2006 and 2016. White oak growing-stock net volume also decreased, by 11 percent. Thirteen of the 24 most voluminous species had increases in growing-stock net volume over the 10 years, ranging from 2 percent for silver maple to 40 percent for American sycamore. Yellow-poplar, the species with the most growing-stock volume, increased by 15 percent between 2006 and 2016. Red maple and sugar maple volume estimates increased by 4 and 12 percent, respectively, during that time.

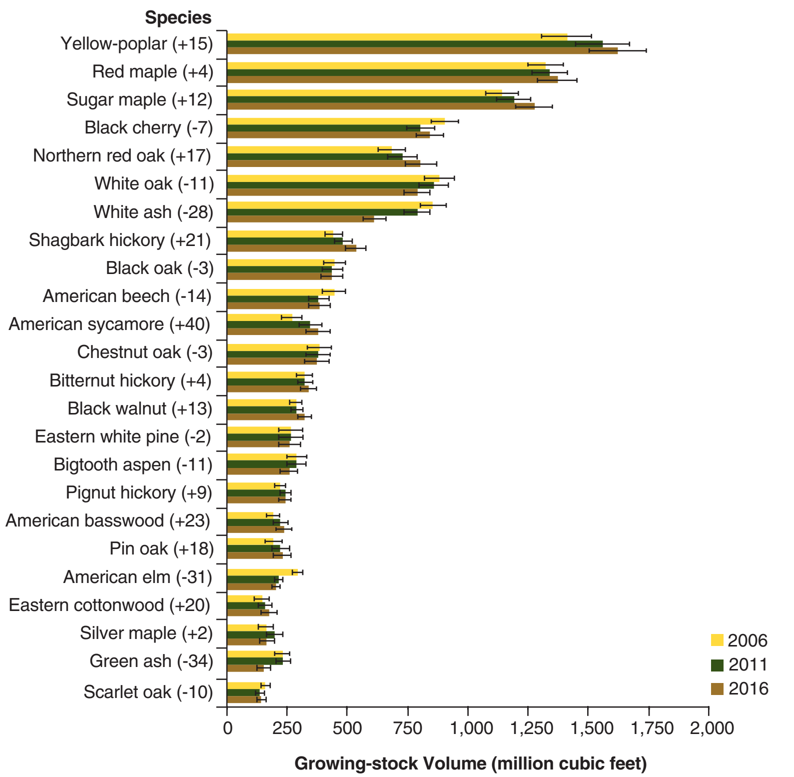


Figure 41.—Growing-stock volume, on timberland, of species having at least 1 percent of total growing-stock volume, by inventory year, with percentage change between 2006 and 2016 in parentheses, Ohio. Error bars represent a 68 percent confidence interval.

Distinct differences in growing-stock volume trends were observed for the major ownership groups. The proportion of net volume in growing-stock trees on private timberland dropped from 91 percent in 2006 to 85 percent in 2016 (Fig. 42). Public timberland growing stock also decreased as a percentage of the whole, though to a lesser degree, going from 94 percent to 91 percent in the same time period. Of the total estimated growing-stock volume on timberland, 14 percent was on the 12 percent of all timberland that is publicly owned. Growing-stock volume on public land increased 26 percent between 2006 and 2016, while privately owned land had a 3 percent decline in growing-stock volume over the same period.

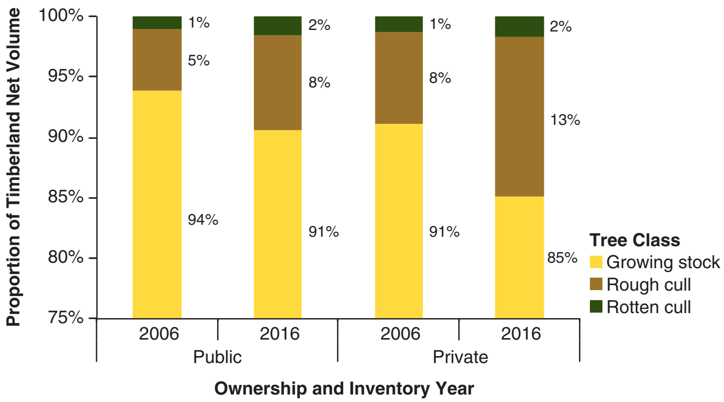


Figure 42.—Percentage of timberland net volume for major ownership groups, by tree class and inventory year, Ohio.

Sawtimber volume on timberland was estimated at 51 billion board feet (International ¼-inch rule), or 6,686 board feet per acre, increasing 8 percent between 2006 and 2016. Twenty-two species had at least 1 percent of total sawtimber volume (Fig. 43), and collectively made up 89 percent of total sawtimber volume. Yellow-poplar had the most sawtimber volume by far with 6.8 billion board feet, 20 percent higher than in 2006 and representing 13 percent of the total sawtimber volume. Red maple remained second with 4.2 billion board feet, or 8 percent of total sawtimber volume and a 16 percent increase since 2006. Sugar maple and northern red oak surpassed white oak with increases of 18 percent and 23 percent, respectively, in contrast to a 7 percent decrease for white oak to 3.5 billion board feet. Notably, white ash sawtimber volume dropped 25 percent between 2006 and 2016 to 2.3 billion board feet, though it is still ranked seventh. Other substantial changes in the 10 leading species by board foot volume include a 54 percent increase for American sycamore and a 32 percent increase for shagbark hickory. Eastern white pine was the only softwood species having at least 1 percent of sawtimber volume, with 1.1 billion board feet for 2 percent of the total. This represents a 16 percent increase in sawtimber volume over 2006 despite a 5 percent loss in net cubic foot volume for the species over the same period.

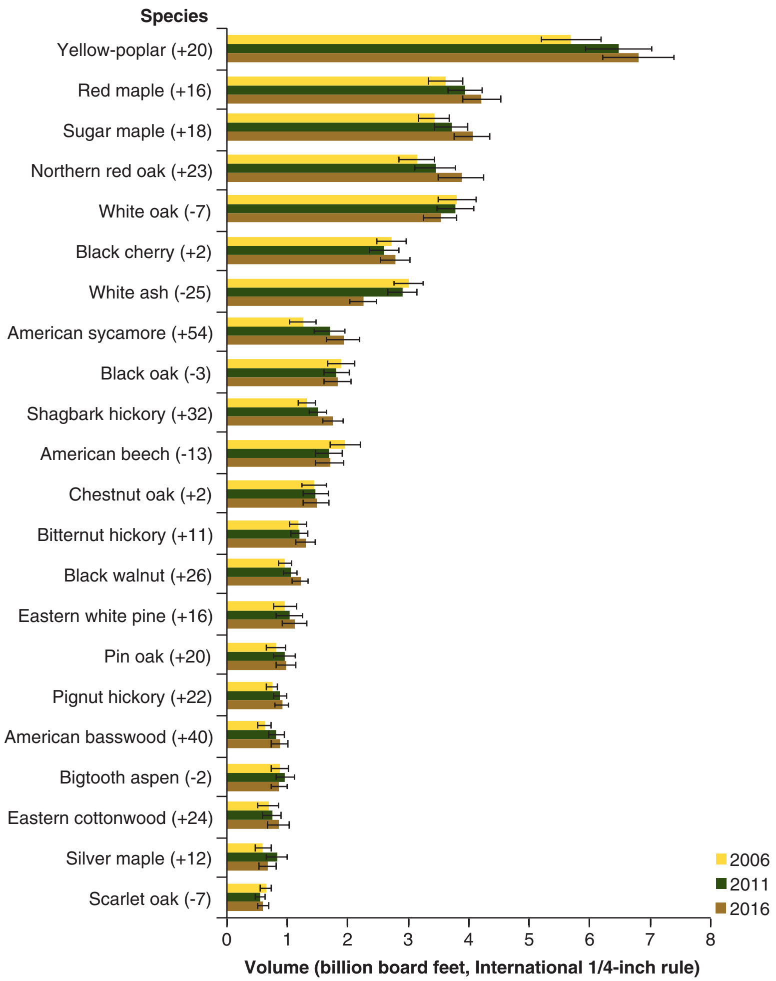


Figure 43.—Net volume of sawtimber trees on timberland for species having at least 1 percent of total sawtimber volume, by species and inventory year, with percentage change between 2006 and 2016 in parentheses, Ohio. Error bars represent a 68 percent confidence interval.

Evaluation of hardwood sawtimber volume by grade also shows some change. In 2006, hardwood grades 1 and 2 combined were 41 percent of total volume (Fig. 44). The same combination in 2016 was 43 percent, with grade 1 accounting for 29 percent of total sawtimber volume compared to just 18 percent in 2006. Grade 3 dropped from 28 percent of the total in 2006 to 26 percent in 2016, while trees graded as tie/local use increased from 18 percent of the total to 20 percent in 2016. Sawtimber volume in trees with qualifying saw logs but without a gradable butt log due to defect (such as rot or forks), referred to as “uppers” in Figures 44 through 46, accounted for 11 percent of total volume in 2016 compared to 12 percent in 2006.

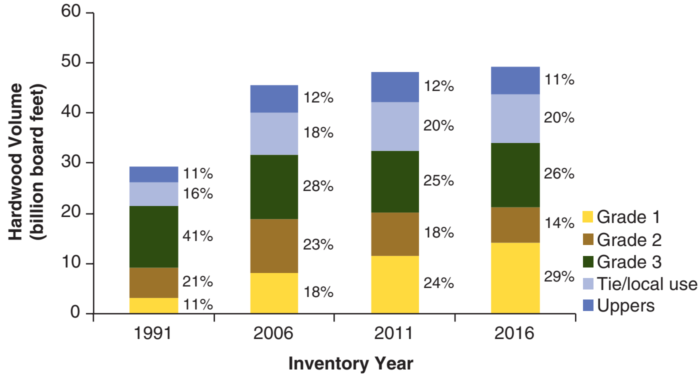


Figure 44.—Hardwood sawtimber volume on timberland, by tree grade and inventory year, with percentage of total hardwood sawtimber volume for each year, Ohio. "Uppers" refers to trees containing a qualifying saw log outside the butt section.

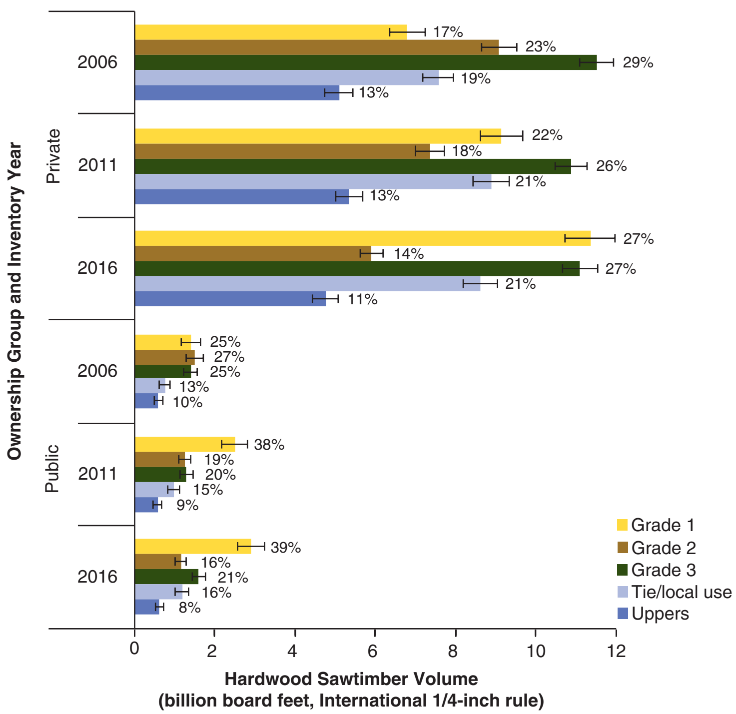


Figure 45.—Hardwood sawtimber volume on timberland, by tree grade, major ownership group, and inventory year, with percentage of total hardwood sawtimber volume for each year, Ohio. "Uppers" refers to trees containing a qualifying saw log outside the butt section. Error bars represent a 68 percent confidence interval.

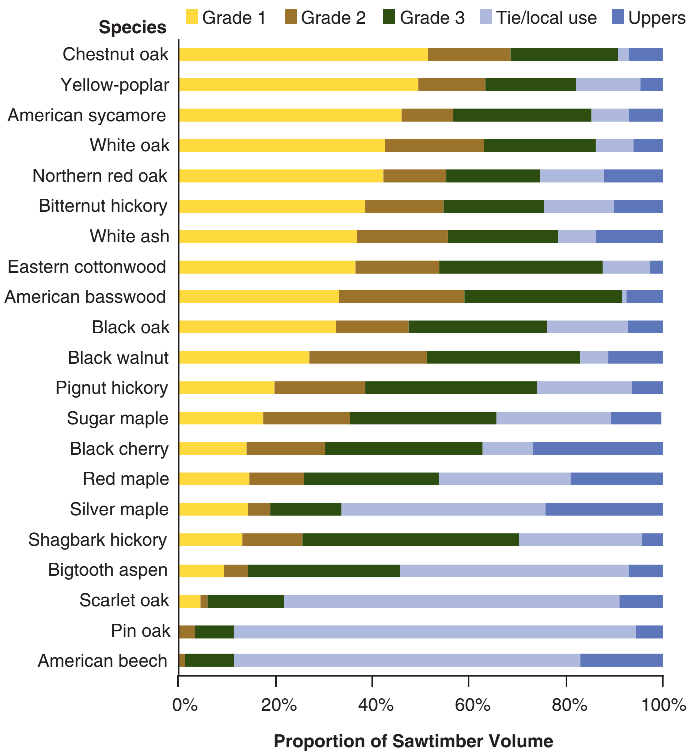


Figure 46.—Proportion of sawtimber volume by tree grade for species composing at least 1 percent of total hardwood sawtimber volume on timberland, Ohio, 2016. "Uppers" refers to trees containing a qualifying saw log outside the butt section.

Differences in major ownership classes are apparent when we look at hardwood sawtimber grades. Grade 1 trees were 27 percent of total sawtimber volume on private land (Fig. 45), but 39 percent on public land. The proportion of grade 2 was similar across ownerships, at 14 percent of total sawtimber volume on private land and 16 percent on public land. A higher percentage of volume on private land was in grade 3 trees, 27 percent versus 21 percent of volume in public ownerships. Similarly, the tie/local use category accounted for a higher share of volume on private land than on public land: 21 percent and 16 percent, respectively.

Grades by species differed as well. Of the 21 species having at least 1 percent of hardwood sawtimber volume, 5 species had at least 40 percent of their volume in grade 1 trees (Fig. 46): chestnut oak with 51 percent, yellow-poplar with 50 percent, American sycamore with 46 percent, white oak with 43 percent, and northern red oak with 42 percent. Sugar maple and red maple had only 17 percent and 14 percent of their volume in grade 1 trees, respectively. These lower percentages are partially due to the distribution of volume across diameter classes. To meet the grading requirements for a tree grade 1, a tree must be at least 16.0 inches in diameter. Species of oak had a higher proportion of sawtimber volume exceeding that diameter limit (79 percent) compared to species of maple (56 percent).

What this means

The forest resources of Ohio continued to gain substantially in volume, as they have since FIA inventories began in the State. Volumes, whether net volume of live trees, net volume of growing-stock trees, or sawtimber volume, are at levels never before recorded. This continued growth brings ever more options to Ohio's landowners.

The rich diversity of species in Ohio contributes to the volume growth observed over the past 10 years. While the diversity of species adds to the ability of the forest resource to weather disturbances, the effects of insect and disease outbreaks is evident in volume estimates. Of the 24 species that have at least 1 percent of total net volume, volume losses have been recorded for 8 between 2006 and 2016. The decreases in white and green ash net volume are largely due to the effects of emerald ash borer, found throughout Ohio.

The various measures of volume have all increased in the past 10 years, though at a lower rate than previously seen. Volume gains over the past 10 years were largely due to increases between 2006 and 2011. Net volume increased 6 percent from 2006 to 2011, but less than 1 percent from 2011 to 2016. Likewise, sawtimber net volume gained 5 percent between 2006 and 2011 and only 2 percent in the subsequent 5 years. If these trends continue, the decades of volume growth in Ohio may be reaching a plateau.

The majority of volume on Ohio's timberland is in trees that meet the requirements of growing stock. However, the proportion of volume that is not in growing-stock trees is rising. This is an indication that low-quality trees are increasing in volume at a faster rate than higher quality timber. Additionally, some high-value species, such as white oak and black cherry, have lost growing-stock volume since 2006. Taken together, these facts cause some concern for the sustainability of the State's higher value timber products.

Disparities in measures of timber quality between public and private ownerships indicate an opportunity for increased engagement with landowners to further management objectives. The loss of growing-stock volume on private timberland, as well as the increased percentage of volume attributed to rough cull trees, is indicative of a degradation of overall timber quality. The practice of high-grading, removing only trees of superior quality and value, can contribute to the shift from growing-stock volume to lower quality volume. Increased emphasis on residual timber quality is necessary to reverse the trend.

One indicator of quality that has improved somewhat is tree grade. A greater proportion of hardwood sawtimber volume is now in trees of grade 1, with less volume in lower quality grade 3. Though this means an increase in higher value timber, it is more indicative of diameter growth. As trees move up in diameter class, they qualify for better grades. Hardwood trees must be at least 16 inches in diameter to meet grade 1 requirements and 13 inches to be grade 2. Given the net volume decreases in trees less than 15 inches, and the gains for trees 15 inches and greater, increases in trees meeting grade 1 specifications can be expected. The increase of volume in trees graded for tie/local use and the steady proportion of trees without a qualifying butt log (uppers) are further indications that the gains in grade are more related to diameter growth than management success.

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

Background

To assess the ability of a forest to continuously provide forest products and ecological services, it is necessary to evaluate changes and the processes that drive them. FIA does this by analyzing growth, removals, and mortality. Gross growth refers to all volume growth, including growth on existing trees (accretion) and growth due to new trees growing into the sample (ingrowth). Mortality is an estimate of the volume of trees that have died between plot visits. Removals refers to trees that are no longer in the sample, whether due to harvest of trees (harvest removals), or a change in land use (other removals). Conversion of a forested condition to a nonforest status results in the removal of those trees from the sample. Similarly, a change in land use due to a change in productivity status or reserve status will result in removal from timberland. Net growth is calculated by subtracting mortality from gross growth. Net growth minus removals is equal to net volume change. All components of change are expressed on an average annual basis.

What we found

On timberland, gross growth totaled 587 million cubic feet per year in 2016 (Fig. 47), a 9 percent decrease from the 2011 estimate of 643 million cubic feet. The drop in gross growth was largely driven by decreased growth in American beech, white ash, green ash, yellow-poplar, and black cherry. Mortality was 222 million cubic feet per year, making net growth 365 million cubic feet per year. This represents a 22 percent decrease from 2011, when the estimated net growth was 469 million cubic feet per year. Nearly half of the reduction in net growth can be attributed to a substantial increase in annual mortality, up more than 48 million cubic feet between 2011 and 2016. Annual removals from harvesting on timberland were 228 million cubic feet. An additional 44 million cubic feet of removals per year were due to land-use change. Subtracting removals from net growth results in a surplus, or net change, of 93 million cubic feet per year, a 61 percent decrease from the 2011 net change estimate on timberland of 240 million cubic feet per year. Annual net change was 0.6 percent of timberland net volume.

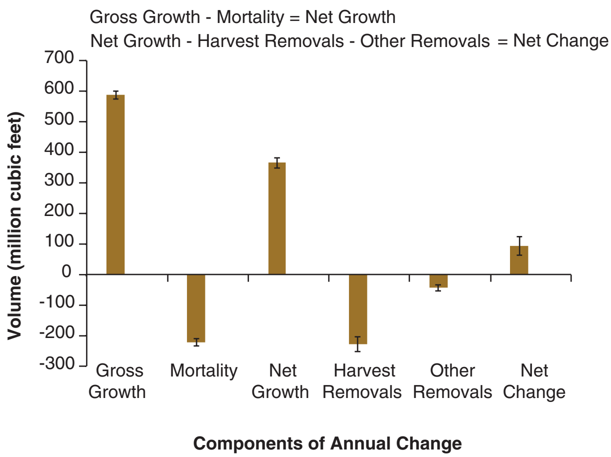


Figure 47.—Components of volume change on timberland, Ohio, 2016. Error bars represent a 68 percent confidence interval.

Net growth on trees that were 5 inches or greater in diameter at the time of last measurement is referred to as accretion. Accretion on timberland totaled 265 million cubic feet per year for 2016, 47 percent of which was on trees previously less than 11.0 inches in diameter. It was greatest on trees in the 5.0 to 6.9 inch d.b.h. range (6-inch diameter class) and generally decreased with each step up in diameter class (Fig. 48). Due to mortality in larger, older trees, those with diameters 29 inches and greater had negative net growth of nearly 10 million cubic feet per year. Ingrowths, trees tallied for the first time due to growing across the 5-inch diameter threshold, accounted for 27 percent of all net growth, or 100 million cubic feet per year.

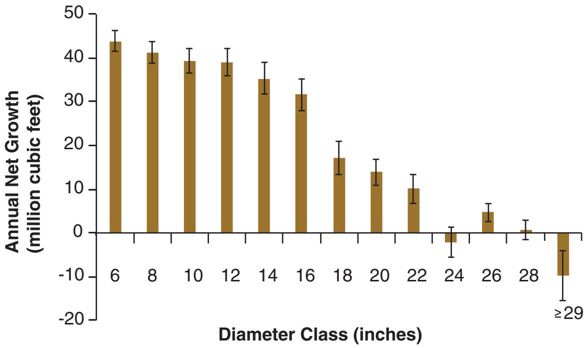


Figure 48.—Net growth on existing trees (accretion) on timberland by diameter class at previous inventory, Ohio, 2016. Error bars represent a 68 percent confidence interval.

Differences in the proportions of net growth by diameter class were apparent across species and species groups (Fig. 49). Generally, species of maple had a higher percentage of net growth coming from ingrowths and accretion on trees less than 11 inches in diameter. Thirteen percent of red maple net growth and 18 percent of sugar maple net growth came from ingrowths, with an additional 44 and 45 percent of net growth, respectively, for each species occurring on trees 5.0 to 10.9 inches d.b.h. In contrast, oaks as a group had a majority (63 percent) of net growth on trees 11 inches d.b.h. or larger. Oak net growth from ingrowths was 15 percent, and 22 percent of oak net growth was on trees between 5.0 and 10.9 inches. Ingrowths made up only 11 percent of hickory net growth while accretion on trees less than 11 inches was 32 percent and accretion on trees 11 inches and greater accounted for 57 percent of net growth. Similarly, yellow-poplar had 9 percent of net growth as ingrowths, with 30 percent of net growth as accretion on trees 5.0 to 10.9 inches and 61 percent as accretion on trees previously 11.0 inches and greater. Black cherry had a greater proportion of net growth as ingrowth at 27 percent with an additional 38 percent as accretion on trees less than 11 inches. Accretion on black cherry 11 inches or greater was 35 percent of net growth.

The harvest removals of 228 million cubic feet per year represent a 9 percent increase over the 2011 estimate. Harvesting was concentrated in sawtimber diameter classes; trees from 13.0 to 18.9 inches d.b.h. accounted for 40 percent of harvested volume. Trees in the 17.0 to 18.9 inch d.b.h. range (18-inch diameter class) made up nearly 15 percent of the total harvest volume at 34 million cubic feet per year (Fig. 50). Growing-stock trees accounted for 92 percent of the harvested volume, despite being only 86 percent of total timberland net volume. Yellow-poplar had the most volume harvested at 21.5 million cubic feet annually, followed by black cherry (20.5 million cubic feet), red maple (18.4 million cubic feet), white oak (18.2 million cubic feet), and northern red oak (17.2 million cubic feet).

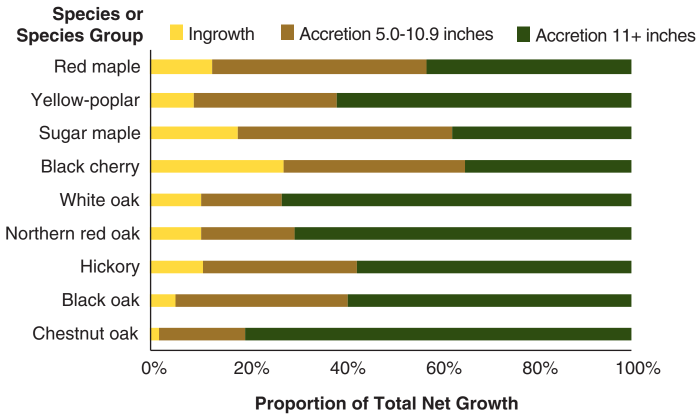


Figure 49.—Sources of net growth for select species on timberland, Ohio, 2016.

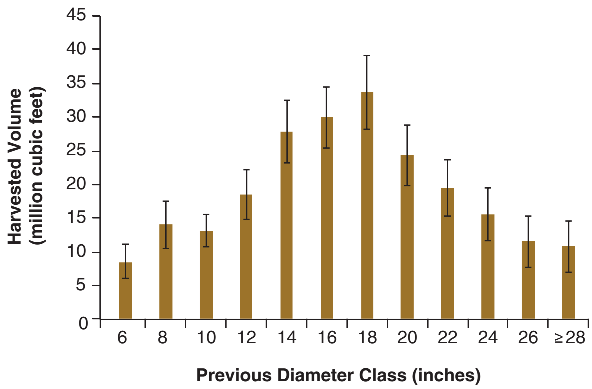


Figure 50.—Harvest removal volume on timberland by diameter class at previous inventory, Ohio, 2016. Error bars represent a 68 percent confidence interval.

Comparing harvest rates to net growth is one way to evaluate the sustainability of harvest practices. A simple ratio of net growth to harvest removal volume (G:R) shows the rate of growth in comparison to harvest; that is, a G:R greater than 1.0 shows that net growth exceeds harvest removals. Across all species statewide, annual net growth was 1.6 times the volume of annual harvests, less than the 2011 estimate of 2.3 times because of decreased net growth and increased harvests between 2011 and 2016. A substantial portion of the reduction in the statewide G:R ratio is due to the negative net growth of ash. Calculating the ratio without ash species results in a ratio of 1.9:1. Regionally, the highest G:R ratio was found in the Northeastern unit at 2.2 (Table 6). The lowest G:R ratio, 0.1, was in the Northwestern unit, where the reduced net growth is largely related to ash mortality from emerald ash borer.

Table 6.—Timberland net volume, net-growth-to-harvest removals ratio, and annual components of change, Ohio, 2016

			Annual change component as a percentage of net volume				
Unit	Net volume (million ft³)	Ratio of net growth to harvest removals (G:R)	Annual net growth	Annual harvest removals	Annual other removals	Annual mortality	Net change
South-Central	3,453	1.9	2.3	1.2	0.2	1.3	0.9
Southeastern	2,885	1.8	2.1	1.2	0.4	1.1	0.5
East-Central	3,539	1.5	2.9	1.9	0.2	0.9	0.8
Northeastern	3,037	2.2	3.0	1.3	0.1	1.1	1.6
Southwestern	1,266	1.5	2.1	1.5	0.5	1.6	0.2
Northwestern	1,658	0.1	0.1	1.4	0.6	3.6	-1.8
Statewide	15,838	1.6	2.3	1.4	0.3	1.4	0.6

Eight of the 10 species with the highest net volume had annual net growth exceeding annual harvest removals (Fig. 51). Of the five species with the most volume removed, only one had net growth that did not exceed harvest rates. White oak, with a G:R ratio of 0.8, was harvested at a rate exceeding net growth by nearly 4 million cubic feet per year. White ash, having negative net growth due to high mortality, was harvested at a rate of 16 million cubic feet per year. Black cherry, black oak, and American beech all had G:R ratios between 1.1 and 1.3, suggesting that they were harvested at rates close to their net growth. In contrast, net growth of red maple and yellow-poplar was 3.3 and 2.3 times the harvest volumes, respectively.

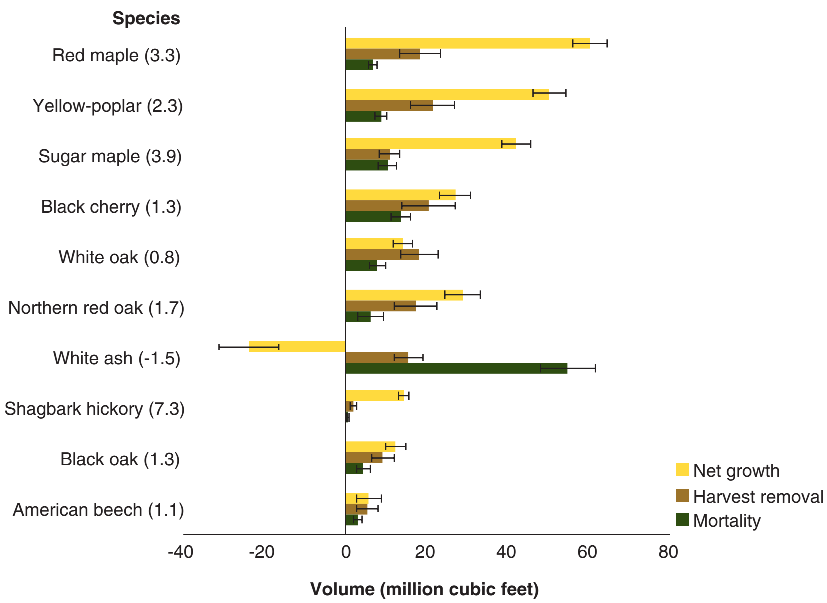


Figure 51.—Net growth, harvest removal, and mortality volume for the 10 species with the highest net volume on timberland, with net-growth-to-harvest-removal ratio in parentheses, Ohio, 2016. Error bars represent a 68 percent confidence interval.

Harvest patterns vary between the major ownership groups. Estimated harvested volume on public land dropped nearly 50 percent from 2011 to 6.3 million cubic feet per year in 2016. This represents only 3 percent of total harvested volume for 2016, though public land accounted for 14 percent of total timberland net volume. Annual harvested volume on private land totaled 221 million cubic feet, up from 195 million cubic feet in 2011.

The majority of harvesting took place in stands having relatively high tree densities. An estimated 63 percent of harvested volume came from forests with basal areas in excess of 120 square feet per acre prior to harvest. Another 30 percent was in stands between 81 and 120 square feet per acre. Nearly half (47 percent) of the volume harvested came from stands that were left with 40 square feet per acre or less after harvest, but only about one-quarter of harvested land area falls into that category. Forty percent of harvested land retained at least 81 square feet per acre of basal area, and an additional 34 percent had basal area of 41 to 80 square feet per acre. Nearly half of harvested timberland remained moderately stocked with an additional 27 percent being fully stocked or overstocked after harvest.

Annual mortality on timberland in 2016 was estimated to be 222 million cubic feet, or 1.4 percent of total net volume per year. This was an increase of almost 50 million cubic feet, or 28 percent, from 2011. The Northwestern unit had the highest annual mortality at 60 million cubic feet, as well as the largest increase, at 110 percent, above the 2011 estimate (Fig. 52), largely due to ash, which accounted for 64 percent of total mortality in the unit. Statewide, ash mortality was 71 million cubic feet per year, or 7.4 percent of ash total net volume annually (Fig. 53), an increase of 156 percent from the 2011 estimate. Oak mortality increased by 14 percent from 2011 to 30 million cubic feet per year, or 0.9 percent of oak total net volume annually. Black cherry mortality increased by 72 percent to 14 million cubic feet per year, or 1.2 percent of net volume. Mortality of yellow-poplar also increased, by 59 percent, but it remained relatively low as a proportion of net volume at 0.5 percent. Red maple had a 12 percent decline in mortality, to 7 million cubic feet, or 0.4 percent of net volume. Sugar maple mortality decreased as well, by 3 percent. A substantial drop in hickory mortality was also observed, for a decrease of 51 percent to 0.4 percent of net volume per year.

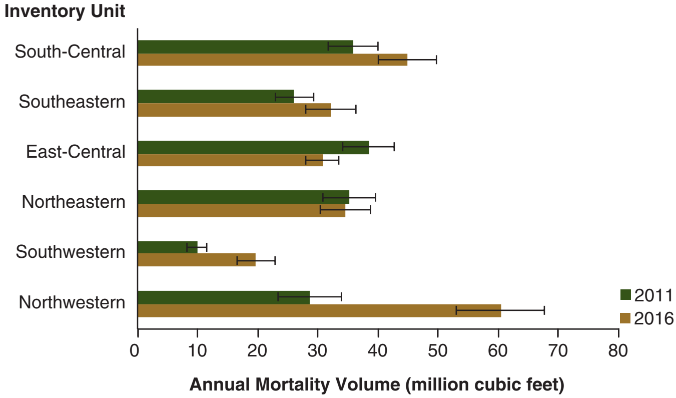


Figure 52.—Annual mortality volume on timberland, by inventory unit and inventory year, Ohio. Error bars represent a 68 percent confidence interval.

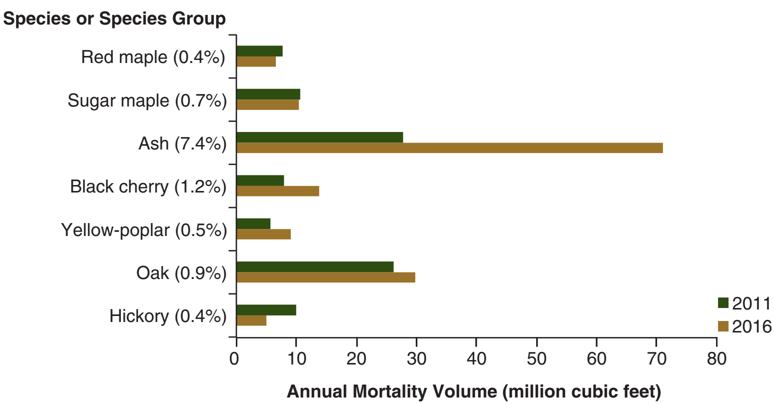


Figure 53.—Average annual mortality volume for select species and species groups on timberland, with mortality as a percentage of each species' net volume in parentheses, by inventory year, Ohio.

What this means

Ohio forests have continued to increase in volume, though stressors have taken a toll on the rate of volume change. Decreased gross growth in conjunction with increased mortality and removals has resulted in net change dropping more than 60 percent from an annual increase of 1.5 percent of net volume in 2011 to 0.6 percent in 2016. In the Northwestern unit, the effects of emerald ash borer have contributed to volume loss at a rate of 1.8 percent of net volume annually. Given that ash remains a major component of Ohio forests, continued mortality increases and reduced growth may be expected into the foreseeable future.

Changes among the major timber species are likely to be seen in upcoming inventories. Most of the net growth in oak species is on sawtimber-size trees, with relatively little growth coming from new trees and those in the smaller diameter classes. As the oak resource further matures, a lack of volume growth in trees moving into sawtimber size is likely to result in oaks being less dominant in measures of sawtimber volume. Conversely, the proportion of net growth in the maples due to ingrowth and accretion on poletimber very likely indicates a growing dominance of maple in the future.

Harvest rates generally appear to be sustainable, as net growth outpaces removals across the State. However, two species of oak, white and scarlet, have been harvested at rates higher than their respective annual net growth. Maintaining volume growth, particularly for these species, will require managing harvests and encouraging regeneration for the recruitment of new trees.

While many harvest operations on Ohio timberlands remove a large amount of basal area, estimates of stocking and basal area remaining after harvest suggest that many other harvests are not substantial enough to be considered stand-initiation events. The percentage of net growth coming from ingrowth and accretion on smaller diameter trees may indicate a higher availability of resources for growth. Given that harvests tend to focus on trees 14 inches d.b.h. and greater, growth on smaller trees and ingrowth will continue to be of major importance in maintaining volume growth over time.

Forest Carbon

Background

Forests sequester carbon from the atmosphere, thus playing a critical role in global climate change. Because the dry biomass of trees is about 50 percent carbon, forests contain the largest reserves of sequestered carbon among terrestrial ecosystems. Regional and national greenhouse gas reporting forums include forest carbon stocks because increases in these carbon stocks represent quantifiable partial offsets to other greenhouse gas emissions. For example, carbon sequestered by U.S. forests represented an offset of about 10 percent of total U.S. greenhouse gas emissions in 2015 (U.S. Environmental Protection Agency [EPA] 2017).

Atmospheric carbon dioxide, water, and energy from sunlight are incorporated into organic material as trees grow, and long-term retention of much of this carbon-rich material is in the form of wood. Over time, this stored carbon also accumulates in dead trees, woody debris, litter, and forest soils. Roots are the belowground portion of trees and are reported as part of live biomass, not in the soils estimates. For most forests, understory grasses, forbs, and nonvascular plants represent minor pools of carbon stocks. In contrast to accumulation through growth, carbon can be lost from a stand via mechanisms such as respiration (including live trees and decomposers), combustion from wildland fires, runoff or leaching of dissolved or particulate organic particles, or direct removal such as the harvest and use of wood. Regarding greenhouse gas reporting, it is important to note that not all losses result in release of carbon dioxide to the atmosphere; many wood products not used as a fuel source represent continued long-term carbon sequestration.

The carbon pools discussed or depicted here are:

- Living plant biomass (live trees greater than or equal to 1 inch d.b.h. and understory vegetation)
- Dead wood (standing dead trees, down dead wood, and forest floor litter)
- Soil organic matter exclusive of coarse roots and estimated to a depth of 1 meter (3.3 feet).

Carbon estimates for ecosystem pools are based on sampling and modeling. Because of the variability in information available for each pool, some carbon estimates are more informative than others. For example, due to the level of sampling and availability of allometric relationships applied to the tree data, the greatest confidence is in the estimate of live-tree carbon. Limited data and high variability mean lower confidence in the soil organic carbon estimates and hence, limited interpretation. Additional information on current approaches for determining forest carbon stocks is provided in U.S. EPA (2017), USDA Forest Service (2014), and O'Connell et al. (2017). The carbon estimates discussed here are consistent with the methods used to develop the forest carbon reported in the U.S. EPA's Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2015 (published April 2017); however, this 2016 inventory summary includes some newer data relative to the Ohio forest contribution within U.S. EPA (2017). Due to the updated carbon estimation procedures used here, the results are not comparable to those in Widmann et al. (2014).

What we found

Total forest ecosystem carbon stocks in Ohio are estimated to be 700 million tons of carbon, a very slight 0.2 percent decrease from 2011. Live trees and soil organic carbon are the largest pools and account for 92 percent of forest carbon stocks (Fig. 54). Forty-two percent of carbon is in the wood and bark of the boles of trees at least 5 inches d.b.h.

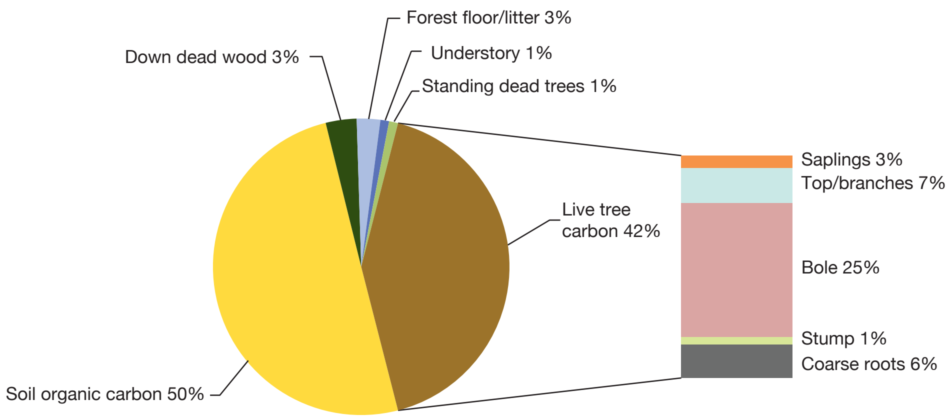


Figure 54.—Percentage of total forest carbon stocks by detailed pool, Ohio, 2016.

Average aboveground carbon per acre increases with stand age (Fig. 55), but total carbon storage also depends on the acreage within each age class. The majority of carbon stocks are in the mid- to older-age classes. Sixty-six percent of total aboveground carbon stocks are in the two age classes from 41 to 80 years old (62 percent of forest land); in contrast, the youngest plus the oldest age classes together account for 9 percent of forest carbon stocks (13 percent of forest land).

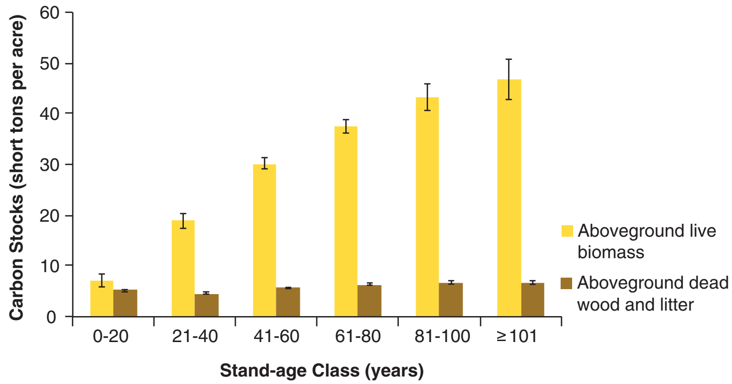


Figure 55.—Aboveground carbon stocks per acre for live and dead components on forest land, by stand-age class, Ohio, 2016. Error bars represent a 95 percent confidence interval.

Species composition also affects the amount of carbon sequestered. Note that the variability in average carbon per acre for the major forest-type groups identified in Ohio (Fig. 56) is most closely associated with variability in live-tree biomass. Statewide, 94 percent of total carbon was in the three forest-type groups that make up 93 percent of forest land area: oak/hickory (63 percent of forest land), maple/beech/birch (21 percent), and elm/ash/cottonwood (9 percent).

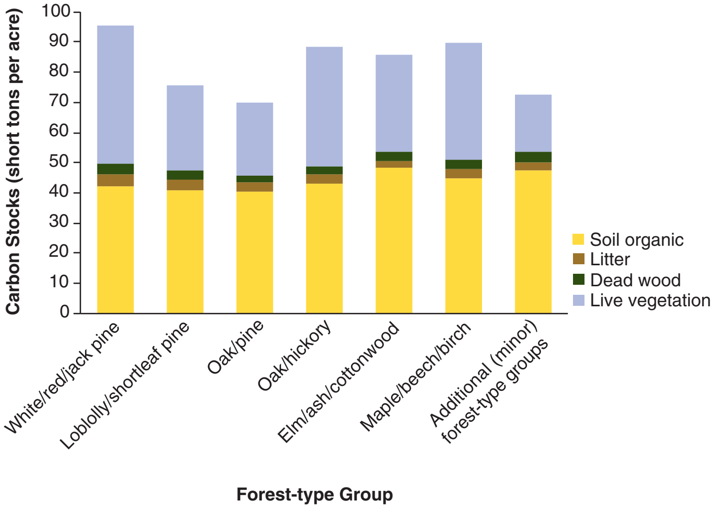


Figure 56.—Average carbon stocks per acre on forest land, by forest-type group and carbon pool, Ohio, 2016.

The current carbon estimation methods and data were also applied to the 2006 and 2011 Ohio forest inventories (Fig. 57) to produce summaries comparable to those provided here for the 2016 inventory. Overall forest carbon per acre increased by 2 percent relative to 2011, but total forest land decreased by 1 percent. These changes resulted in the approximately 0.2 percent decrease in total forest carbon stocks over the 5 years. In contrast, increases in both carbon per acre (5 percent) and total forest acreage (2 percent) produced a total carbon stock increase of 4 percent during the previous 5-year interval (2006-2011). For perspective on the more recent change in forest carbon stocks, the 68 percent confidence intervals around total forest carbon stocks for 2016 and 2011 average ±1.2 percent of the estimates (error bars not shown on Figure 57), which indicates that the estimated 0.2 percent change is well within the uncertainty bounds on carbon stocks.

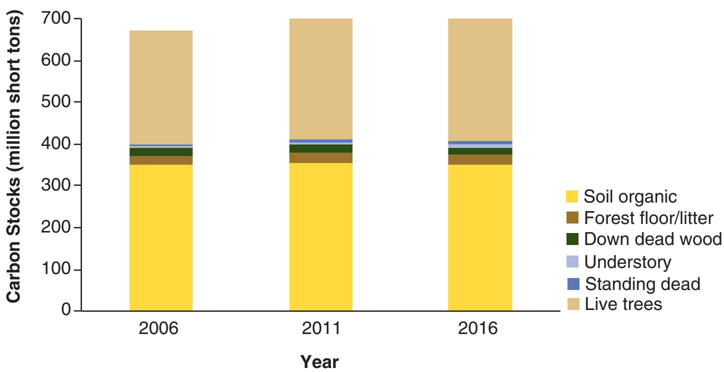


Figure 57.—Total carbon stocks on forest land, by carbon pool and inventory year, Ohio.

What this means

In general, forest carbon stocks and changes broadly reflect other measures of forest resources such as stand age, volume, or stocking. The carbon summaries presented here are useful to compare to those of other states, regions, and the Nation. In brief, the carbon summaries show:

- Almost half of total carbon is in live trees
- The majority of carbon is in stands of 41 to 80 years
- Specific stand-level carbon varies
- Overall forest carbon stocks in Ohio remained essentially unchanged between 2011 and 2016.

For any stand, carbon stocks depend on site history, management, stand age, and tree composition and size, much of which can be heavily influenced by forest management practices. Removal of wood products used in construction and furniture manufacturing results in long-term carbon storage and makes room for new, younger stands to capture and store new carbon. Although older forests store more carbon, younger age classes show greater rates of increase in carbon sequestration. Stands show the greatest rate of carbon accumulation as they move from the 0-20 year class to the 21-40 year class, and from the 21-40 year class to the 41-60 year class. This storage is equivalent to an additional 11 tons of carbon per acre for each increase of one age class. Subsequently, this rate of increase slows in more-mature stands, which gain only 3 tons of carbon per acre with an increase in age class from the 81-100 year to the ≥101 year age class. Thus, managing forests for a more balanced age-class distribution could result in greater rates of increase in carbon stocks in the future. Continued monitoring of forest carbon is prudent as we look for ways to mitigate the effects of increasing atmospheric carbon dioxide levels.

Down Woody Materials

Background

Down woody materials, in the various forms of fallen trees and shed branches, play a critical role in Ohio's forests. Down woody materials provide valuable wildlife habitat, browse protection for seedlings, stand structural diversity, and storage of carbon and biomass. They also contribute to forest fire hazards via surface woody fuels. FIA assesses down woody materials on a subset of plots as part of the P2+ protocols. Down woody materials are classified into three categories: coarse (3 inches or greater in diameter and 6 inches or greater in length), fine (less than 3 inches in diameter), and residue piles.

What we found

The total carbon stored in down woody materials (coarse and fine woody debris and residue piles) on Ohio's forest land exceeded 27 million tons in 2016, which is roughly equivalent to what was estimated in 2010. Down woody debris carbon was positively related to the amount of live-tree basal area. Forests with more than 80 square feet per acre of basal area have the highest amounts of down dead wood carbon, about 21 million tons (Fig. 58). The down dead wood biomass within Ohio's forests is dominated by coarse woody debris (Fig. 59), at approximately 39 million tons, with fine woody debris representing 35 percent (21 million tons) of statewide totals. No piles of coarse woody debris (i.e., harvest residue piles) were sampled during the latest inventory.

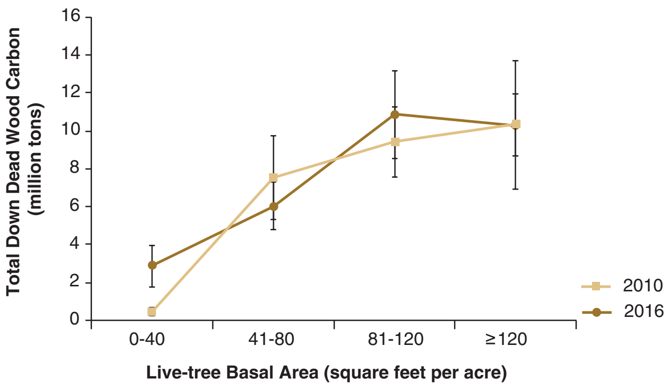


Figure 58.—Total carbon and associated sampling errors in down woody materials (fine and coarse woody debris and piles), by stand basal area on forest land, Ohio, 2006-2010 and 2012-2016.

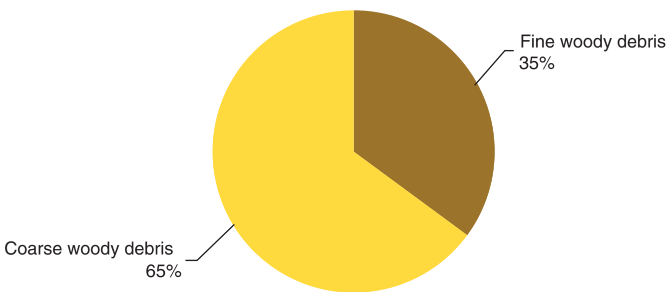


Figure 59.—Percentage of down woody material biomass by dead wood component on forest land, Ohio, 2012-2016. Note that no residue piles were found.

The total volume of coarse woody debris in 2016 was highest in the private ownership category at approximately 3.5 billion cubic feet in Ohio's forests. State and local (county and municipal) forests had the second largest totals of coarse woody debris volume (548 million cubic feet). On a per acre basis, coarse woody debris volume was highest on State and local forest land at 689 cubic feet per acre, compared to 485 cubic feet per acre on private land (Fig. 60). Coarse woody debris volume per acre increased over 2010 estimates by 61 percent on State and local forest land and 26 percent on private ownerships.

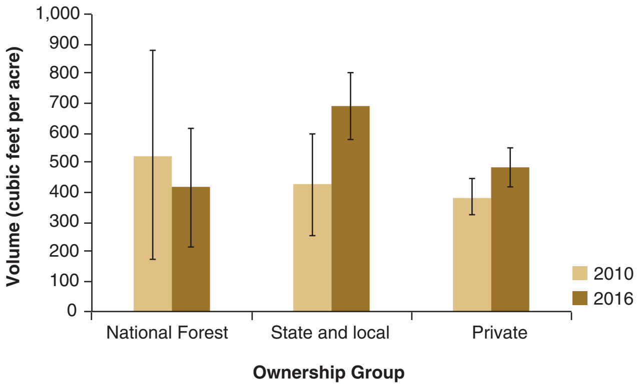


Figure 60.—Coarse woody debris volume per acre of forest land, by ownership group and inventory year, Ohio. Error bars represent a 68 percent confidence interval.

What this means

Given the relatively moist temperate forests across Ohio, only in times of drought would the biomass of down woody materials be considered a fire hazard, especially as no residue piles were sampled during the current inventory. This stands in contrast to forests in southeastern states (Woodall et al. 2013), where industrial forest management is more pervasive with higher rates of residue pile detection. Although the carbon stocks associated with Ohio's down woody materials are relatively small compared to those of soils and standing live biomass, these materials are still a critical component of the carbon cycle as a transitory stage between live biomass and other detrital pools such as litter (Russell et al. 2015). Given that the vast majority of coarse woody debris volume was estimated to be in private ownership, it is the management of Ohio's private forests that may affect the future of down woody material contributions to statewide forest carbon stocks and wildlife habitat (i.e., stand structure). While some of the increases in coarse woody debris, particularly on private forest land, were within statistical confidence bounds, the focus on a greater sample intensity (i.e., more sample plots) since 2010 has substantially reduced sample errors associated with population estimates. Overall, because fuel loadings are estimated to be relatively low across Ohio, at this point possible fire danger may be outweighed by the numerous ecosystem services provided by down woody materials. Nonetheless, drought is expected to increase in the future, which could change this dynamic (Matthews et al. 2018).

Urban Forest Resources

Background

Urban forests include all trees growing in urban areas. More than 80 percent of the U.S. population lives in urban areas. Trees in cities and towns offer a wide range of benefits to urban residents including the improvement of air and water quality, aesthetic appeal and visual barriers, mitigation of rainfall runoff and flooding, and lower noise impacts. Given the ecological and economic importance of urban forests, there is a need to quantify and monitor this critical resource.

Historically, the focus of the FIA inventory had been to collect information on trees that were part of a forest at least 1 acre in size with a natural or unmaintained understory. Because many urban trees do not fall into this category, they were not captured in the traditional FIA inventory. To address this data gap and improve urban forest monitoring, FIA established a national urban forest inventory program in 2014 and began monitoring in urban areas, focusing on the 100 most populous cities. The urban FIA program uses established FIA data collection methods, database and reporting tools, and statistical techniques, along with i-Tree software tools that quantify ecosystem services. The ultimate goal of this effort is to have a seamless reporting system that uses the existing FIA protocols to provide new and valuable information on trees in previously unmeasured areas.

What we found

According to the 2010 U.S. Census, Ohio has 2.8 million acres of urban land, covering almost 11 percent of the State's land area (U.S. Census Bureau 2010). Ohio is one of the most populous states in the Nation though the rate of population growth is well below the national average. Nevertheless, urban area continues to expand at a low to moderate pace and is projected to increase nearly 13 percent by the year 2060 (Nowak and Greenfield 2018b).

With the goal of characterizing Ohio's urban tree resource and its associated benefits and values, the urban FIA program was implemented in the State in 2016. The inventory collects data in select cities with the future goal of expanding data collection across the whole State. The Ohio cities of Cleveland, Columbus, Cincinnati, and Toledo are among the most populous in the United States, account for a large proportion of the State's urban land area (Fig. 61), and have been identified as potential sites for intensified urban FIA sampling.

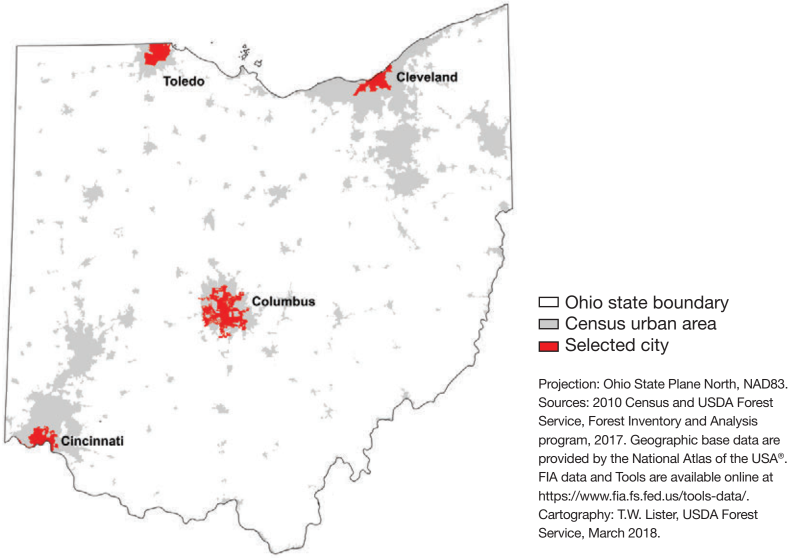


Figure 61.—Distribution of census urban areas and cities proposed for intensified urban sampling by Forest Inventory and Analysis, Ohio.

Annualized inventory monitoring began in the City of Cleveland in summer 2016. A full cycle of plots will have tree and site field data collected on 203 sample plots within the city and 80 plots within associated counties surrounding the city (Fig. 62). Data collection on these plots is spread over a 7-year cycle, so one-seventh of the plots are visited each year and remeasurement occurs every seventh year.

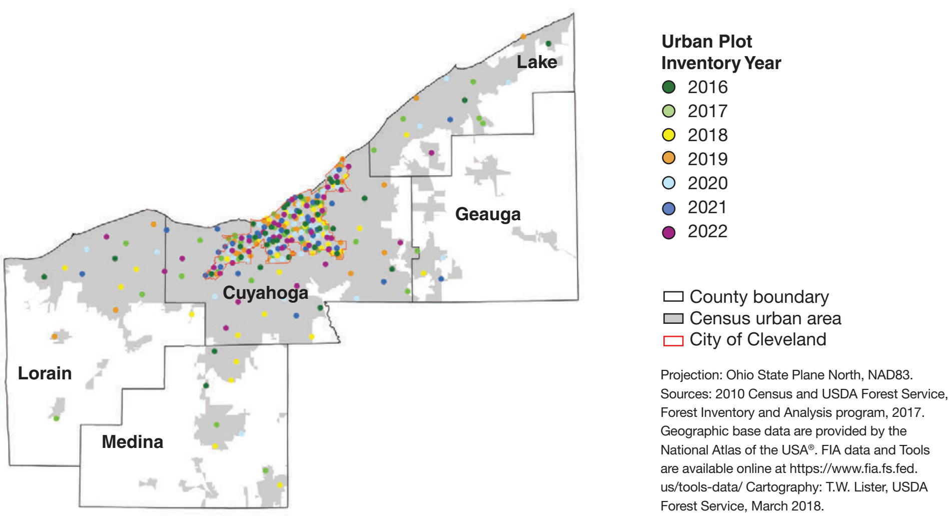


Figure 62.—Forest Inventory and Analysis urban inventory monitoring plots by year of initial sample collection in Cleveland, OH and surrounding counties. Plot locations are approximate.

The urban FIA inventory in Ohio is just beginning, so it will be several years before there are data published based on the full cycle of field data; however, information about Ohio's urban forests is available from a nationwide study (Nowak and Greenfield 2018a) that quantifies urban forest cover and cover change by using aerial photointerpretation methods. According to data from that study, forest cover in Ohio's urban areas was 37.6 percent in 2014, a decline from 39.0 percent in 2009. This is an average decrease of 0.36 percent per year, as compared to the 0.20 percent per year decrease in urban forest cover estimated for the Nation. During this same time period, impervious surface cover in Ohio increased by 1.4 percent (Nowak and Greenfield 2018a).

Based on the forest cover data and various generalizations and assumptions, the dollar values of a set of ecosystem services associated with the urban forest (carbon sequestration, air pollution removal, avoided energy use, and avoided emissions) were estimated and summed. The approximate value of these benefits from urban forests in Ohio is $972 million per year, a total that places the State among the five states that lead the Nation in annual value derived from urban forest ecosystem services (Nowak and Greenfield 2018b).

What this means

Ohio ranks seventh in the Nation in total amount of urban land. The tree cover in these areas represents a sizable resource, and with nearly a third of Ohio's urban land area in grass cover, there may be opportunities to increase urban forest cover in the future. Urban forests are important to the health and well-being of the people of Ohio, and the ecosystem services they provide have both ecological and economic value. For these reasons it is especially important to monitor the urban forest resource and quantify changes in its structure, composition, and health. With implementation of the urban FIA program in Cleveland, FIA will soon be able to provide sample-based estimates of urban forest structure and associated ecosystem services and value data for the city and will be poised to monitor changes through time.

Urban inventory data for cities with completed cycles are available on the Urban Data Mart Web site (https://apps.fs.usda.gov/fia/urban/datamart.html) and posted for interactive data exploration on the My City's Trees app (http://tfsfrd.tamu.edu/mycitystrees). More information on the FIA program, including field guides, and a national implementation status map are available on the Urban FIA Web site (https://www.nrs.fs.fed.us/fia/urban/).

Forest Indicators of Health and Sustainability

Sugar maple borer damage. Photo by Thomas Albright, USDA Forest Service.

Regeneration Status

Background

The composition and abundance of tree seedlings drive the sustainability of forest ecosystems in the early years of stand development and set the stage for future composition and structure, and hence, the viability of timber and ecosystem services provided. Ohio forests support a timber products industry that contributes more than $24 billion to the Ohio economy; employment related to forestry and the forest products industry provides about 116,000 full- and part-time jobs (Appalachian Partnership for Economic Growth 2017).

The previous 5-year report for Ohio listed several positive trends in the volume and size of the State's forest (Widmann et al. 2014). Among the highlights were the findings that stands of large diameter trees continued to increase in extent, and both cubic-foot and board-foot inventory volumes increased. Important issues to watch were also listed. Oak/hickory forest continued to dominate the forest landscape, occupying about two-thirds of the forest land. But the number of oaks had decreased in the 2- and 4-inch diameter classes, compared to a 27 percent increase for maple species. In addition, invasive species were detected on 93 percent of the inventory plots.

The vitality of Ohio's young forest depends directly on the condition of the regeneration component that fuels the development of future stands. Early successional young forest habitat that follows stand-initiation disturbance supports unique plant and animal assemblages, as well as landscape heterogeneity (Greenberg et al. 2011). Examples of wildlife that depend on young forest are the golden-winged warbler (*Vermivora chrysoptera*), American woodcock (*Scolopax minor*), and eastern cottontail (*Sylvilagus floridanus*) (Gilbart 2012, Wildlife Management Institute 2014). Forest systems of Ohio are subject to a number of regeneration stressors such as animal browsing (herbivory), invasive plants, insects, diseases, and changing climate. As stands that make up these systems mature and undergo stand-replacing disturbances, it is imperative to know the condition of the regeneration component. In most situations, establishing desirable regeneration is the key to replacing stands with high-canopy species that meet managers' objectives. Tending of young stands to control composition and stocking levels is also an important consideration (Dey 2014, Smith et al. 1997). Regeneration data are critical to understanding and projecting future forest character, which ultimately determines sustainability of the full suite of forest values available.

To meet the need for more detailed information on regeneration, the Northern Research Station (NRS) FIA program added measurement protocols collected on a subset of the sample plots measured during the growing season (McWilliams et al. 2015). The results in this report are based on measurements of 152 sample plots measured from 2012 to 2016, or 70 percent of the baseline sample collected so far. The procedures measure all established tree seedlings less than 1 inch in d.b.h. by height class and include a browse impact assessment for the area surrounding the sample location. The regeneration indicator (RI) findings improve NRS-FIA's ability to evaluate this important aspect of forest health and sustainability.

What we found

The distribution of forest land by stand-age class shows increases in stands 60 years and older; however, young forest is becoming more scarce. Change in the 0-20 year age class is a short-term indicator of young forest sustainability. Forest land in the 0-20 year age class decreased by 75,000 acres since 2006 to 725,000 acres, a decline from 9 percent to 8 percent of total forest land. The proportion of oak/hickory forest aged 0-20 years decreased from 8 percent to 6 percent of the oak/hickory forest-type group. The 2016 estimate of 311,000 acres of young oak/hickory forest—a loss of 84,000 acres—represents the lowest estimate for the forest-type group since FIA inventories began in the State in 1952.

Results of the browse impact assessment show that 86 percent of the samples had moderate (71 percent) or high (15 percent) levels of browse impact on understory plants. Statewide examination of browse impact reveals that the samples with moderate or high browse impact were distributed throughout the forest land of the State (Fig. 63). Plots with low impact were more likely to be found in areas with higher percentages of agricultural land, that is, the northern half of the State, specifically the Northwest. Samples with high impacts were most common in southwestern Ohio and in forested areas around population centers. It should be noted that NRS-FIA does not take measurements in most urbanized areas and nonforest conditions where high herbivory pressure is common. Other conditions where ungulates are typically concentrated that have few FIA samples because of the coarse sampling intensity are fragmented forests consisting of smaller tracts and strips.

The total number of seedlings is estimated at 84.1 billion, or a statewide average of 10,517 seedlings per acre. Seventy-two percent of the seedlings were less than 1 foot tall, 24 percent were 1.0 to 4.9 feet, and 4 percent were 5.0 feet and taller (Fig. 64). High densities of seedlings (greater than 15,000 per acre) were found on 20 percent of Ohio's forest land (Fig. 65A) and were most common in the southern part of the State (Fig. 65B).

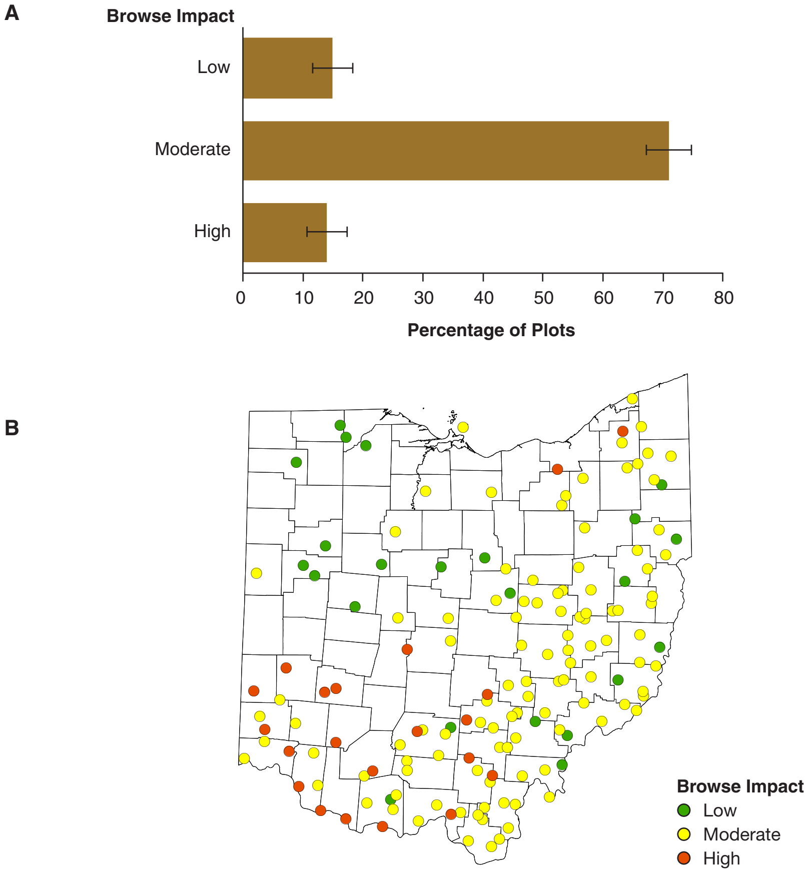


Figure 63.—Percentage of sample plots by browse impact level (A) and geographical distribution of browse impact level (B), based on forested P2+ sample plots, Ohio, 2012-2016. Error bars represent a 68 percent confidence interval. Plot locations are approximate.

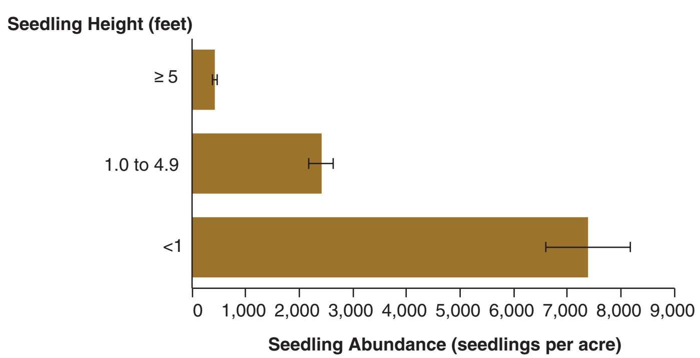
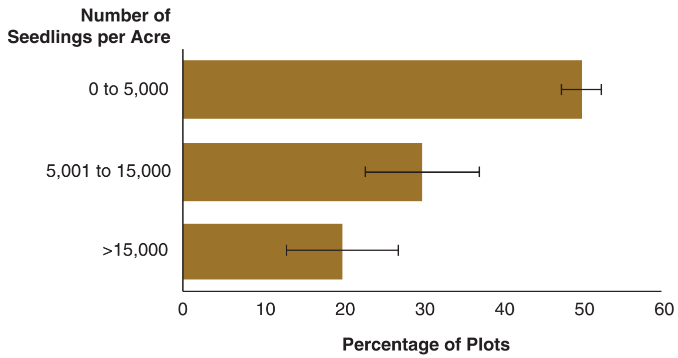


Figure 64.—Seedling density on forested P2+ sample plots by height class, Ohio, 2012-2016. Error bars represent a 68 percent confidence interval.

A



B

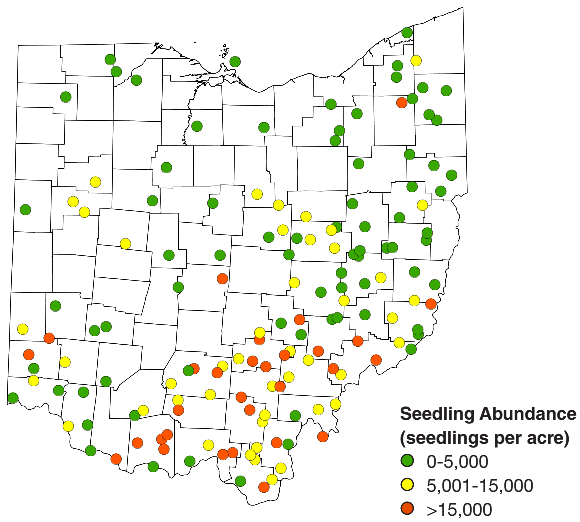


Figure 65.—Percentage of sample plots by seedling density class (A) and geographical distribution of seedling density classes (B), based on forested P2+ sample plots, Ohio, 2012-2016. Error bars represent a 68 percent confidence interval. Plot locations are approximate.

Sixty-nine tree species were encountered in the RI samples so far. Maple was the most common genus with 32 percent of the seedling population, followed by ash (25 percent), elm (9 percent), cherry (7 percent), and oak (6 percent). All the other genera had less than 5 percent of the population. The five species with the most seedlings per acre were white ash (23 percent of the seedlings), sugar maple (15 percent), red maple (15 percent), black cherry (7 percent), and slippery elm (6 percent) (Fig. 66). There was an abundance of seedlings of species that do not typically achieve high canopy, such as American hornbeam, sassafras, and eastern hophornbeam.

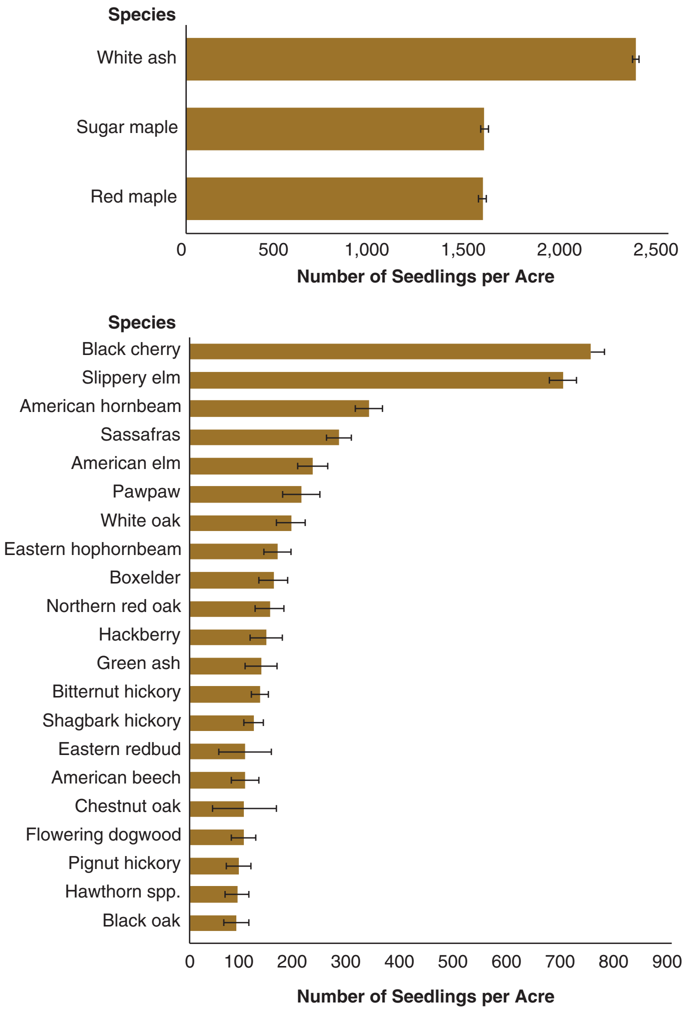


Figure 66.—Average seedling density for species with at least 1 percent of the total number of seedlings and sampling error less than 25 percent, based on forested P2+ sample plots, Ohio, 2012-2016. Error bars represent a 68 percent confidence interval.

Comparing species abundance by size class highlights potential pathways for species that may dominate the canopy in the future. For select taxa of seedlings, saplings, and dominant or codominant adults, the percentage that each contributes to the total for each size class can be estimated (Fig. 67). Size classes are height classes for seedlings, and 2-inch diameter classes for saplings and adults. Prospective “gainers” are those taxa with relatively high percentages of stems in the regeneration pool of seedlings and saplings compared to larger trees. Ash, sugar maple, red maple, and the “other” group are the most apparent gainers. Expectations for ash should be tempered with information on the prospective demise of ash due to impacts of the emerald ash borer. Prospective "losers" in the process of developing future canopy dominants are species with lower percentages in the regeneration pool than the adult pool. The list of potential losers includes red oak, white oak, and hickory, all of which normally regenerate following significant disturbance and are either shade intolerant or intermediate in shade tolerance. The result is a distribution of stem abundance by size class that is out of balance for replacing species typically found in the overstory of oak/hickory stands. That is, seedling, sapling, and young adult species tend not to include oaks and hickories, but rather, maples.

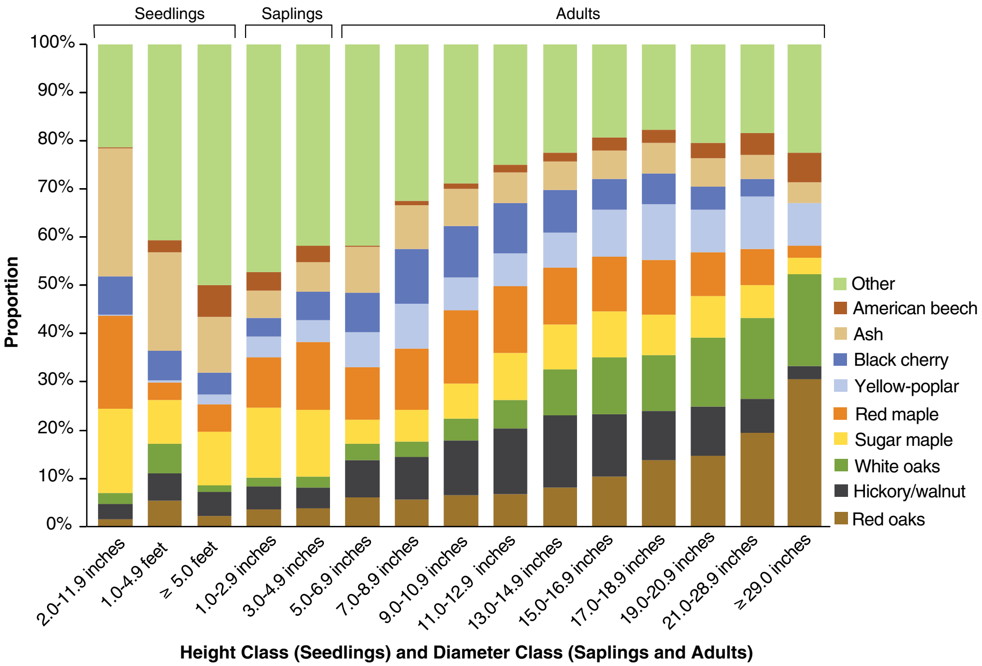


Figure 67.—Percentage of total number of live seedlings, saplings, and dominant and codominant trees (adults) for select taxa, Ohio, 2016. Note that seedling estimates are based on forested P2+ sample plots, 2012-2016. Black walnut is included with hickory. Select taxa are those with the most aboveground biomass.

What this means

Ohio forests face a variety of forest health risks, and establishing desired regeneration is an integral step toward ameliorating most of them during the early phases of forest development.

Deer browse is a major factor affecting regeneration in the eastern United States (Russell et al. 2001, White 2012). In general, forest managers need to consider regeneration management methods that limit the effects of deer browsing during the stand-initiation phase when browse impact is moderate or high (Brose et al. 2008). The finding that nearly 90 percent of the RI samples had at least moderate browse impact indicates that browse has become a management concern. It would be expected that local areas with high deer populations will have limited reproduction of palatable tree species. Impacts of deer browsing are especially problematic when occurring in combination with habitat fragmentation. Forest fragmentation is more prevalent in areas of denser population within the State (Augustine and deCalesta 2003), where RI samples are too sparse for statistically reliable estimates.

The most noteworthy issue found in the results is a proliferation of maple and ash seedlings and saplings along with far fewer oak seedlings and saplings. These phenomena have created an imbalance in the distribution of trees by size class; maple seedlings dominate the seedling and sapling size classes at the expense of other species that are shade intolerant and more site-specific. Since the RI reporting began in 2012, the pattern of maple gaining and oaks and hickories losing has been observed in 10 states: Delaware, Illinois, Indiana, Maryland, Maine, Michigan, Minnesota, Missouri, New Jersey, and Pennsylvania.

Oak regeneration is a common problem in the eastern United States and management challenges, such as lack of fire and overbrowsing, have been described by numerous authors (e.g., Holt and Fischer [1979]). The size-class imbalance described earlier is especially problematic because oak/hickory forests are the dominant forest-type group in the State. This means that forest policy makers and managers will need to consider these trends when planning for the future of oak/hickory. The long-term future of oak-dominated forests will depend on management strategies that establish oak seedlings and foster development of saplings and adults by using stand-tending prescriptions that forestall development of shade-tolerant species (Abrams 1992, Dey 2014). One way to improve the establishment of young oak/hickory forest with proven success is to reintroduce fire and thinning to assist the development of oak and hickory (Hutchinson et al. 2012, Iverson et al. 2017). These efforts are most effective on drier sites (e.g., ridges and south-facing slopes), which can be mapped and prioritized for silviculture treatment (Iverson et al. 2018). Federal and State forest managers are adopting this approach, yet the small forest landowners who own most of Ohio's forests typically cannot undertake management operations of such scale.

Eventually, most forest stands will undergo either anthropogenic or natural stand-replacement events, such as mortality or harvest, and require regeneration to establish a new young forest. Clearly, forest regeneration management will be needed to reinitiate healthy young forests. Management options for establishing regeneration of palatable species will also be influenced by the amount of browse and invasive species present. The key to successful regeneration will be diligent stewardship and continued monitoring to ensure a bright future for Ohio's forest ecosystems.

The results presented here reflect five of seven panels of measurements that will eventually form the first RI baseline dataset. Barring any extension of the inventory cycle, the next 5-year inventory report for Ohio will discuss full baseline results. This will support more detailed analyses, such as more species-specific details, and improve the level of statistical confidence in the estimates. The dataset will also facilitate research to evaluate regeneration for the major forest-type groups and contribute to a more complete understanding of future trends in composition, structure, and health of Ohio's forests.

Tree Crown Health and Damage

Background

Various abiotic and biotic stressors can affect the crown condition of trees. Abiotic stressors include drought, flooding, cold temperatures or freeze injury, nutrient deficiencies, the physical properties of soils that affect moisture and aeration, and toxic pollutants. Biotic stressors include native or introduced insects, diseases, invasive plant species, and animals. 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, Vitousek et al. 1996). Ohio's forests have suffered from the impacts 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 (an interaction between the scale insect *Cryptococcus fagisuga* and a fungus of the genus *Neonectria*) and emerald ash borer (*Agrilus planipennis*).

Tree-level crown dieback is collected on P2+ plots. Crown dieback is defined as recent mortality of branches with fine twigs and reflects the severity of recent stresses on a tree. A crown was labeled as "poor" if crown dieback was greater than 20 percent. This threshold is based on findings by Steinman (2000) that associated crown ratings with tree mortality. Additionally, crown dieback has been shown to be the best crown variable to use for predicting tree survival (Morin et al. 2015).

Tree damage is assessed for all trees with d.b.h. of 5.0 inches or greater. Up to three of the following types of damage can be recorded: insect damage, cankers, decay, fire, animal damage, weather, and logging damage. If more than three types of damage are observed, decisions about which three are recorded are based on the relative impact to tree health (USDA Forest Service 2015).

What we found

The incidence of poor crown condition for all species combined is relatively low across Ohio (Fig. 68). The proportion of basal area with poor crowns was greater than 16 percent for white ash, more than double the amount of unhealthy basal area surveyed in 2011 (Table 7). The proportion of basal area with poor crowns also increased substantially for black cherry since 2011. Conversely, most other species have a very low occurrence of poor crowns.

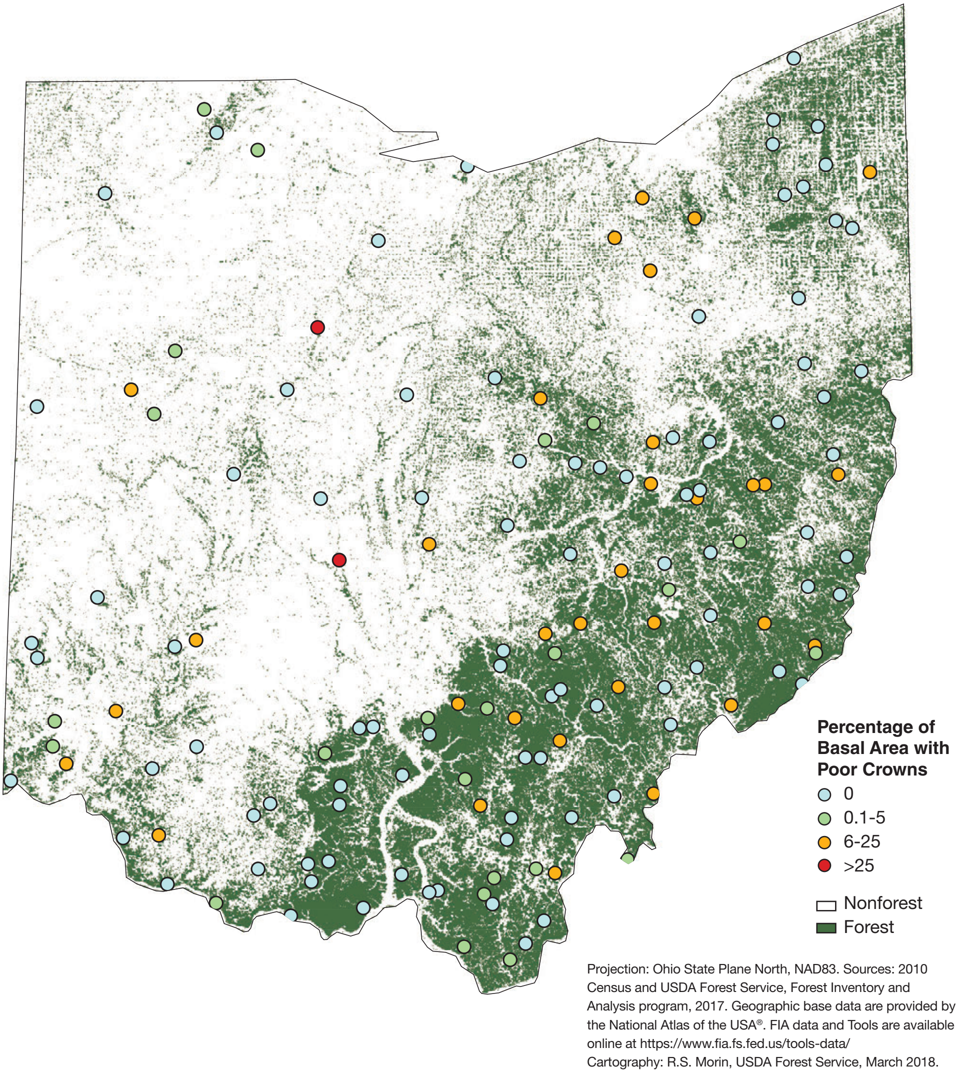


Figure 68.—Percentage of live-tree basal area with poor crowns, Ohio, 2016. Plot locations are approximate.

Table 7.—Percentage of live basal area with poor crowns, Ohio, 2011 and 2016

Species	Percentage of basal area with poor crowns	
	2011	2016
White ash	8.0	16.8
Black cherry	5.5	8.7
White oak	6.1	2.5
Red maple	2.2	2.3
Sugar maple	4.4	2.2
Yellow-poplar	0.2	1.5
Shagbark hickory	0.0	0.3
American beech	0.0	0.0
Northern red oak	0.0	0.0
Black oak	2.1	0.0

Average crown dieback ranged from 2 percent for American beech to 15 percent for white ash (Table 8). An analysis of the trees from the 2011 inventory that were remeasured in the 2016 inventory revealed that the proportion of the trees that die increases with increasing crown dieback (Fig. 69). Nearly 50 percent of trees with crown dieback above 20 percent during the 2011 inventory were dead when visited again during the 2016 inventory.

Table 8.—Mean crown dieback expressed as a percentage and other statistics for live trees (≥5 inches d.b.h.) on forest land by species, Ohio, 2016

Species	Trees	Mean	SE	Minimum	Median	Maximum
	-number-	*-------------------------percent-----------------------*				
White ash	124	14.5	2.48	0	5	99
Black cherry	214	8.7	1.29	0	5	99
Yellow-poplar	171	5.6	1.28	0	0	99
White oak	121	3.8	0.85	0	5	99
Sugar maple	393	3.3	0.50	0	0	99
Red maple	291	3.0	0.62	0	0	99
Shagbark hickory	89	2.7	0.82	0	0	70
Black oak	58	2.7	0.37	0	2.5	10
Northern red oak	63	2.1	0.37	0	0	10
American beech	49	2.0	0.41	0	0	10

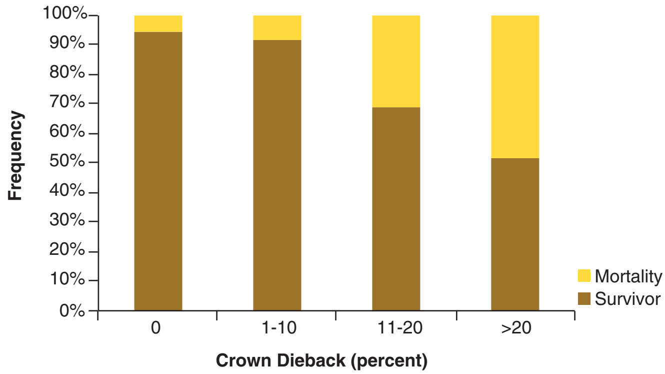


Figure 69.—Crown dieback distribution by tree survivorship for remeasured trees, Ohio, 2011 to 2016.

Damage was recorded on about 36 percent of the trees in Ohio, and there was considerable variation between species. The most frequent damage on all species was decay (21 percent of trees), but it ranged from 9 percent on shagbark hickory to 36 percent on American beech trees. The occurrence of all other injury types was very low (Fig. 70).

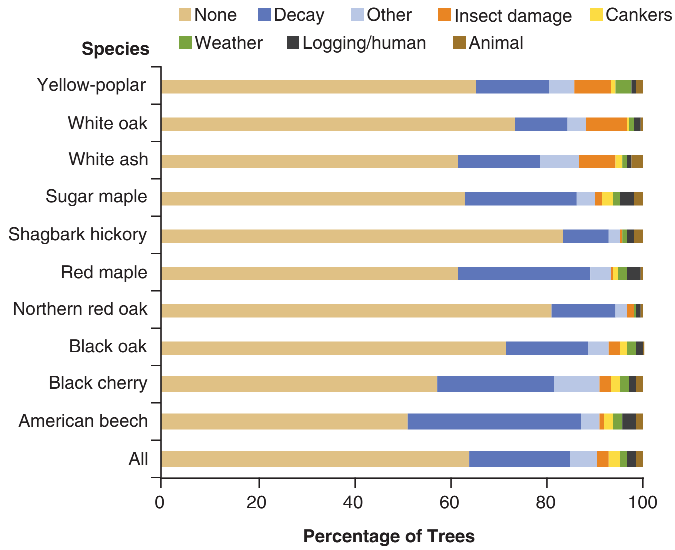


Figure 70.—Percentage of trees with damage, Ohio, 2016.

What this means

Most of Ohio's commercial forest tree species are generally in good health, but poor crown health particularly afflicts white ash, again, very likely due to the effects of emerald ash borer (see Emerald Ash Borer in Tree Pests and Diseases of Special

Concern on p. 92). As in most eastern forests, decay is the most commonly observed damage in Ohio's forests. This is not unusual given that nearly 70 percent of Ohio's forests are large diameter stands composed of mature trees.

Invasive Plants

Background

Invasive plant species (IPS) are both native and nonnative species that can have negative ecological effects. These species can quickly invade forests, changing the availability of water, light, and nutrients (Kuebbing et al. 2014). IPS can form dense monocultures, reducing regeneration as well as diminishing wildlife habitat quality through altering forest structure and forage availability (Pimentel et al. 2005). Aside from the impacts of invasive species on forested environments, they can also affect agricultural systems (Kurtz 2013). An example is dames rocket, which is an alternate host of many crop mosaic viruses. Despite some beneficial uses for these invaders, such as culinary and medicinal uses, and soil contaminant extraction (Kurtz 2013), the negative effects are worrisome. Each year the inspection, management, and mitigation of IPS costs billions of dollars (Kurtz 2013, Pimentel et al. 2005).

To aid in monitoring these species, FIA assessed the presence of 40 IPS (39 species and one undifferentiated genus[2]) on 220 forested P2 invasive plots in Ohio for the 2016 inventory. To maintain regional consistency, the species list is not customized for Ohio but represents native and nonnative species of regional concern. When reviewing these data, one must remember that the inventory takes place only on forested land so areas with less forest have fewer plots.

What we found

Of the 40 invasives monitored (Appendix 2), 22 are present on P2 invasive plots in Ohio (Table 9). The number of invasive species observed per plot ranged from zero to nine (Fig. 71). Multiflora rose is the most commonly observed IPS (194 plots, or 88.2 percent of sampled plots), followed by Japanese honeysuckle (81 plots; 36.8 percent). Multiflora rose is found throughout the State (Fig. 72).

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[2] Hereafter these 39 species and one undifferentiated genus (nonnative bush honeysuckles, *Lonicera* spp.) are referred to as "invasive species," "invasive plants," "invasives," or "IPS" in this section.

Table 9.—Invasive plant species recorded on P2 invasive plots, Ohio, 2016

Invasive species	Number of observations	Percentage of plots
Multiflora rose (*Rosa multiflora*)	194	88.2
Japanese honeysuckle (*Lonicera japonica*)	81	36.8
Nonnative bush honeysuckles (*Lonicera* spp.)	75	34.1
Garlic mustard (*Alliaria petiolata*)	68	30.9
Autumn olive (*Elaeagnus umbellata*)	48	21.8
Black locust (*Robinia pseudoacacia*)	43	19.5
Japanese barberry (*Berberis thunbergii*)	38	17.3
Japanese stiltgrass (*Microstegium vimineum*)	37	16.8
European privet (*Ligustrum vulgare*)	36	16.4
Tree of heaven (*Ailanthus altissima*)	21	9.5
Oriental bittersweet (*Celastrus orbiculatus*)	18	8.2
Creeping jenny (*Lysimachia nummularia*)	12	5.5
Reed canarygrass (*Phalaris arundinacea*)	11	5
Canada thistle (*Cirsium arvense*)	11	5
Common buckthorn (*Rhamnus cathartica*)	6	2.7
Glossy buckthorn (*Frangula alnus*)	6	2.7
Dames rocket (*Hesperis matronalis*)	3	1.4
Common barberry (*Berberis vulgaris*)	3	1.4
Bull thistle (*Cirsium vulgare*)	2	0.9
Common reed (*Phragmites australis*)	2	0.9
Giant knotweed (*Polygonum sachalinense*)	1	0.5
Russian olive (*Elaeagnus angustifolia*)	1	0.5

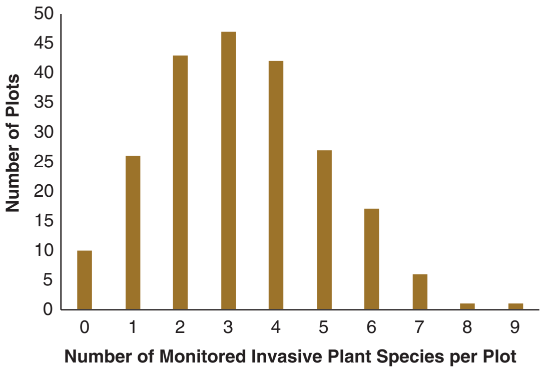

Figure 71.—Number of monitored invasive plant species per plot, by number of P2 invasive plots on which they were found, Ohio, 2016.

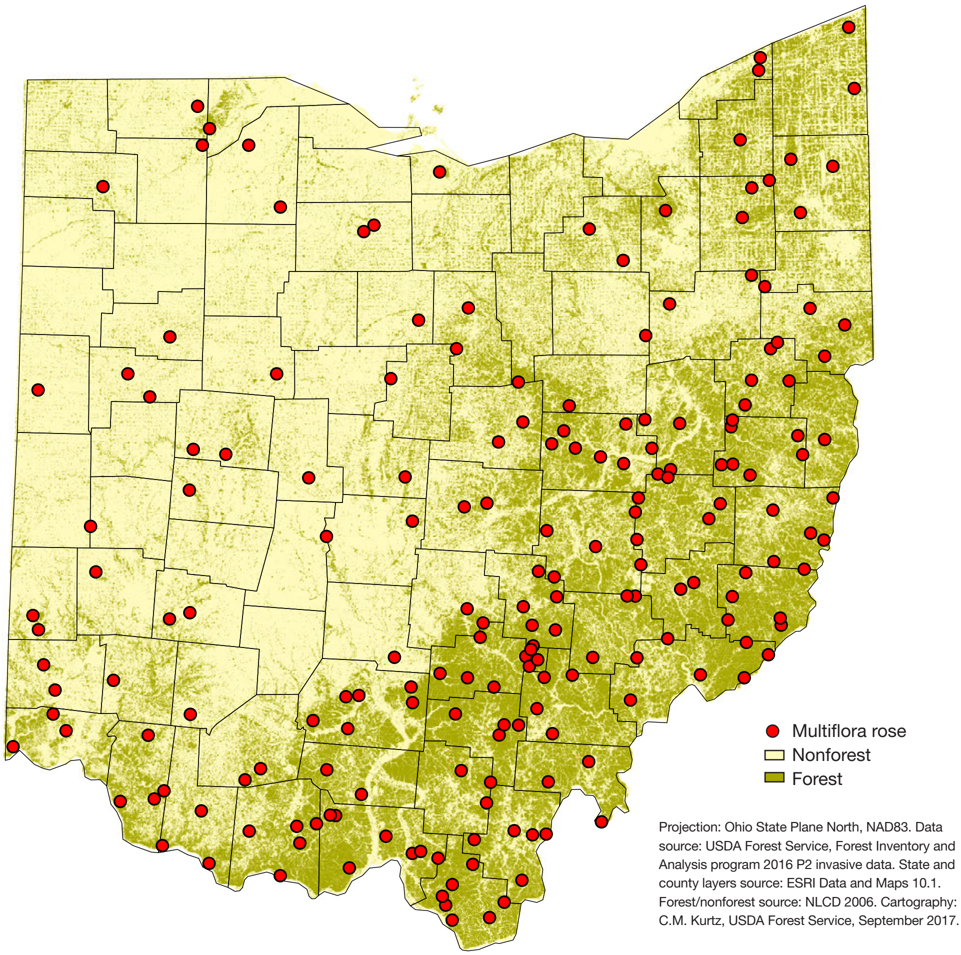

Figure 72.—Presence of multiflora rose on P2 invasive plots, Ohio, 2016. Plot locations are approximate.

Analysis of the 2016 data suggests Ohio has a higher percentage of plots with one or more invasive plant species (96 percent) than the surrounding states. Indiana has 92 percent of plots with one or more invasives present, West Virginia has 78 percent, Pennsylvania has 63 percent, and Michigan has 31 percent. A comparison of 2016 data to 2011 data (Widmann et al. 2014) indicates that multiflora rose remained the most commonly observed invasive. If we look at the other IPS observed, all of the species recorded in this inventory were found in 2011; however, six species that were recorded in 2011 were not recorded on inventory plots in 2016 (spotted knapweed, European cranberrybush, purple loosestrife, Norway maple, Japanese knotweed, and princesstree). For this report the species-level nonnative bush honeysuckle data were combined into one group for analysis.

What this means

Invasive species are a concern throughout the Midwest because many IPS are effective competitors and able to change forested ecosystems by displacing native species and altering forage. Furthermore, IPS can cause negative economic impacts by reducing timber yield and aesthetic beauty. Several characteristics contribute to their success, such as prolific seed production, rapid growth, vegetative propagation, and endurance of harsh conditions. Many modes of disturbance promote forest invasion such as browsing by ungulates, development, fragmentation, and timber harvesting; however, some invasive species can establish with little to no disturbance. Additional investigation may reveal correlations between IPS and influential site and climate features. Even with limited samples, continual monitoring and reporting of IPS informs managers and the public of their occurrence and spread.

Tree Pests and Diseases of Special Concern

Emerald Ash Borer

Background

Emerald ash borer (*Agrilus planipennis*; EAB), a wood-boring beetle native to Asia, was first detected in North America in 2002, when it was found near Detroit, Michigan (Herms and McCullough 2014). As EAB is difficult to detect at low levels, natural spread was enhanced by transportation of infested materials; therefore, the spread of EAB has outpaced detection, with population establishment averaging 3 to 8 years prior to identification (Herms and McCullough 2014). EAB was first detected in northwestern Ohio in 2003; subsequently rapid and variable spread, facilitated by movement along road networks (Prasad et al. 2010), resulted in a known infestation in every county by 2016. All North American ash are hosts of EAB and mortality has increased, resulting in decreases in ash volume and abundance in counties where EAB has been present for 6 or more years (Morin et al. 2017). Although EAB shows some preference for stressed trees, all trees 1 inch in diameter or greater are susceptible regardless of vigor (Herms and McCullough 2014). Though mortality due to EAB varies by infestation level, a mortality-to-gross-growth ratio above 0.6 is indicative of an acute forest health issue (Conkling et al. 2005).

What we found

Four species of ash (white, green, blue, and black) are present on Ohio forest land and total an estimated 235.9 million ash trees (greater than or equal to 1 inch diameter). White ash is the most abundant ash species (67 percent), followed by green ash (29 percent);

blue ash and black ash together make up 4 percent of ash abundance. Ash is found throughout Ohio, but occurs in the highest concentrations in the less densely forested areas, especially the southwestern portion of the State (Fig. 73). Since 2006, much of Ohio has seen a reduction in the number of ash trees on forest land (Fig. 74). The most substantial decreases have occurred in northwestern Ohio, where several counties have lost more than 95 percent of ash trees. Average annual mortality of ash on forest land increased from 28.7 million cubic feet in 2011 to 75.0 million cubic feet in 2016; ash mortality represented 32 percent of total mortality in 2016. Between 2011 and 2016, the mortality-to-gross-growth ratio for ash more than tripled, increasing from 0.7 to 2.3; this is an indicator of unusually high mortality, which reflects the activity of emerald ash borer (Fig. 75).

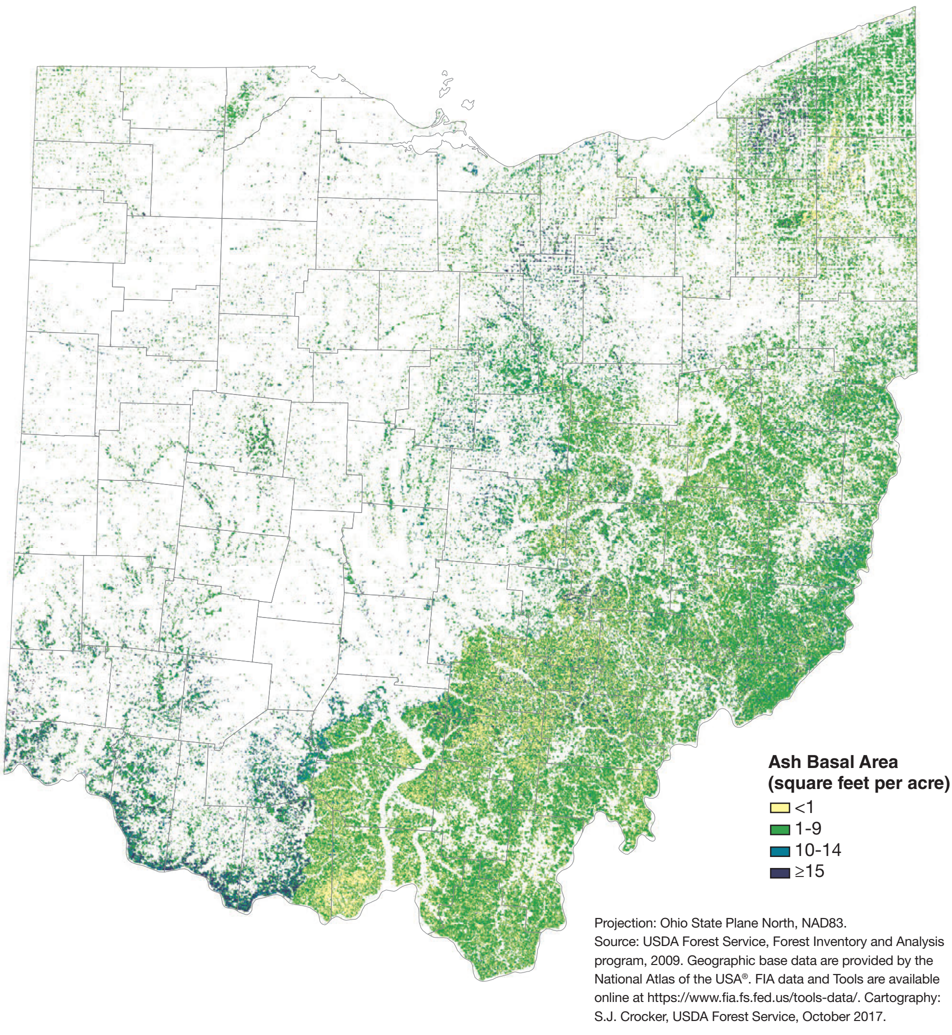

Figure 73.—Ash density on forest land, Ohio, 2009.

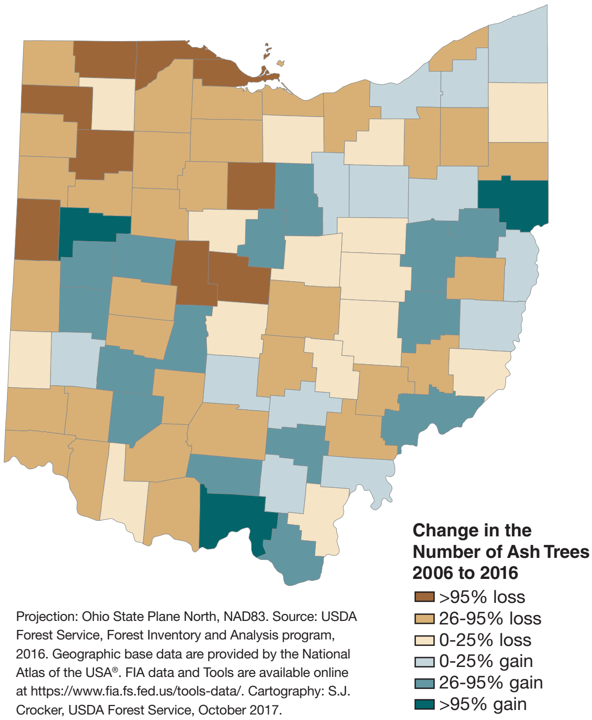

Figure 74.—Change in the number of ash trees 1 inch or greater in diameter on forest land, by inventory year, Ohio, 2006 to 2016.

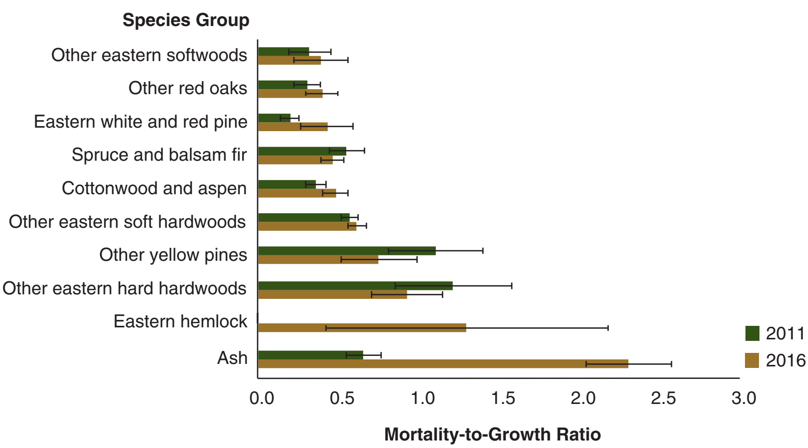

Figure 75.—Ratio of average annual mortality volume to gross growth volume for the 10 species groups with the most volume in 2016, by inventory year, Ohio. Error bars represent a 68 percent confidence interval.

What this means

The ash resource in Ohio has been dramatically altered since 2006; these changes are largely attributable to the activity of EAB. While the pattern of EAB spread has been variable, impacts are now visible statewide. Greater impacts to ash are seen in northwestern Ohio due to a longer exposure to EAB. Mortality of ash is expected to increase elsewhere in the State as EAB persists. The loss of ash in forested ecosystems will affect species composition and alter community dynamics. But there is a proliferation of ash seedlings in the understory with the potential to replace ash trees lost to EAB. Continued monitoring will help to identify the long-term impacts of EAB within Ohio's forests.

Thousand Cankers Disease

Background

Thousand cankers disease (TCD) is a disease complex that primarily affects black walnut and results from the interaction between the *Geosmithia morbida* fungus and the walnut twig beetle, *Pityophthorus juglandis* (Seybold et al. 2012). TCD occurs throughout the western United States and has been introduced to several eastern states including Pennsylvania and Tennessee. TCD was identified in Butler County, in southwestern Ohio, in 2013.

What we found

An estimated 45.7 million black walnut trees (greater than 1 inch in diameter) are found on Ohio forest land; this is equivalent to 1 percent of total tree abundance. Though the abundance of black walnut is relatively low, tree volume is comparatively higher. Black walnut accounts for 419.3 million cubic feet of live-tree volume (trees 5 inches and greater in diameter) and 1.4 billion board feet of sawtimber volume, each representing 2.5 percent of the total for the respective measure of volume. Black walnut is distributed across the State, but it is found in the highest concentrations in southwestern Ohio, where TCD has been found (Fig. 76). Harvest removals and mortality rates for black walnut are both low; the harvest-removals-to-volume ratio is 0.01 and the mortality-to-gross-growth ratio is 0.1.

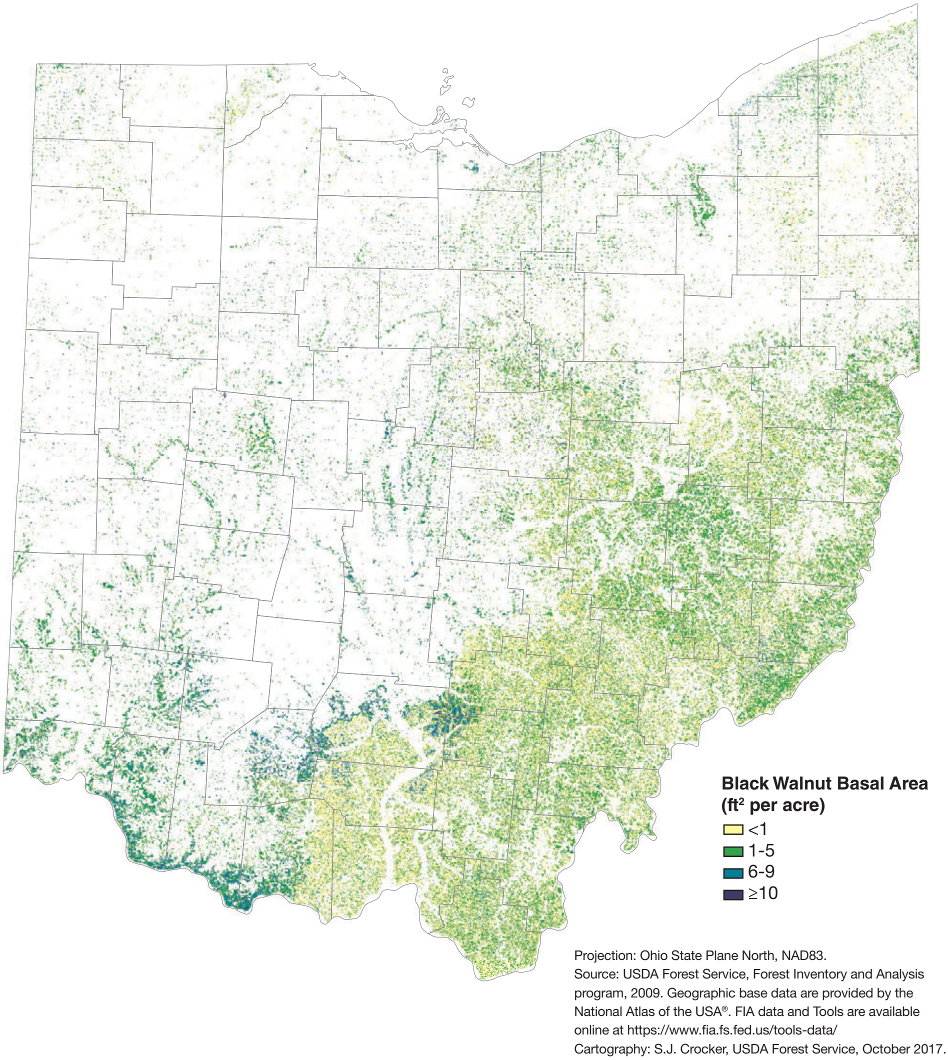

Figure 76.—Density of black walnut on forest land, Ohio, 2009.

What this means

Black walnut represents a small, but important, component of Ohio's forests. In addition to its ecological importance, black walnut is extremely valuable for lumber and veneer. To date, TCD has not spread past its initial introduction in Butler County. However, the presence of this disease increases risk of infection for the entire black walnut resource in Ohio. Although no mortality from TCD is apparent on forest land, future spread could result in extensive walnut mortality.

Looking Forward

Old sawmill in Hocking County. Photo by Ohio Department of Natural Resources, used with permission.

Future Forests of Ohio

Background

This section focuses on anticipated changes to the forests of Ohio between 2010 and 2060. The analysis is derived entirely from the Northern Forest Futures study (Shifley and Moser 2016). A large component of future forest change will be the result of normal forest growth, aging, natural regeneration, and species succession. In addition, the following external forces will drive forest change:

- Population increases will cause a substantial amount of forest land to be converted to urban land from 2000 to 2050 (Nowak and Walton 2005)
- Economic conditions will affect forest products consumption, production, and harvest rates
- Invasive species will spread and affect forest change
- Changes in population, the economy, energy consumption, and energy production will affect future climate change
- Climate change will affect patterns of forest growth and species succession

The Northern Forest Futures study used several alternative scenarios that cover a range of different assumptions about the economy, population, climate, and other driving forces. The assumptions were incorporated into analytical models that estimated how northern forests are likely to change under each alternative scenario. The seven scenarios (A1B-C, A1B-BIO, A2-C, A2-BIO, A2-EAB, B2-C, and B2-BIO) are based on a storyline originating from the Intergovernmental Panel on Climate Change (IPCC 2000) and a storyline variation. They are identified by their storyline identifier (A1B, A2, or B2) followed by a hyphen and their storyline variation (C, BIO, or EAB). The scenarios can be grouped by the two climate models, three storylines, and three variations used to produce them (Table 10).

Table 10.—Scenarios used to project future forest conditions for Ohio

General circulation model[a]	IPCC[b] Storyline A1B	IPCC Storyline A2	IPCC Storyline B2
CGCM3.1	Scenario A1B-C	Scenario A2-C	
	Scenario A1B-BIO	Scenario A2-BIO	
		Scenario A2-EAB	
CGCM2			Scenario B2-C
			Scenario B2-BIO

[a] Source: Canadian Centre for Climate Modelling and Analysis (2014).

[b] Intergovernmental Panel on Climate Change (IPCC 2000).

The three storylines:

1) A1B—Rapid economic globalization. International mobility of people, ideas, and technology. Strong commitment to market-based solutions. Strong commitment to education. High rates of investment and innovation in education, technology, and institutions at the national and international levels. A balanced energy portfolio including fossil-intensive and renewable energy sources. Uses the CGCM3.1 climate model (Canadian Centre for Climate Modelling and Analysis 2014).

2) A2—Consolidation into economic regions. Self-reliance in terms of resources and less emphasis on economic, social, and cultural interactions between regions. Slower diffusion of technology than in the other scenarios. International disparities in productivity, and hence, income per capita, largely maintained or increased in absolute terms. Uses the CGCM3.1 climate model.

3) B2—A trend toward local self-reliance and stronger communities. Community-based solutions to social problems. Regional differences in energy systems, depending on the availability of natural resources. Development of less carbon-intensive technology in some regions spurred by the need to use energy and other resources more efficiently. Uses the CGCM2 climate model (Canadian Centre for Climate Modelling and Analysis 2014).

The three storyline variations:

1) C—Continuation of the observed recent rates of forest removals due to timber harvesting and land use conversion from forest to another land use; available for all three storylines (A1B, A2, and B2).

2) BIO—Increased harvest and utilization of woody biomass for energy; available for all three storylines.

3) EAB—Potential impact of continued spread of the emerald ash borer with associated mortality of all ash trees in the affected areas; available for only one storyline (A2).

What we found

The projected declines in forest land from 2010 to 2060 are based on data from the 2008 inventory. From 2010 to 2060 forest land area is projected to decrease from an estimated 8.06 million acres in 2010 to 7.59 million acres (-5.8 percent) in 2060 under scenario A1B-C; to 7.63 million acres (-5.3 percent) under scenario A2-C; and to 7.84 million acres (-2.8 percent) under scenario B2-C (Fig. 77). Only three scenarios are represented in Figure 77 as the climate model and variations on the storylines do not change the area of forest land projected by this model. Only the storylines (developed around differing demographics and levels of economic activity) alter the area of forest land in the model. Scenarios with increasing population and economic activity have more forest land loss over the time period.

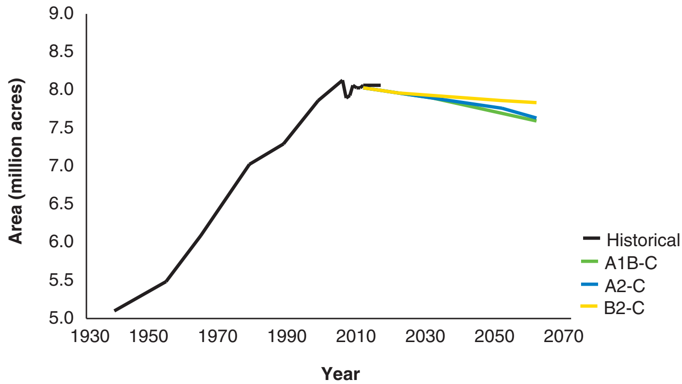

Figure 77.—Projected forest land area for Ohio by scenario, 2010-2060.

Emerald ash borer, initially detected in Ohio in 2003, has been detected in all of Ohio's 88 counties (Ohio Department of Agriculture 2018). Ash species compose 6.1 percent of the current total live-tree volume on forest land. Under the A2-EAB scenario live ash volume is projected to go to zero by 2020. The impact on total live-tree volume from the loss of the ash component is short-lived as other species are expected to fill the void (Fig. 78).

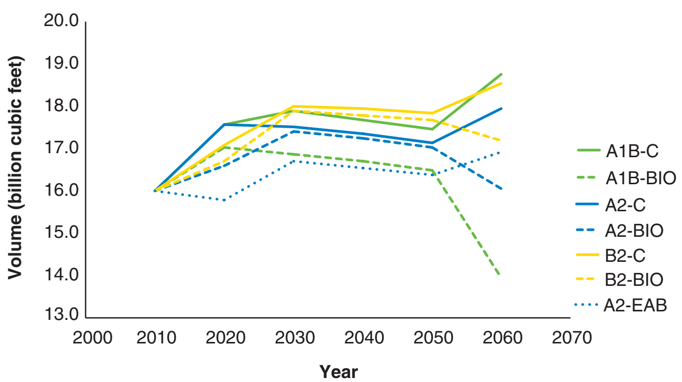

Figure 78.—Live-tree volume on forest land in Ohio by scenario, 2010-2060.

The impacts of high biomass utilization on total live-tree volume are more pronounced than the impacts of EAB. As a result of high levels of annual removals of growing stock on timberland (Fig. 79), live-tree volume on forest land is projected to decrease below the 2010 level under one of the three high biomass utilization scenarios, A1B-BIO (-13 percent) (Fig. 78).

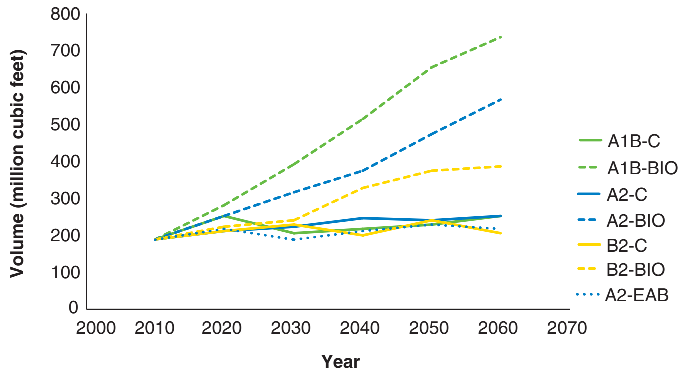

Figure 79.—Average annual growing-stock removals on timberland in Ohio by scenario, 2010-2060.

What this means

The area of forest land is expected to decrease under each of the three storylines in response to increases in population and economic activity. Scenarios assuming greater increases in population and economic activity are projected to have greater losses of forest land.

The projected loss of forest land reverses the upward trend of forest area in Ohio since the 1930s. The loss of between 3 and 6 percent of forest land, depending on scenario, is somewhat offset by increases in volume per acre under all but the A1B-BIO scenario. Harvest rates under the high biomass utilization scenarios A1B-BIO and A2-BIO have a large impact on volumes for those scenarios after 2050, resulting in declining volumes per acre under scenario A1B-BIO.

Though the scenarios discussed are real possibilities, they are not inevitable. Potential losses of future forest area and volume can be substantially mitigated with thoughtful and effective forest and development planning, energy policy, and control of invasive plants and pests.

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Appendixes

Appendix 1.—Tree species, greater than or equal to 1 inch in diameter, found on FIA inventory plots, Ohio, 2016

Common name	Genus	Species	Species group
balsam fir	*Abies*	*balsamea*	Spruce and balsam fir
eastern redcedar	*Juniperus*	*virginiana*	Other eastern softwoods
Norway spruce	*Picea*	*abies*	Other eastern softwoods
blue spruce	*Picea*	*pungens*	Other eastern softwoods
red spruce	*Picea*	*rubens*	Spruce and balsam fir
shortleaf pine	Pinus	echinata	Loblolly and shortleaf pine
Austrian pine	*Pinus*	*nigra*	Other eastern softwoods
red pine	*Pinus*	*resinosa*	Eastern white and red pine
pitch pine	*Pinus*	*rigida*	Other yellow pines
eastern white pine	*Pinus*	*strobus*	Eastern white and red pine
Scotch pine	*Pinus*	*sylvestris*	Other yellow pines
loblolly pine	*Pinus*	*taeda*	Loblolly and shortleaf pine
Virginia pine	*Pinus*	*virginiana*	Other yellow pines
baldcypress	*Taxodium*	*distichum*	Cypress
eastern hemlock	*Tsuga*	*canadensis*	Eastern hemlock
boxelder	*Acer*	*negundo*	Other eastern soft hardwoods
black maple	*Acer*	*nigrum*	Hard maple
Norway maple	*Acer*	*platanoides*	Hard maple
red maple	*Acer*	*rubrum*	Soft maple
silver maple	*Acer*	*saccharinum*	Soft maple
sugar maple	*Acer*	*saccharum*	Hard maple
yellow buckeye	*Aesculus*	*flava*	Eastern noncommercial hardwoods
Ohio buckeye	*Aesculus*	*glabra*	Other eastern soft hardwoods
ailanthus	*Ailanthus*	*altissima*	Eastern noncommercial hardwoods
European alder	*Alnus*	*glutinosa*	Eastern noncommercial hardwoods
serviceberry spp.	*Amelanchier*	spp.	Eastern noncommercial hardwoods
pawpaw	*Asimina*	*triloba*	Eastern noncommercial hardwoods
yellow birch	*Betula*	*alleghaniensis*	Yellow birch
sweet birch	*Betula*	*lenta*	Other eastern hard hardwoods
river birch	*Betula*	*nigra*	Other eastern soft hardwoods
paper birch	*Betula*	*papyrifera*	Other eastern soft hardwoods
gray birch	*Betula*	*populifolia*	Other eastern soft hardwoods
American hornbeam (musclewood)	*Carpinus*	*caroliniana*	Eastern noncommercial hardwoods
mockernut hickory	*Carya*	*alba*	Hickory
bitternut hickory	*Carya*	*cordiformis*	Hickory

(Appendix 1 continued on next page.)

(Appendix 1 continued)

Common name	Genus	Species	Species group
pignut hickory	*Carya*	*glabra*	Hickory
shellbark hickory	*Carya*	*laciniosa*	Hickory
shagbark hickory	*Carya*	*ovata*	Hickory
Chinese chestnut	*Castanea*	*mollissima*	Eastern noncommercial hardwoods
northern catalpa	*Catalpa*	*speciosa*	Other eastern soft hardwoods
catalpa spp.	*Catalpa*	spp.	Other eastern hard hardwoods
hackberry	*Celtis*	*occidentalis*	Other eastern soft hardwoods
eastern redbud	*Cercis*	*canadensis*	Eastern noncommercial hardwoods
yellowwood	*Cladrastis*	*kentukea*	Eastern noncommercial hardwoods
flowering dogwood	*Cornus*	*florida*	Other eastern hard hardwoods
hawthorn spp.	*Crataegus*	spp.	Eastern noncommercial hardwoods
common persimmon	*Diospyros*	*virginiana*	Other eastern hard hardwoods
American beech	*Fagus*	*grandifolia*	Beech
white ash	*Fraxinus*	*americana*	Ash
black ash	*Fraxinus*	*nigra*	Ash
green ash	*Fraxinus*	*pennsylvanica*	Ash
blue ash	*Fraxinus*	*quadrangulata*	Ash
honeylocust	*Gleditsia*	*triacanthos*	Other eastern hard hardwoods
Kentucky coffeetree	*Gymnocladus*	*dioicus*	Other eastern hard hardwoods
butternut	*Juglans*	*cinerea*	Other eastern soft hardwoods
black walnut	*Juglans*	*nigra*	Black walnut
sweetgum	*Liquidambar*	*styraciflua*	Sweetgum
yellow-poplar	*Liriodendron*	*tulipifera*	Yellow-poplar
Osage-orange	*Maclura*	*pomifera*	Eastern noncommercial hardwoods
cucumbertree	*Magnolia*	*acuminata*	Other eastern soft hardwoods
magnolia spp.	*Magnolia*	spp.	Other eastern soft hardwoods
umbrella magnolia	*Magnolia*	*tripetala*	Other eastern soft hardwoods
sweet crab apple	*Malus*	*coronaria*	Eastern noncommercial hardwoods
apple spp.	*Malus*	spp.	Eastern noncommercial hardwoods
white mulberry	*Morus*	*alba*	Other eastern hard hardwoods
red mulberry	*Morus*	*rubra*	Other eastern hard hardwoods
blackgum	*Nyssa*	*sylvatica*	Tupelo and blackgum
eastern hophornbeam	*Ostrya*	*virginiana*	Eastern noncommercial hardwoods
sourwood	*Oxydendrum*	*arboreum*	Eastern noncommercial hardwoods
paulownia, empress-tree	*Paulownia*	*tomentosa*	Other eastern soft hardwoods
American sycamore	*Platanus*	*occidentalis*	Other eastern soft hardwoods
eastern cottonwood	*Populus*	*deltoides*	Cottonwood and aspen
bigtooth aspen	*Populus*	*grandidentata*	Cottonwood and aspen

(Appendix 1 continued on next page.)

(Appendix 1 continued)

Common name	Genus	Species	Species group
quaking aspen	*Populus*	*tremuloides*	Cottonwood and aspen
American plum	*Prunus*	*americana*	Eastern noncommercial hardwoods
sweet cherry, domesticated	*Prunus*	*avium*	Eastern noncommercial hardwoods
sour cherry, domesticated	*Prunus*	*cerasus*	Eastern noncommercial hardwoods
pin cherry	*Prunus*	*pensylvanica*	Eastern noncommercial hardwoods
black cherry	*Prunus*	*serotina*	Other eastern soft hardwoods
cherry and plum spp.	*Prunus*	spp.	Eastern noncommercial hardwoods
chokecherry	*Prunus*	*virginiana*	Eastern noncommercial hardwoods
white oak	*Quercus*	*alba*	Select white oaks
swamp white oak	*Quercus*	*bicolor*	Select white oaks
scarlet oak	*Quercus*	*coccinea*	Other red oaks
shingle oak	*Quercus*	*imbricaria*	Other red oaks
bur oak	*Quercus*	*macrocarpa*	Select white oaks
swamp chestnut oak	*Quercus*	*michauxii*	Select white oaks
chinkapin oak	*Quercus*	*muehlenbergii*	Select white oaks
pin oak	*Quercus*	*palustris*	Other red oaks
chestnut oak	*Quercus*	*prinus*	Other white oaks
northern red oak	*Quercus*	*rubra*	Select red oaks
post oak	*Quercus*	*stellata*	Other white oaks
black oak	*Quercus*	*velutina*	Other red oaks
black locust	*Robinia*	*pseudoacacia*	Other eastern hard hardwoods
black willow	*Salix*	*nigra*	Other eastern soft hardwoods
willow spp.	*Salix*	spp.	Eastern noncommercial hardwoods
sassafras	*Sassafras*	*albidum*	Other eastern soft hardwoods
European mountain-ash	*Sorbus*	*aucuparia*	Eastern noncommercial hardwoods
American basswood	*Tilia*	*americana*	Basswood
American elm	*Ulmus*	*americana*	Other eastern soft hardwoods
Siberian elm	*Ulmus*	*pumila*	Other eastern soft hardwoods
slippery elm	*Ulmus*	*rubra*	Other eastern soft hardwoods
rock elm	*Ulmus*	*thomasii*	Other eastern hard hardwoods

Appendix 2.—List of invasive plant species monitored on NRS-FIA P2 invasive plots. An asterisk indicates species found in the Ohio 2016 inventory.

Tree Species

*black locust	*Robinia pseudoacacia*
chinaberry	*Melia azedarach*
Chinese tallow	*Triadica sebifera*
Norway maple	*Acer platanoides*
princesstree	*Paulownia tomentosa*
punktree	*Melaleuca quinquenervia*
*Russian olive	*Elaeagnus angustifolia*
saltcedar	*Tamarix ramosissima*
Siberian elm	*Ulmus pumila*
silktree (mimosa)	*Albizia julibrissin*
*tree of heaven	*Ailanthus altissima*

Shrub Species

*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*
*multiflora rose	*Rosa multiflora*
*nonnative bush honeysuckles	*Lonicera* spp.

Herbaceous Species

black swallow-wort	*Cynanchum louiseae*
Bohemian knotweed	*Polygonum xbohemicum*
*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*
purple loosestrife	*Lythrum salicaria*
spotted knapweed	*Centaurea stoebe* ssp. *micranthos*

Grass Species

*common reed	*Phragmites australis*
*Japanese stiltgrass	*Microstegium vimineum*
*reed canarygrass	*Phalaris arundinacea*

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This report constitutes the third full report of annualized inventory on Ohio forest land and summarizes field data collected from 2011 through 2016. Ohio has 8.0 million acres of forest land containing 103 tree species and 50 forest types. Net cubic-foot and sawtimber volumes continued to increase, as did the area occupied by large diameter stands. Growing-stock volume remained stable overall, though it decreased 3 percent on private land since 2006. The net-growth-to-harvest-removals ratio dropped from 2.3:1 in 2011 to 1.6:1 in 2016. Invasive insects have had a substantial impact on Ohio's forests, particularly for ash species. Additional information on land-use change, fragmentation, ownership, forest composition, structure, age, carbon stocks, regeneration, invasive plants, insect pests, and the possible future of Ohio's forests is also presented. Sets of supplemental tables are available online at https://doi.org/10.2737/NRS-RB-118 and contain: 1) tables that summarize quality assurance and 2) a core set of tabular estimates for a variety of forest resources.

KEY WORDS: inventory, land use, fragmentation, forest statistics, forest land, timberland, forest ownership, forest regeneration, volume, carbon, growth, removals, mortality, forest health, timber product, forest pest, invasive plant, Ohio

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