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Abstract

This report summarizes the third annual inventory of Wisconsin's forests, conducted 2009–2014. Wisconsin's forests cover 17.1 million acres with 16.6 million acres classified as timberland. Forests are bountiful in the north with Florence, Forest, Menominee, and Vilas Counties having over 90 percent forest cover. In the southeastern part of the State, forest cover is lowest with Dodge, Fond du Lac, Milwaukee, and Racine Counties having less than 10 percent forest cover. The sawtimber volume on timberland has been rising and is estimated to be 69.5 billion board feet. Oak/hickory is the predominant forest-type group, covering one-quarter of the forest land. The statewide growth-to-removal ratio on timberland is 2.2, indicating growth is outpacing removals. Additional information on Wisconsin's forests such as growth, mortality, species composition, ownership, diseases, invasive plant species, and forest economics is detailed in this report. Information on forest inventory methods, data quality estimates, and important resource statistics can be found online at https://doi.org/10.2737/NRS-RB-112.

Acknowledgments

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Cover: Northwoods lake. Photo by Christie L. Kurtz, used with permission.

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Foreword

Our forests are one of our most precious assets. Today, Wisconsin's forests cover 48 percent of our State, totaling more than 17 million acres. Since the mid-1960s the extent of forest land in Wisconsin has been expanding, while both the average age and volume of trees has been increasing.

We know our forests are expanding and diversifying because of the information collected by the Forest Inventory and Analysis (FIA) Program of the U.S. Forest Service. The annual inventory of Wisconsin's forests is administered through the FIA Program in partnership with the Wisconsin Department of Natural Resources, Division of Forestry. The latest 5-year inventory of Wisconsin covers the period 2009-2014, with analysis in 2016 by the Wisconsin Department of Natural Resources and the U.S. Forest Service.

FIA collects, analyzes, and reports information on the status and trends of America's forests: how much forest exists, where it exists, who owns it, and how it is changing, as well as how the trees and other forest vegetation are growing and how much has died or has been removed in recent years. Since 1968, Wisconsin has provided funding to intensify the inventory by doubling the number of permanent plots from which data are collected. The reason for intensifying the inventory is to provide more reliable data on areas smaller than on a statewide basis and stratified components of the data such as forest type, condition class, species volume, etc.

The information provided by FIA can be used in many ways, such as in evaluating wildlife habitat conditions, assessing the sustainability of forest management practices, and supporting planning and decisionmaking activities undertaken by public and private enterprises. FIA combines its information with related data on insects, diseases, and other types of forest damages and stressors to assess the health condition and potential future risks to forests. Those types of analyses are increasingly important to monitor the effects of insects and diseases that are already in Wisconsin, such as emerald ash borer and oak wilt, and to assess the risks of those that are not yet here, such as Asian longhorn beetle or thousand cankers disease.

Wisconsin proudly supports one of the nation's largest forest products industries. We produce more value from forest products than any other state and the forest industry employs nearly 65,000 people. The forest industry often uses FIA information in making business decisions regarding the timber resource quantity, quality, and availability in their area. Information can be provided to industry on a county level basis or radius from a mill location. This information, whether for a traditional wood processing plant or a biomass facility, is invaluable in determining whether there will be an adequate supply of the desired species and size in the area to sustain both the current or proposed operation, and the forest itself.

Wisconsin also benefits from programs administered by the FIA program such as the Timber Products Output Survey (TPO) and the National Woodland Owners Survey (NWOS). The TPO provides information on the amount of wood products that are produced in Wisconsin, where raw materials originate, and where wood products are exported. The NWOS supplies insight into how private forest land owners perceive their land and its benefits as well as their attitudes toward managing their lands.

Wisconsin is also a partner and supporter of new endeavors from the FIA program such as expanding FIA measurements into urban forests. Wisconsin was an active partner in the FIA urban pilot project that was initiated in the State in 2002, and was a key partner in the establishment of the annualized, national urban FIA inventory in 2014. We expect that over the next several years the information derived from these efforts will expand our ability to sustainably manage our urban forest resources that supply benefits to the more than 70 percent of Wisconsin residents that live in urban areas.

In this report, we briefly describe and highlight the current status and trends observed within Wisconsin's forests. We hope this information will stimulate discussion about the State's forest resources and motivate additional research and analysis, as well as increase our shared commitment to protect and sustainably manage one of Wisconsin's most precious assets.

Paul DeLong

Chief State Forester

Contents

Highlights

On the Plus Side

- Wisconsin's forest land area increased since the 2009 inventory period to 17.1 million acres (16.7 million acres in 2009) with approximately 70 percent privately held. Timberland area is estimated at 16.6 million acres (16.5 million acres in 2009). On plots in these forests, a diverse mix of 74 tree species were observed.
- Forest-type groups vary across the region with oak/hickory being dominant, covering one-quarter of the forest land.
- Snag size is generally less than 13 inches in diameter (91 percent) and 64 percent of all timberland contains at least one snag per acre. The number of snags over 17 inches diameter has increased 20 percent in the last 10 years.
- Since 2009, forest carbon per acre has increased; 62 percent of the total carbon stocks are in three forest-type groups: maple/beech/birch, oak/hickory, and aspen/birch.
- In 2013, 311.5 million cubic feet of industrial roundwood was harvested from Wisconsin's forest land. This is an increase from the 261.3 million cubic feet harvested in 2008.
- The low incidence of poor crowns and minimal tree damage suggest that Wisconsin's urban forests are generally healthy and vigorous.

Issues to Watch

- Mortality of black and northern pin oak is a concern. The black and pin oak mortality is much greater than that of northern red oak.
- Red pine dynamics are changing with a considerable increase in large diameter stands and a reduction in small diameter stands. This reflects the aging red pine forest and impacts the future availability for timber products.
- Sawtimber volume has steadily increased since the 1950s as the forests mature. Stand dynamics need to be monitored for wildlife, timber, and aesthetic reasons.
- The area of forest 60 years and older has increased 78 percent since 1983 while young forest (0 to 20 years old) area has decreased 9 percent.
- Browse is a concern throughout the State with 70 percent of measured plots having medium or high levels of browse on understory plants (this includes tree seedlings).

- In urban forests, about 20 percent of the tree species are invasive.
- The number of invasive plant species recorded on FIA plots (of the species monitored) has increased from 17 species in 2009 to 21 species in 2014. Nonnative bush honeysuckle and common buckthorn are the most commonly observed invasives.
- Five pulp and composite mills closed between 2003 and 2013. Since these mills use smaller diameter trees than sawmills and veneer mills, utilization may be reduced. Use of logging slash at cogeneration facilities and pellet mills could help increase utilization.

Background

Closed canopy sugar maple stand. Photo by Christie L. Kurtz, used with permission.

An Overview of Forest Inventory

What is a tree?

Trees are perennial woody plants with central stems and distinct crowns. In general, the Forest Inventory and Analysis (FIA) program of the U.S. Department of Agriculture, Forest Service defines a tree as any perennial woody plant species that can attain a height of at least 15 feet at maturity. Throughout this report, the size of a tree is expressed as diameter at breast height (d.b.h) in inches, unless otherwise indicated. Diameter at breast height is the diameter, outside the bark, at a point 4.5 feet above ground.

A complete list of tree species measured in Wisconsin during this inventory is included in the appendix.

What is a forest?

FIA defines forest land as land that is at least 10 percent stocked with trees of any size or land 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 at least 120 feet in width. There are more specific criteria for defining forest land near streams, rights-of-way, and shelterbelt strips (U.S. Forest Service 2012).

These definitions, as well as definitions for many other terms used in this report, are available in the FIA online glossary: https://www.nrs.fs.fed.us/fia/data-tools/state-reports/glossary/.

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

FIA defines three subcategories of forest land: timberland, reserved forest land, and other forest land. Reserved forest is land that has been withdrawn from timber utilization through legislation. Other forest land is typical of poor soils where the forest is incapable of producing 20 cubic feet per acre per year at the culmination of mean annual increment. Timberland is forest land that is not reserved and meets minimum productivity requirements.

During the periodic inventories conducted before 2000, only trees on timberland plots were measured. We are therefore unable to report estimates for some attributes (e.g., volume) on nontimberland for those older inventories. Beginning with the implementation of FIA's annual inventory system, forest attributes on all forest land—not just timberland—are reported. With the remeasurement of the same annual inventory plots during 2004, 2009, and 2014, FIA now reports growth, removals, and mortality on all forest land, whereas for prior inventories FIA could only report growth, removals, and mortality on timberland.

How do we estimate forest land area and number of trees?

Forest inventory plots have been established throughout Wisconsin at double intensity resulting in approximately one plot for every 3,000 acres. This results in 5,300 nonforest plots and 6,424 forest plots. Only those plots located on forest land are measured "in the field"; all plots comprise a statistical sample of observations used for estimating various forest attributes. Unless indicated otherwise, sampling errors reported in text and figures represent one standard error (SE). For information on sampling errors, see “Statistics and Quality Assurance for the Northern Research Station Forest Inventory and Analysis Program, 2016” (Gormanson et al. 2017), which is available at https://doi.org/10.2737/NRS-GTR-166.

How do we estimate a tree's volume?

Forest inventories typically express volume in cubic feet (or cubic meters), but most people are more familiar with a cord—a stack of wood 8 feet long, 4 feet wide, and 4 feet high. A cord of wood, which is a typical unit for firewood, contains approximately 79 cubic feet of solid wood and 49 cubic feet of bark and air. Volume can be determined precisely by immersing a tree in a pool of water and measuring the volume of water displaced. A less precise, but much cheaper and easier method has been employed in forest inventories, whereby several hundred trees were cut, and detailed diameter measurements were taken along their lengths to accurately determine their volumes (Hahn 1984). Statistical tools were used to model this data by tree species group. Using these models, we can estimate tree volume based on species, diameter, and site index. This method was also used to calculate sawtimber volumes. FIA reports sawtimber volumes in International 1/4-inch board foot scale as well as Doyle rule. To convert to the Scribner board foot scale, see Smith (1991).

How much does a tree weigh?

Building on previous work, the U.S. Forest Service's Forest Products Laboratory and others have developed specific gravity estimates for many tree species (Miles and Smith 2009). These specific gravities were then applied to estimates of tree volume to derive estimates of merchantable tree biomass (the weight of the tree's merchantable bole). All live tree biomass is estimated by including biomass estimates for the stump, top/limbs, and bark. We do not currently report the live biomass in roots or foliage. Forest inventory can report biomass as either green weight or oven-dry weight. Green weight is the weight of a freshly cut tree. Oven-dry weight is the weight of a tree with zero percent moisture content. On average 1 ton of oven-dry biomass is equal to 1.9 tons of green 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/dead trees consists of carbon. Additional carbon pools (e.g., soil, understory vegetation, belowground biomass) are modeled based on stand/site characteristics (e.g., stand age and forest type).

How do we compare estimates from different inventories?

Estimates from new inventories are often compared with earlier inventories to determine trends in forest resources. References to the periodic inventories of 1936 (Cunningham and Moser 1938, Cunningham et al. 1939), 1956 (Stone and Thorne 1961), 1968 (Spencer and Thorne 1972), 1983 (Spencer et al. 1988), and 1996 (Kotar et al. 1999, Schmidt 1998) refer to that single year of Wisconsin inventory, but references to annual inventories of 2004 (Perry et al. 2007), 2009 (Perry et al. 2012), and 2014 refer to the periods ending in those years, i.e., 2000 to 2004, 2005 to 2009, and 2010 to 2014, respectively. Comparisons are valid between 2004, 2009, and 2014 inventories, which are based on FIA's annual inventory system. Comparisons with older periodic inventories, however, are problematic because procedures for assigning stand characteristics such as forest type and stand size have changed as a result of FIA's ongoing efforts to improve the efficiency, reliability, and national consistency of the inventory.

The 1996 inventory used modeled plots, i.e., plots measured in 1983 and projected forward using the STEMS (Belcher et al. 1982) growth model. This was done to save money by reducing the number of undisturbed plots that were sent to the field for remeasurement. Disturbance was determined by comparing aerial photographs of the plots over time and looking for reductions in canopy cover. The idea was that parameters for the STEMS growth model could be fine-tuned using the measured, undisturbed plots and then applied to the remaining unmeasured, undisturbed plots. Unfortunately, the use of modeled plots introduced errors, so the current inventory includes full remeasurements. Thus, only field measured plots are used for comparisons with the 1996 inventory in this publication.

Reserve Status—Improved Implementation

FIA defines reserved forest land as forest land withdrawn by law(s) prohibiting the management of land for the production of wood products (not merely controlling or prohibiting wood harvesting methods). All private forest land, regardless of conservation easements that may restrict harvesting, are considered not reserved. These lands are declared timberland if they meet minimum productivity requirements, and considered "other forest" if they do not. Timberland does not include reserved forest land.

In an effort to increase consistency among states and across inventory years, a refined set of procedures determining reserve status have been implemented with version 6.0 of the FIA field manual (U.S. Forest Service 2012) that took effect with the 2013 inventory year (began October 2012). Furthermore, all previously collected annual inventory data (1999 to present) have been updated using the new standardized interpretation.

Starting with this report, timberland estimates generated for earlier annual inventories will differ from previously published estimates. The 2012 inventory was the last inventory in which all data were available under the previous and improved implementations. Small changes are associated with timberland area, number of trees, volume, and biomass. The changes associated with the remaining timberland estimates are minor given the inherent variability in the associated estimates. The improved implementation of the reserve status definition increases the spatial and temporal precision of timberland estimates allowing for higher quality trend analyses and potentially better forest management decisions.

A word of caution on timberland suitability and availability

The FIA program does not attempt to identify which lands are actually suitable or available for timber harvesting. Land classified by FIA as timberland is not necessarily suitable or available for timber production, but merely has the potential for such production. Actual suitability and availability are subject to changing laws, economic/market constraints, physical conditions, adjacency to human populations, ownership objectives, and other factors.

How do we produce maps?

Maps produced by FIA are for graphic display to meet general reporting requirements. A geographic information system (GIS) and various geospatial datasets were used to produce the maps portrayed within figures of this report. Depicted FIA plot locations are approximate. Sources and intended uses of FIA data are available at: http://fia.fs.fed.us/tools-data/. Sources of other geospatial datasets are cited within each figure, where appropriate.

Forest Features

Red pine plantation. Photo by Cassandra M. Kurtz, U.S. Forest Service.

Forest Area

Background

Wisconsin has historically had a blend of agricultural and forest land uses. Trends in forest area are often an early indicator of future forest resource trends. Fluctuations in area may indicate changing land use or forest health conditions. Monitoring these changes provides information essential for management and decisionmaking.

What we found

Following a trend that began in the 1960s, forest land area in Wisconsin has steadily increased to 17.1 million acres in 2014 (Fig. 1) across the five FIA survey units (Fig. 2). Of that, approximately 16.6 million acres are classified as timberland. Northern Wisconsin continues to have the highest proportion of forest land (Fig. 3) with Florence, Forest, Menominee, and Vilas Counties all exceeding 90 percent forest land. Counties with the least forest land area are concentrated in the southeastern part of the State: Dodge, Fond du Lac, Milwaukee, and Racine Counties have less than 10 percent forest land. Since the 1960s, counties in central and southwestern Wisconsin have generally experienced the greatest increase in percentage of forest land in the State. Regionally, there were large gains in forest land in northeastern, southwestern, and southeastern Wisconsin. Overall, 74 percent of Wisconsin counties gained forest land area over the last 5 years. Twenty-eight counties gained more than 5 percent in forest land area while in the same period six counties lost more than 5 percent (Fig. 4). The expansion of forest land area between the 2009 and 2014 inventory is supported by the majority of counties around the State that gained forest land over the past 5 years. Forest land was gained in 53 of the 72 counties. Most counties in northern Wisconsin maintained heavy forest cover many at 80 percent or higher, with forest area held close to 2009 levels. An exception is Ashland County, where 65.4 percent of the land within the county is classified as forest land.

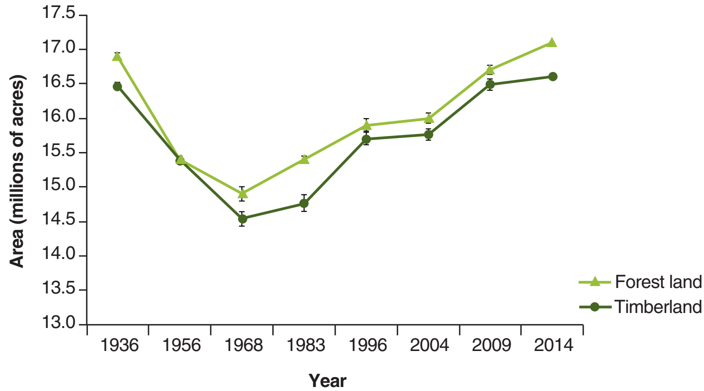


Figure 1.—Area of forest land and timberland, Wisconsin, 1938 to 2014. Error bars represent the 68 percent confidence interval.

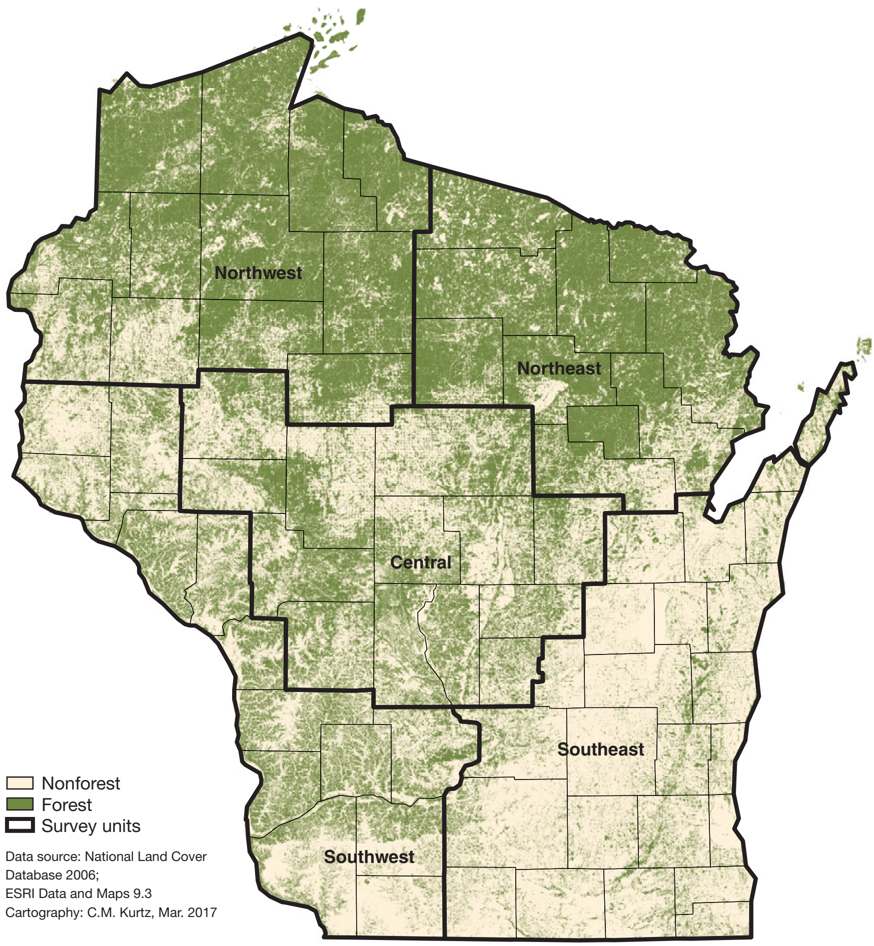


Figure 2.—FIA survey units in Wisconsin

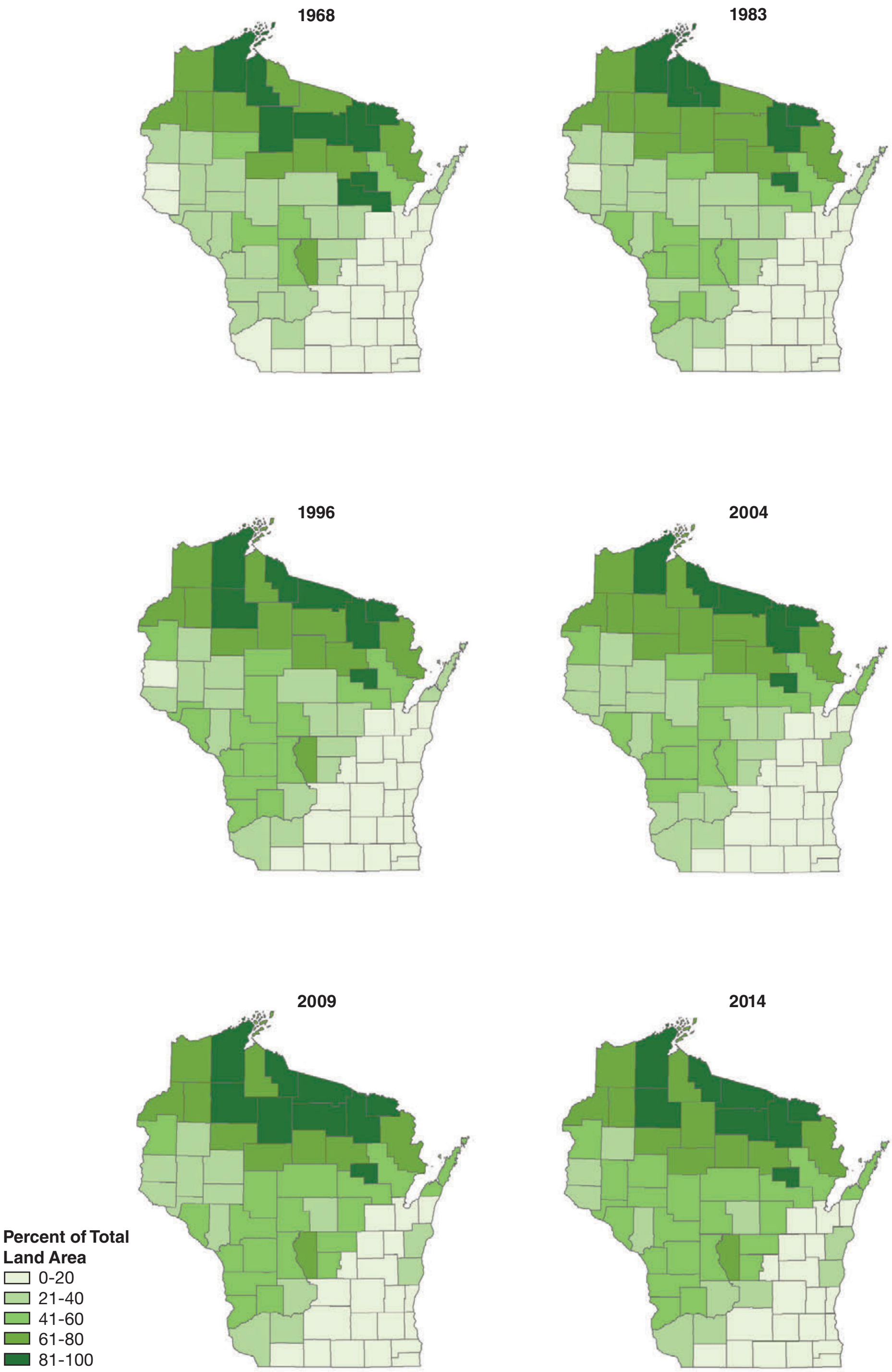


Figure 3.—Forest land area as a percentage of total land area, by county and inventory year, Wisconsin.

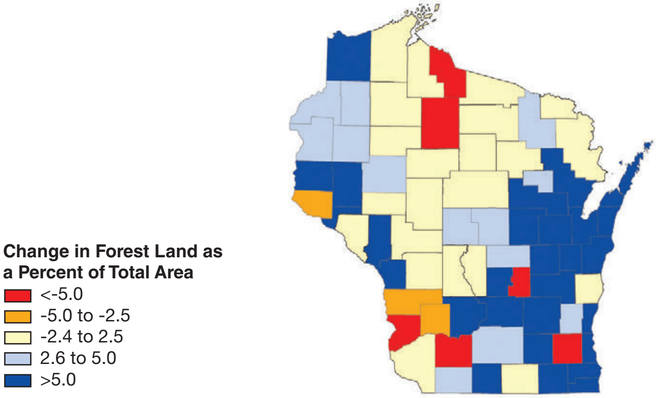


Figure 4.—Change in forest land as a percentage of total land, by county, Wisconsin, 2009 to 2014.

What this means

Wisconsin's forest land area has been steadily increasing since 1968, primarily due to the conversion of marginal agricultural lands to forest land in the northern and central regions of the State. Across the State, forest land increases include most southern counties, though overall percent forest land is still low in this region, especially the southeast. Declines in this region may be due to changing land use, primarily residential development. Overall, forest land in Wisconsin has continued to expand, with regions of the State having relatively low forest cover adding forest land area, and regions with heavy forest cover generally maintaining forest land area.

Mortality of Black and Northern Pin Oak

Background

The oak/hickory forest type is among the largest in Wisconsin and oaks are an important component of this forest type. Oak mortality can be caused by many factors. Oak wilt and oak decline are common causes of mortality among the red oaks. Oak decline is more closely related to stresses such as drought and the accompanying pathogens that attack stressed trees. In a 2007 study of oak decline in Missouri (Dwyer et al. 2007), black oak and scarlet oak were the most affected species and several factors, including stand age and site quality, were identified as increasing the severity of the disease. Oak decline is most prominent in large oaks in older stands growing on dry, nutrient poor sites and is often associated with periods of severe drought. Oak wilt, on the other hand, is much less likely to be related to site characteristics or drought. It is typified by sudden leaf fall and mortality, whereas trees suffering from decline may persist for years with thinning crowns.

What we found

Northern red oak (*Quercus rubra*), which makes up 25 percent of species volume in oak/hickory forests, is increasing in volume and decreasing in mortality. However, black and northern pin oak are not faring as well. In Wisconsin, the number of black oak and northern red oak saplings (1.0 to 4.9 inch d.b.h.) and poles has decreased since 1996. In addition, mortality has increased among the black oak and northern pin oaks. Both of these species are much more likely to occur on drier, poorer sites than northern red oak and mortality is higher on these dry sites. For instance, just over half of the black and northern pin oak volume is found on the drier soils of the Northwest Sands, Central Sand Plains, and Central Sand Hills Ecological Landscapes (Fig. 5), but two-thirds of black and northern pin oak mortality is located in these regions. The 16 ecological landscapes of Wisconsin differ in management and other attributes (Wisconsin Department of Natural Resources 2012).

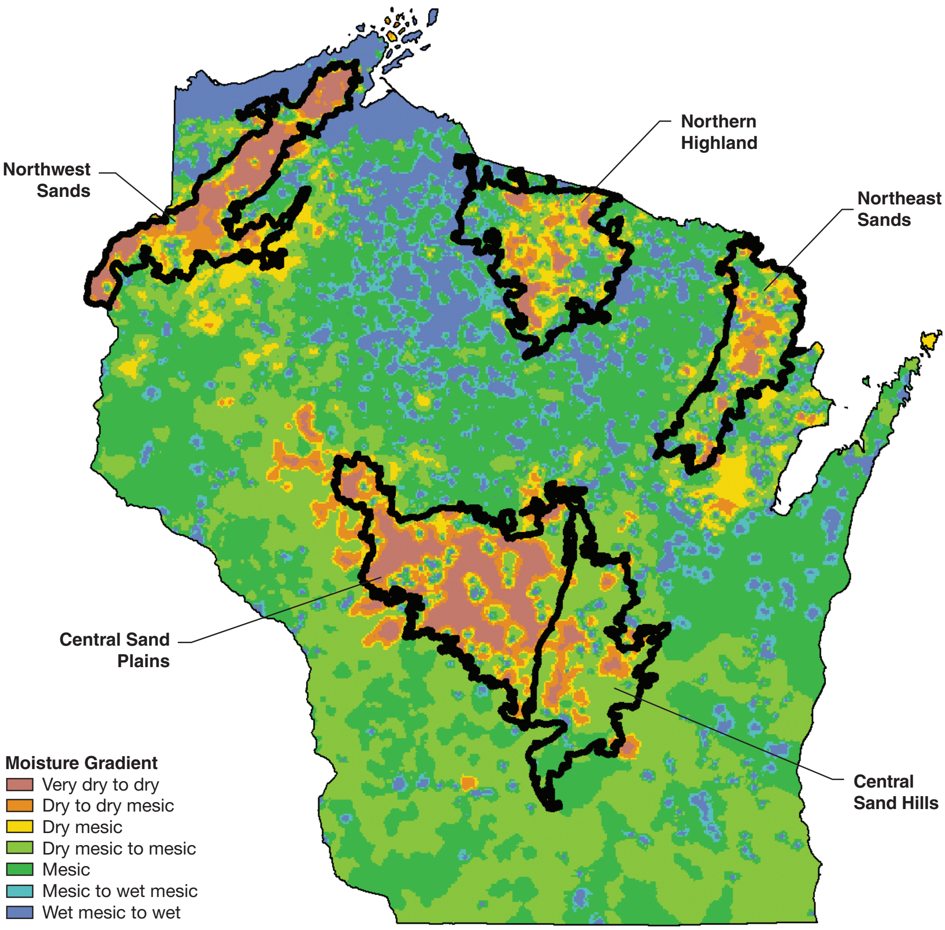


Figure 5.—The five ecological landscape regions of Wisconsin dominated by very dry to dry habitat types.

The volume of black and northern pin oaks started to decline after 2009 due to increasing mortality. While the volume of northern red oak was more than twice that of black and northern pin oaks in 2014 (Fig. 6), the mortality-to-growth ratio for black and northern pin oaks is over five times greater (Fig. 7). The average ratio of mortality to gross growth is much higher for black and pin oaks (62 percent), compared to 28.8 percent for all tree species and 12 percent for northern red oak.

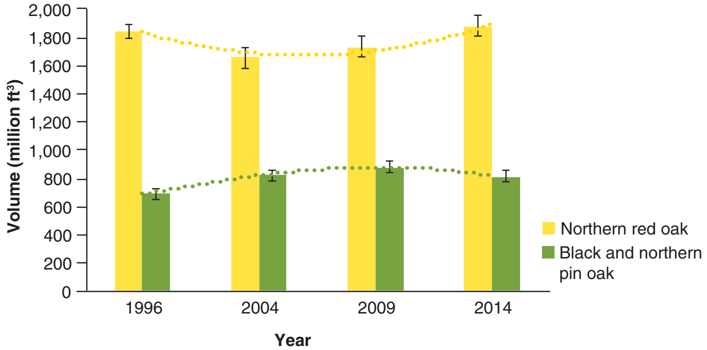


Figure 6.—Volume of growing stock by inventory year for northern red, black, and northern pin oaks on timberland, Wisconsin, 2014. Error bars represent the 68 percent confidence interval.

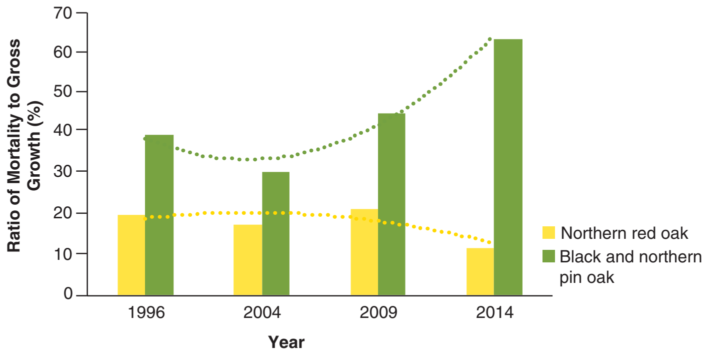


Figure 7.—The ratio of mortality to gross growth by inventory year for northern red oak, black oak, and northern pin oak on timberland, Wisconsin, 2014.

Mortality increases with stand age for both species groups but especially for black and northern pin oak (Fig. 8). There is a large increase in the ratio of mortality to gross growth in the black and northern pin oak over 40 years in comparison to northern red oak. Mortality of black and northern pin oaks is elevated in drier ecological landscapes (Northwest Sands, Northern Highland, Northeast Sands, Central Sand Plains, and Central Sand Hills) (Fig. 9). The ratio of mortality to volume for black

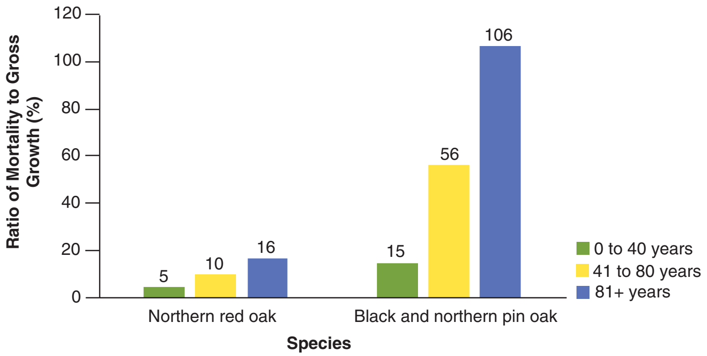


Figure 8.—Ratio of mortality to gross growth by stand-age class and species group on timberland, Wisconsin, 2014.

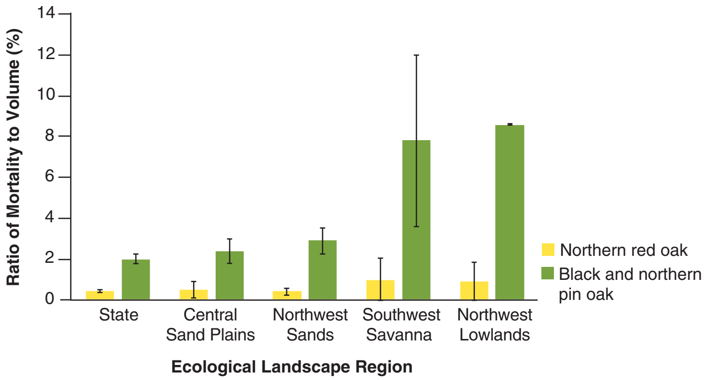


Figure 9.—Regional and statewide comparison of the percentage of mortality to volume for northern red oak, black oak, and pin oak, Wisconsin, 2014. Error bars represent the 68 percent confidence interval.

and northern pin oaks is considerably higher in these very dry to dry ecological landscapes (Fig. 5). The mortality ratio is over four times higher on the Northwest Sands Ecological Landscape than statewide and over nine times higher than for red oak in this region. The mortality-to-growth ratio is almost 1:1 in the Northwest Sands Ecological Landscape, which means that almost all new growth of black and northern pin oaks is lost to mortality. In the Central Sand Plains and Central Sand Hills Ecological Landscape regions, over 60 percent of new growth is lost to mortality.

In addition to the variable site properties that influence survival, the growing-season drought Wisconsin experienced from 2005 to 2012 affected different regions each year (Fig. 10). Between 25 and 50 percent of the State experienced severe to extreme drought sometime during the summer in 6 of these 8 years. Northwest Wisconsin in particular suffered from successive drought years. These extreme droughts cause stress and increased mortality.

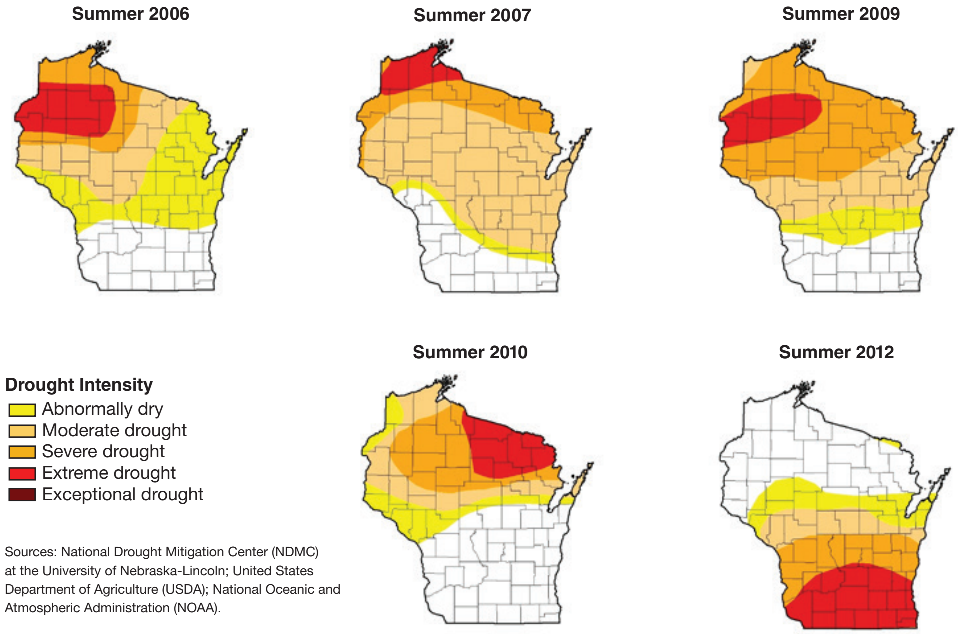


Figure 10.—Drought conditions in Wisconsin during the summer for select years between 2006 and 2012. The map is a composite index based on measurements of climatic, hydrologic, and soil conditions.

What this means

Oak decline has affected black oak and northern pin oak disproportionately. As discovered in the previously cited Missouri study, mortality is most likely related to severe drought. However, without laboratory testing, it is difficult to determine whether this mortality in Wisconsin is due primarily to oak decline or oak wilt; it is likely a combination of both. While oak wilt can be more severe in areas of drought, such as central and southwest Wisconsin, the high mortality that we are seeing in black and northern pin oaks is occurring in areas of northwestern Wisconsin where oak wilt has not been documented until very recently.

In addition, several pests (e.g., forest tent caterpillar [*Malacosoma disstria*], gypsy moth [*Lymantria dispar*], elm spanworm [*Ennomos subsignarius*], and fall cankerworm [*Alsophila pometaria*]) are major defoliators of oak, which are especially devastating to trees predisposed from drought stress. Repeated defoliation can lead to mortality either directly or by predisposing trees to infestations by other pests. Defoliation may show in the crown dieback and transparency attributes that have been much higher in black and northern pin oak compared to northern red oak in the past two inventory periods (2009 and 2014).

If the number of sapling and pole-size trees continues to decrease and mortality of black oak sawtimber remains high, this species could decline in abundance. However, if drought stress subsides for several years, populations of black oak and northern pin oak may rebound.

Red Pine Forest Changes

Background

Red pine is an important timber species in Wisconsin. It has high aesthetic, cultural, and economic value within the State. If this species is to maintain its role as a major timber product, there will need to be a change in current planting and management trends.

What we found

Removal of red pine growing stock has increased since 2009. This species accounts for about 10 percent of sawtimber volume and over 12 percent of removals, second only to aspen. It has the lowest ratio of mortality to gross growth of any species and the highest growth-to-volume ratio of any major species. The area of large diameter red pine stands has increased considerably since 1996, from 173,000 acres to 464,000 acres in 2014 (Fig. 11).

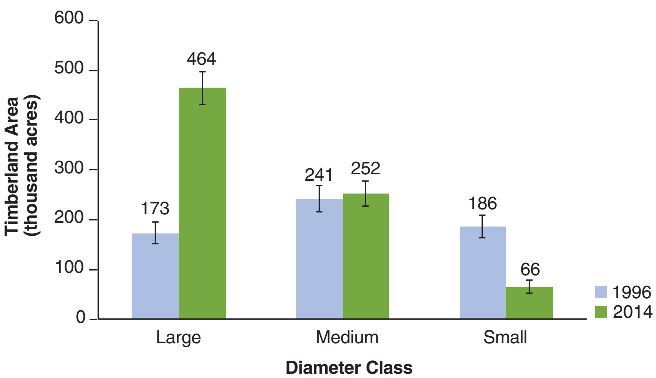


Figure 11.—Area of timberland of the red pine forest type by stand-size class, Wisconsin, 1996 and 2014. Error bars represent the 68 percent confidence interval.

Red pine is mainly a planted species in Wisconsin with about 80 percent of the area in plantations. A large amount of planting was done in Wisconsin after 1956. Red pine acreage more than doubled between 1956 and 1968 with half of this acreage on public lands. Red pine, capable of good growth on droughty soils, was highly favored to recuperate abandoned farm lands and to control erosion. However, planting dropped off in the later part of the 20th century. In 1968, 56 percent of red pine area was in seedling/sapling stands. This percentage dropped to only 10 percent of the total red pine area in 2004 and 8 percent in 2014.

The red pine forest type is aging mainly due to the maturing of stands planted before 1996 and the drop in the number of planted acres since 1996. Area of small diameter stands decreased dramatically in the last two decades from 186,000 acres in 1996 to 66,000 acres in 2014. Area of small diameter stands has remained unchanged since 2004 (Fig. 12). As a percentage of total red pine acreage, the area of small and medium diameter stands dropped from 71 percent in 1996 to 41 percent in 2014.

This change in small diameter stands varies across different regions of the State. Area in seedling/sapling stands has remained unchanged in northern Wisconsin since 2004 but decreased substantially in central Wisconsin after 2009 (Fig. 13).

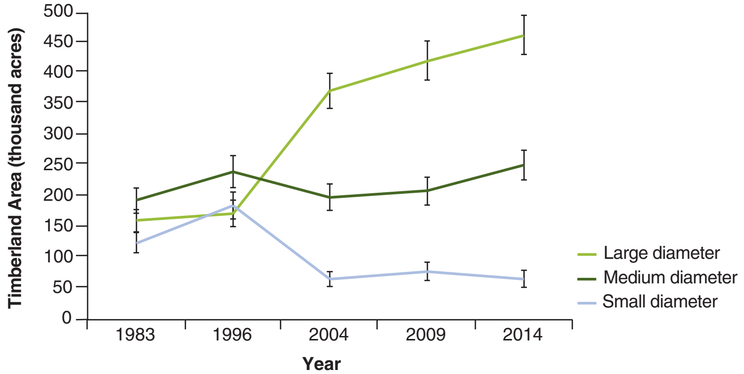


Figure 12.—Area of timberland of the red pine forest group by stand size and inventory year, Wisconsin. Error bars represent the 68 percent confidence interval.

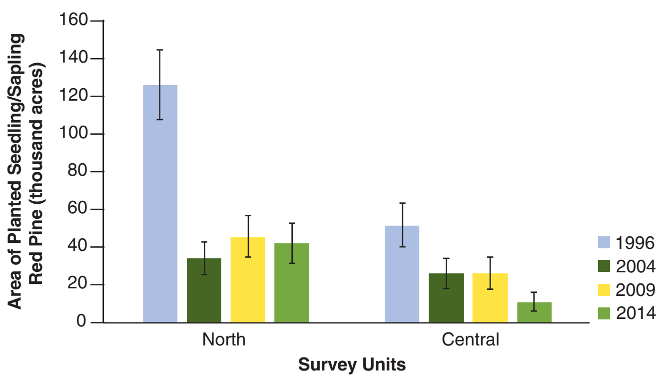


Figure 13.—Area of planted seedling/sapling red pine in northern and central Wisconsin survey units by inventory year. Error bars represent the 68 percent confidence interval.

About two-thirds of the red pine acreage and 90 percent of the acreage in planted seedling/sapling stands is located in four ecological landscape regions: Northwest Sands, Central Sand Plains, Northern Highland, and North Central Forest (Fig. 14). There has been a decrease in planted young red pine in all four regions after 1996 but acreage has remained mostly unchanged after 2004 (Fig. 15). In the Central Sand Plains, however, there was a decrease in planted seedling/sapling stands from about 22,000 acres in 2009 to 7,700 acres in 2014. This decrease is notable in Adams County where there has been a 77 percent decrease in area, from 13,000 acres in 2009 to 3,000 acres in 2014 (Fig. 16).

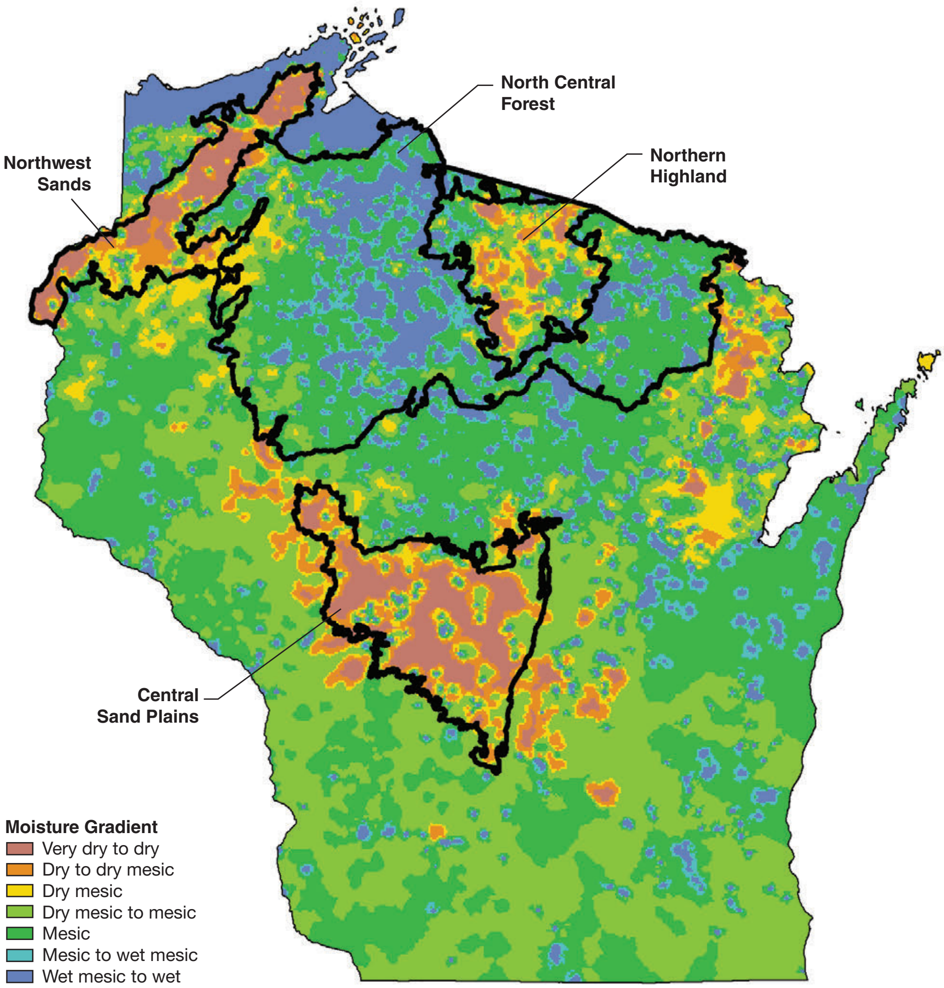


Figure 14.—Four ecological landscape regions of Wisconsin with large acreage of red pine.

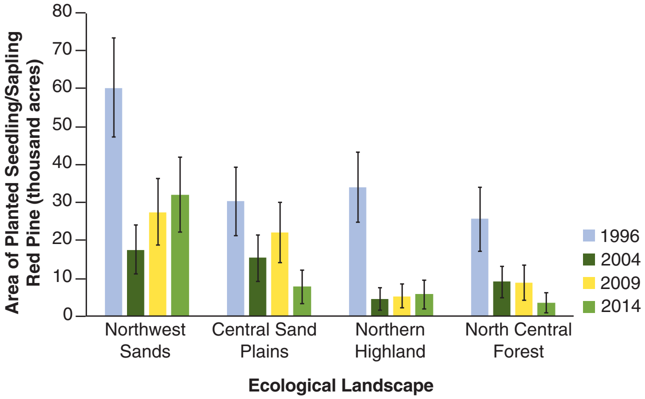


Figure 15.—Area of planted seedling/sapling red pine by ecological landscape region and inventory year, Wisconsin. Error bars represent the 68 percent confidence interval.

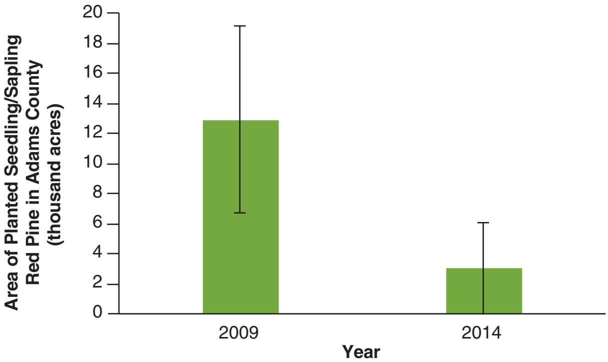


Figure 16.—Area of planted seedling/sapling red pine in Adams County, Wisconsin, by inventory year. Error bars represent the 68 percent confidence interval.

In the Northwest Sands and the North Central Forest Ecological Landscape regions, there is an increase in the area of young stands (<21 years old), both planted and natural, between 2004 and 2014, but a decrease in young stand area in the Central Sand Plains region (Fig. 17). At the county level, young stand area increased in Douglas and Dunn Counties and decreased in Adams and Wood Counties between 2004 and 2014 (Fig. 18).

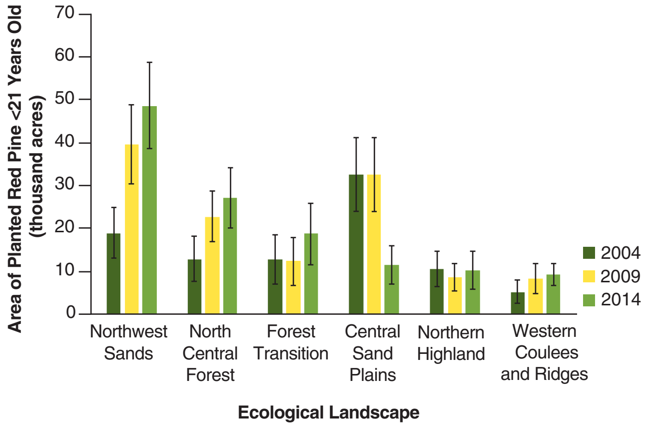


Figure 17.—Area of young (<21 years old) red pine stands, both planted and natural, by ecological landscape region and inventory year, Wisconsin. Error bars represent the 68 percent confidence interval.

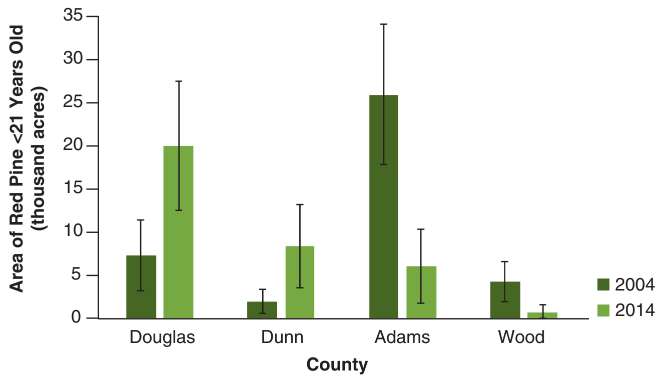


Figure 18.—Area in young (<21 year old) red pine, both planted and natural, by county and inventory year, Wisconsin. Error bars represent the 68 percent confidence interval.

What this means

The red pine forest type is aging as the area of older stands increases, but is not being replaced to an equal extent by seedling/sapling stands. With decreasing area in young red pine, it may mean that the supply of red pine could diminsh in the future as older age classes are harvested, and there is less acreage in younger classes to fill in. This trend impacts potential red pine timber supply and structural diversity for wildlife.

Land Use Change

Background

Forests provide a critical resource and offer a wide range of aesthetic, economic, and wildlife benefits. To better understand Wisconsin's forest land dynamics, it is important to explore the underlying land use changes occurring in the State. 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). 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 is defined as net forest change. Comparing the land uses on current inventory, plots with the land uses recorded for the same plots during the previous inventory allows for characterization of forest land use change dynamics. Understanding land use change dynamics is essential for monitoring the sustainability of Wisconsin's forest resources and helps land managers make informed decisions.

What we found

Wisconsin's land area is almost evenly split between forest and nonforest uses. Although the total area of forest land in Wisconsin remained fairly stable between 2009 and 2014, increasing slightly from 16.7 to 17.1 million acres since the previous inventory, some areas of the State experienced forest loss, whereas other areas saw increases in forest land. Agricultural land uses, along with urban, water, and other nonforest land uses, cover over 51.8 percent of the State's surface area (Fig. 19). Between 2009 and 2014, most of the land use in Wisconsin either remained forested (45.7 percent), or stayed in a nonforest land use (51.8 percent) (Fig. 19). FIA plots with forest gain, loss, and persisting forest/nonforest classes are shown in Figure 20. The locations where forest has been gained and lost are spread across the State with no apparent spatial pattern.

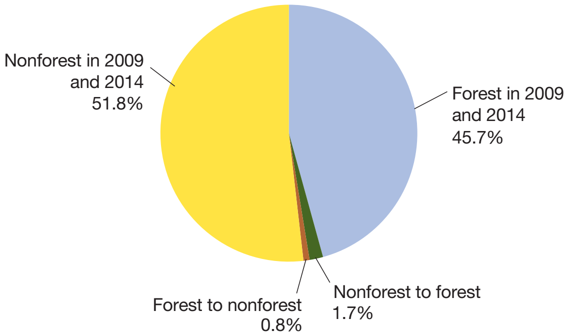


Figure 19.—Land use dynamics showing percentage of unchanged forest land, forest loss, and forest gain, Wisconsin, 2009 to 2014.

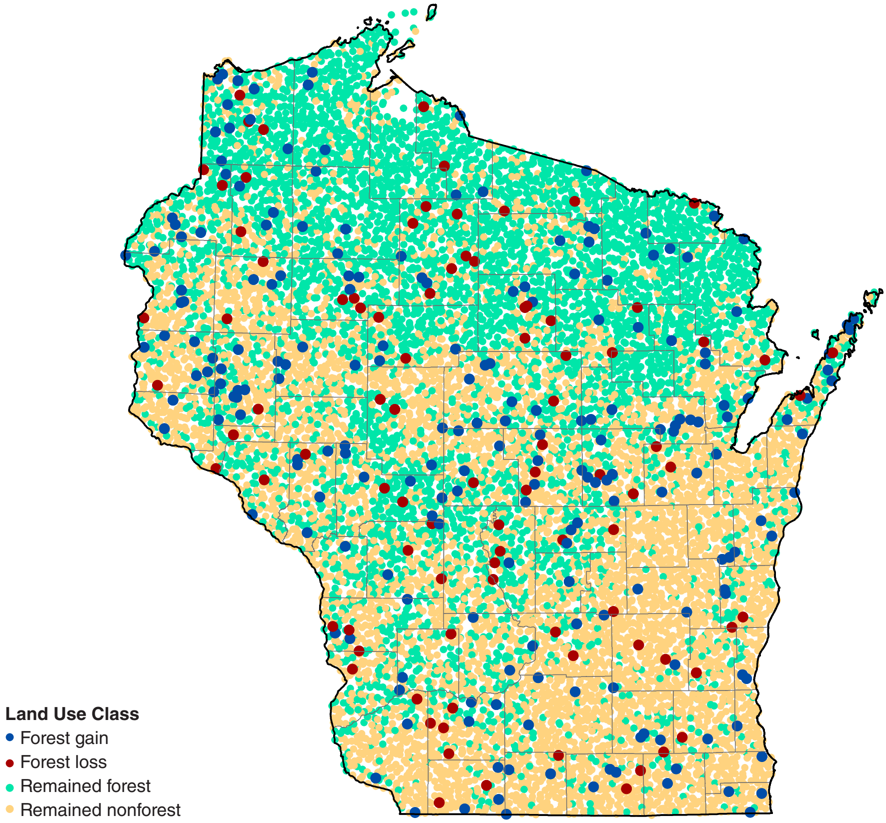


Figure 20.—FIA plots showing forest gains, forest losses, persisting forest, and persisting nonforest, Wisconsin, 2009 to 2014. All plot locations are approximate.

On the 2.5 percent of area where land use changed between inventories, the amount of nonforest that reverted to new forest land exceeded the amount diverted from forest to nonforest, leading to a net gain of forest land (Fig. 19). Remeasurement data show Wisconsin gained nearly 613,000 acres (3.7 percent) from 2009 to 2014, which was only partially offset by a loss of 275,000 acres (1.6 percent) of forest land during the same time period (Fig. 21). Just over 41 percent of the gross forest loss is due to diversion to agricultural land uses including cropland (20 percent), pasture (8 percent), and agricultural land grouped with idle farmland (14 percent; totals sum to 42 percent due to rounding) (Fig. 22). The other 59 percent of forest loss is forest land converted to developed land (17 percent), rights-of-way (13 percent), water or marsh (2 percent), or other land uses (26 percent). Fifty-four percent of forest gain in Wisconsin is from agricultural land (Fig. 21), primarily cropland (32 percent) and pasture (17 percent) converting to forest. Other land use sources for new forest land included developed land (11 percent), rights-of-way (3 percent), water (3 percent), other (22 percent), and unknown (6 percent) (Fig. 22).

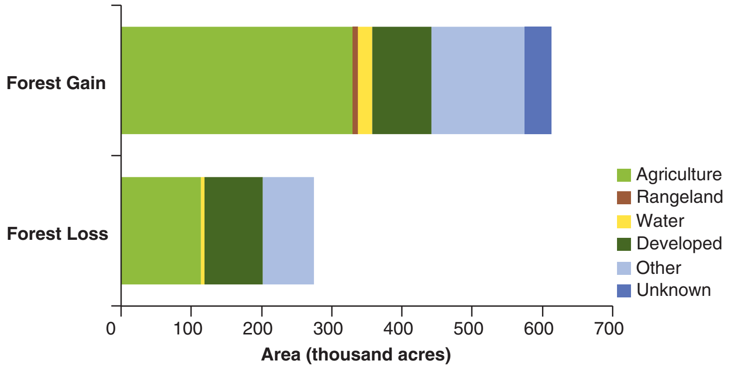


Figure 21.—Gross area forest loss and forest gain by land use category, Wisconsin, 2009 to 2014.

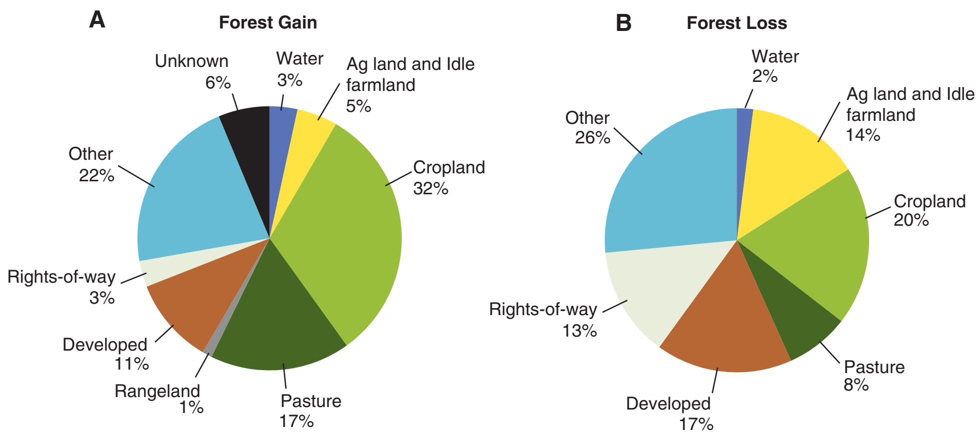


Figure 22.—Forest gain from previous land use (A) and forest loss to current land use (B), Wisconsin, 2009 to 2014.

Land use change differs among stand-size classes. Wisconsin's forests are dominated by stands in the large diameter size class (42 percent), followed by medium diameter (36 percent), and small diameter (21 percent) size classes. A greater percentage of large diameter stands are lost (32 percent) than gained (19 percent), and small diameter stands dominate both losses (38 percent) and gains (43 percent) in forest land area. Nonstocked forest comprises less than 1 percent of Wisconsin forest land but contributes to over 9 percent of the forest land use loss and gain (Fig. 23). Similar to stand-size classes, disproportionate rates of gain and loss occurred in forest-type groups (Fig. 24).

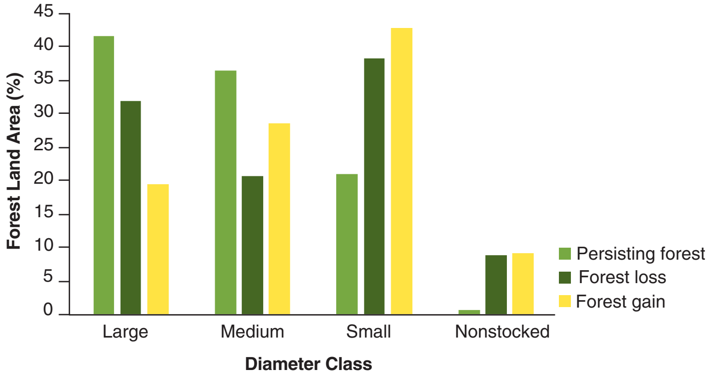


Figure 23.—Percentage of current forest land use by stand-size class for persisting forest, forest lost from previous size class, and forest gained to current size class, Wisconsin, 2009 to 2014.

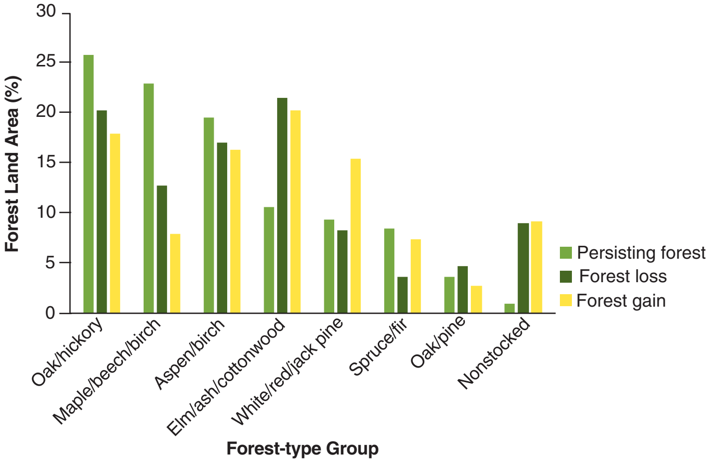


Figure 24.—Percentage of forest land use by forest-type group for persisting forest, forest lost from previous forest-type group, and forest gained to current group, Wisconsin, 2009 to 2014.

What this means

Gains and losses in agriculture appear to drive land use change dynamics in the State. Some of the diversion and reversion of forest land in Wisconsin is probably the result of marginal forest land moving into and out of the forest land base, as suggested by the high 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).

The fact that much of the forest change in Wisconsin is occurring in stands of smaller diameter trees may support the idea that this type of nonpermanent land use change is occurring in the State.

Overall, Wisconsin gained forest land since the last inventory. The net gain of forest land reported in this inventory is relatively small. The gross and net changes are very similar to those observed during the 2009 inventory (Perry et al. 2012). Nonforest categories differ somewhat from the previous report, making direct comparisons challenging, but aggregations of classes appear to show similar patterns across inventories.

Ownership of Forest Land in Wisconsin

Background

How land is managed is primarily the owner's decision. Therefore, to a large extent, the availability and quality of forest resources are determined by landowners, including recreational opportunities, timber, and wildlife habitat. By understanding the priorities of forest land owners, 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 FIA, 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 are based on the responses from 354 family forest ownerships from Wisconsin that participated between 2011 and 2013 (Butler et al. 2016).

What we found

An estimated 70 percent of the forest land of Wisconsin is privately owned (Fig. 25). The vast majority of these private acres, an estimated 9.8 million acres, are owned by family forest owners. Corporations own an estimated 1.5 million acres and Native American tribes and other private owners, including conservation organizations and unincorporated clubs and partnerships, own an estimated 700,000 acres.

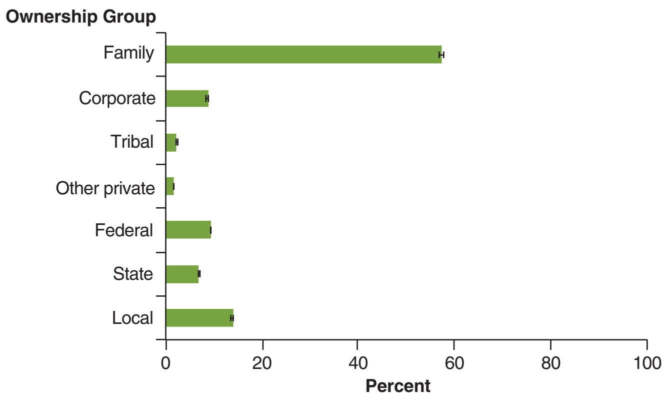


Figure 25.—Percentage of forest land by ownership group, Wisconsin, 2013. Error bars represent the 68 percent confidence interval.

Public owners control 5.2 million acres of Wisconsin's forest land. The Federal government manages an estimated 1.6 million acres of forest land, much of this in the Chequamegon-Nicolet National Forest. State forest, park, and wildlife agencies are stewards of another 1.2 million acres of forest land. Local, primarily county, government agencies control an estimated 2.4 million acres of forest land in the State.

There are an estimated 183,000 family forest ownerships across Wisconsin that each own at least 10 acres of forest land, a collective 9.0 million acres. The average forest holding size of this group is 49 acres. Seventy percent of these family forest ownerships own less than 50 acres of forest land, but 66 percent of the family forest land is in holdings of at least 50 acres (Fig. 26). The primary reasons for owning forest land are related to wildlife, aesthetics, hunting, and nature (Fig. 27). The most common activities on their land are personal recreation, such as hunting and hiking, and cutting trees for personal use, such as firewood (Fig. 28). Most family forest

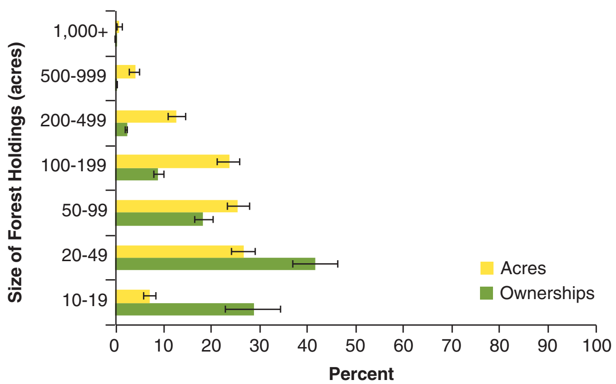


Figure 26.—Percentage of family forest ownerships and acres of forest land by size of forest land holdings, Wisconsin, 2013. Error bars represent the 68 percent confidence interval.

ownerships have not participated in traditional forestry management and assistance programs in the past 5 years (Fig. 29); the most common occurrence is having a written forest management plan, but this is the case for just less than 25 percent of the ownerships. The average age of family forest owners in Wisconsin is 61 years with 37 percent of the family forest land owned by people who are at least 65 years of age (Fig. 30).

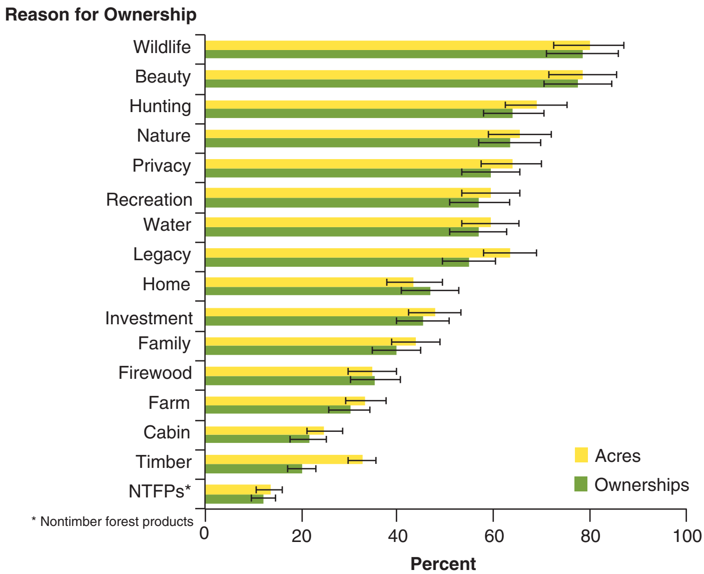


Figure 27.—Percentage of family forest ownerships and acres of forest land by reasons given for owning forest land ranked as very important or important, Wisconsin, 2013. Categories are not exclusive. Error bars represent the 68 percent confidence interval.

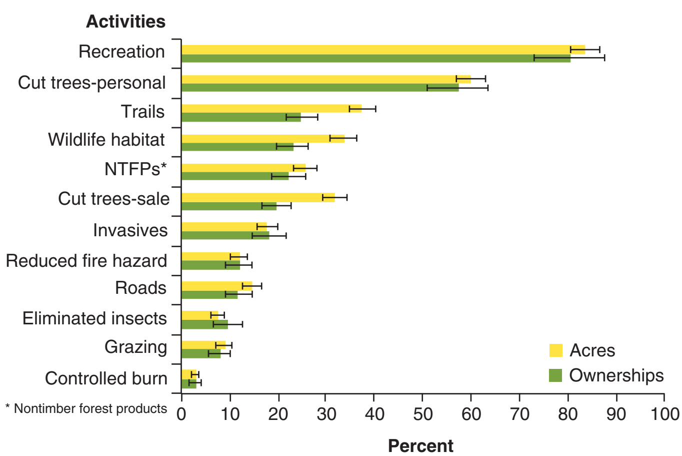


Figure 28.—Percentage of family forest ownerships and acres of forest land by activities in the past 5 years, Wisconsin, 2013. Categories are not exclusive. Error bars represent the 68 percent confidence interval.

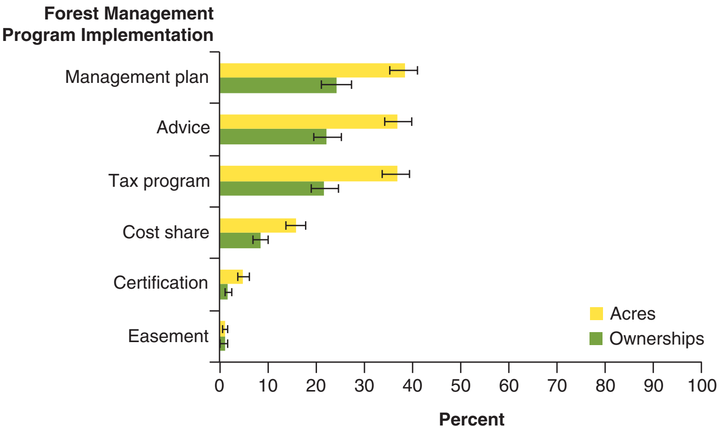


Figure 29.—Percentage of family forest ownerships and acres of forest land by participation in forest management programs, Wisconsin, 2013. Categories are not exclusive. Error bars represent the 68 percent confidence interval.

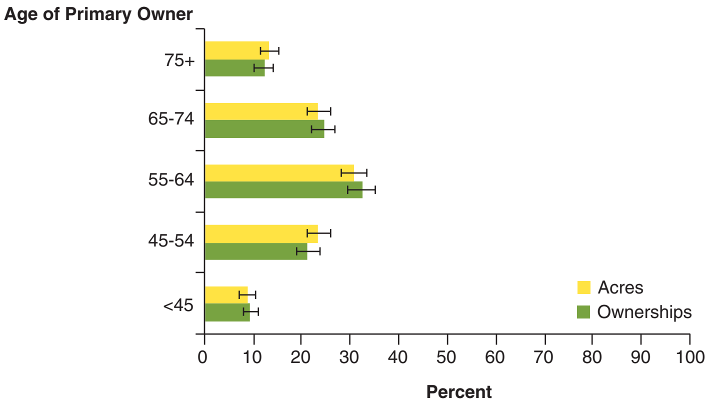


Figure 30.—Percentage of family forest ownerships and acres of forest land by age of primary owner, Wisconsin, 2013. Error bars represent the 68 percent confidence interval.

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 forest owners and what policies and programs can help them conserve the forests for current and future generations. Looking particularly at family forest ownerships, the group that is the least understood and the fate whose land is arguably the most uncertain, they own their land primarily for amenity reasons, but many are actively doing things with their land. That being said, most do not have a management plan and most have not participated in any other traditional forest management planning or assistance programs. There are significant opportunities to help these owners increase their engagement and stewardship of their lands. 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 aging of the family forest owners. With many of them being relatively advanced in age, this portends many acres of land passing on to the next generation in the not too distant future. There are 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) that 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.

Tree Biomass

Background

Stand characteristics beyond merchantable timber have become increasingly important for renewable sources of energy such as biofuel. Biomass estimates are ecologically important as they can help answer complex questions about carbon sequestration, wildlife habitat, and fiber availability. Tree biomass is inclusive of the branches, stumps, boles, and roots. Estimates provided in this section include only the aboveground biomass portion.

What we found

Over the past decade, there has been an increase in live aboveground biomass on Wisconsin's forest land (Fig. 31). Live aboveground biomass of trees at least 1 inch d.b.h. on forest land in Wisconsin's forests is currently 649 million dry tons. Hardwoods make up the majority, at 523 million dry tons. Of the total biomass, 71 percent (460 million tons) is found on private lands. Seventy-three percent of the hardwood biomass and 64 percent of the softwood biomass is on land held by private owners. Public land has a higher proportion of the aboveground dry weight composed of softwoods (Figs. 32A, 32B).

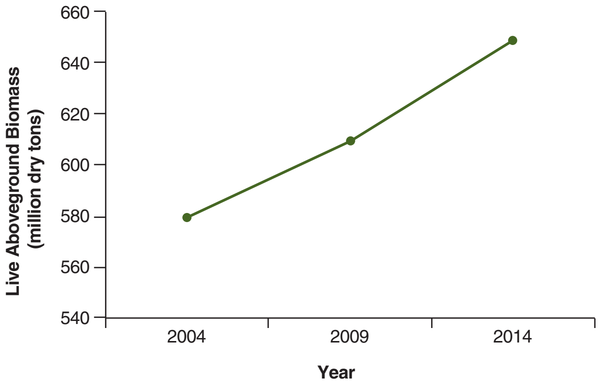


Figure 31.—Aboveground dry weight of live trees at least 1 inch d.b.h. on forest land, by inventory year, Wisconsin.

Figure 32.—Aboveground dry weight of live hardwood and softwood trees at least 1 inch d.b.h. on public forest land, Wisconsin, 2014.

What this means

Total live tree biomass is increasing in Wisconsin, facilitated by the past 50 years of forest management that has supported growth. Biomass, a renewable energy source, can be used to reduce our fossil fuel dependence. High quality trees can be utilized for wood products such as veneer, cabinetry, and other mill uses, while lower grade and underutilized trees have potential for products such as fuel pellets. Estimates of tree biomass are increasingly economically and environmentally valuable as these estimates are important for analysis of energy and carbon storage.

As markets change, forest managers can incorporate biomass utilization into their management plans. Aside from the aboveground live tree biomass discussed here, other carbon sources and sinks such as soil, nontimber vegetation, and dead trees are also important to incorporate into the carbon budget.

Forest Carbon

Background

Tree biomass is approximately 50 percent carbon, based on dry weight. This mass of carbon has become an important part of forest resource reporting in recent years primarily because forests tend to sequester carbon from the atmospheric greenhouse gas carbon dioxide, which is linked to global climate change. Among terrestrial ecosystems, forests contain the largest reserves of sequestered carbon. Regional and national greenhouse gas reporting forums include forest carbon stocks because increases in forest carbon stock represent quantifiable partial offsets to other greenhouse gas emissions. For example, carbon sequestration by U.S. forests represented an offset of more than 11 percent of total U.S. greenhouse gas emissions in 2013 (US EPA 2015) and the continuing increase in Wisconsin forest carbon stocks contributes to this.

Carbon accumulates in growing trees via the photosynthetically-driven production of structural and energy containing organic (carbon) compounds that primarily accumulate in trees as wood. This stored carbon is also found in other forest ecosystem components: dead trees, woody debris, litter, forest soils, understory grasses, forbs, and nonvascular plants as well as animals. Within soils, the larger woody roots are readily distinguished from the bulk of soil organic carbon so the roots are generally reported as the belowground portion of trees and not included in the soils estimates. Carbon loss from a forest stand can include mechanisms such as respiration (including live trees and decomposers), combustion, runoff or leaching of dissolved or particulate organic particles, or direct removal such as the harvest and utilization of wood. From the greenhouse gas reporting perspective, it is important to note that not all losses result in release of carbon dioxide into the atmosphere; some wood products represent continued long-term carbon sequestration.

The carbon pools discussed here include living plant biomass (live trees ≥1 inch d.b.h. and understory vegetation), dead wood and litter (standing dead trees, down dead wood, and forest floor litter—i.e., nonliving plant material), and soil organic matter exclusive of coarse roots and estimated to a depth of 1 meter. Carbon estimates, by ecosystem pool, are based on sampling and modeling; for additional information on current approaches to determining forest carbon stocks see U.S. EPA (2015), U.S. Forest Service (2014), and O'Connell et al. (2014). The level of information available for making the carbon estimates varies among pools. For example, the greatest confidence is in the estimate of live tree carbon due to the level of sampling and availability of allometric relationships applied to the tree data. Limited data and high variability associate lower confidence in the soil organic carbon estimates and for this reason, interpretation of these estimates is limited. Ongoing research is aimed at improving the estimates (US EPA 2015). The carbon estimates provided here are consistent with the methods used to develop the forest carbon reported in the "U.S. Environmental Protection Agency's Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2013" (published April 2015). However, the 2014 inventory summarized here includes some newer data relative to the Wisconsin forest contribution to U.S. EPA (2015).

What we found

Soil organic carbon estimates account for 67 percent of forest carbon and live trees account for 26 percent of forest carbon stocks (Fig. 33). Fourteen percent of live tree carbon is in the wood and bark of the bole of trees at least 5 inches d.b.h. Average aboveground carbon increases with stand age, and greater net accumulation is within biomass (Fig. 34). Total carbon stocks are estimated by taking the product of carbon per acre and total acres of forest within each age class. Most carbon stocks are in the middle-age classes. Thirty-three percent of total aboveground carbon stocks are represented by the 61 to 80 year age class. Looking at stands 41 to 100 years old, this class has 77 percent of the aboveground forest carbon stocks while the youngest and oldest age classes together only account for 12 percent of forest carbon stocks.

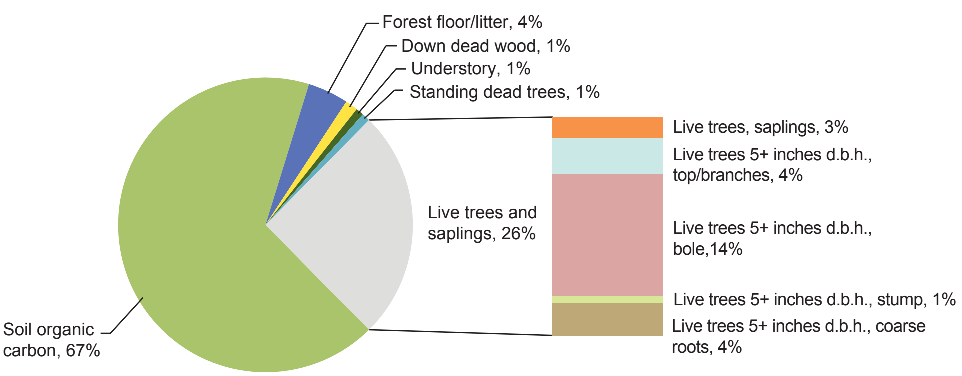


Figure 33.—Percentage of forest carbon stocks within each forest ecosystem component, Wisconsin, 2014.

Figure 34.—Forest carbon stocks by stand-age class for aboveground living plant biomass (live trees at least 1 inch d.b.h. and understory) versus dead wood (standing dead and down dead) and litter pools, Wisconsin, 2014.

The current carbon estimation methods and data were also applied to the 2009 Wisconsin forest inventory (data not shown) to produce summaries consistent with those provided here for the 2014 inventory. Overall, per-acre forest carbon increased by 0.9 percent relative to 5 years ago, and live tree carbon values increased by 4.4 percent. Total forest area increased by 2.1 percent over the same period so total carbon stocks in 2014 are 3.0 percent greater than the equivalent values calculated for 2009.

Species composition affects carbon stocks. Figure 35 illustrates this with average tons of carbon per acre according to the more common forest-type groups identified within Wisconsin forests. Carbon per acre is provided according to four classifications: biomass (live tree and understory), dead wood (standing dead trees and down dead wood), litter, and soil. In Wisconsin, 62 percent of total carbon stocks are in the three forest-type groups: maple/beech/birch, oak/hickory, and aspen/birch, with 24 percent of carbon within the maple/beech/birch group.

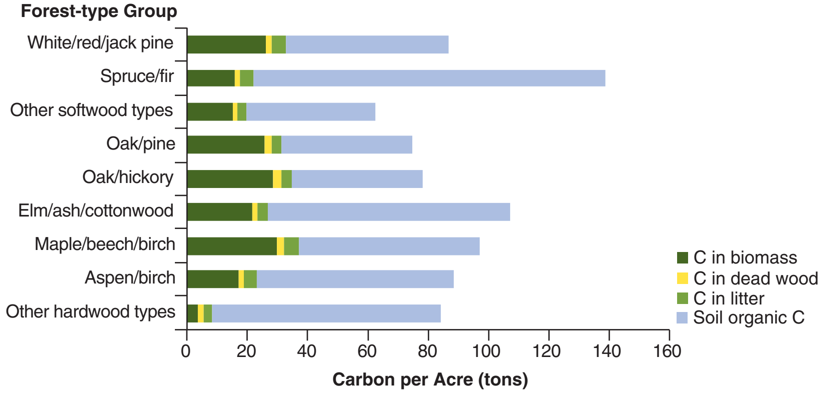


Figure 35.—Carbon stocks by forest-type group for biomass (live tree and understory), dead wood (standing dead trees and down dead wood), litter, and soil, Wisconsin, 2014. The less common groups are pooled as "other" softwood or hardwood groups.

What this means

Actual stocks for a particular stand will depend on a combination of influences—site history, management, stand age, or component species, for example—so that individual sites can vary from the summaries provided in Figures 33 through 35. As an example, the statewide average carbon per acre for live trees is 31 tons for stands that are identified as fully stocked, but the site-to-site variability is such that 50 percent of measured plots fell between 21 and 41 tons of carbon per acre with 25 percent of plots with greater carbon estimates and 25 percent with lower carbon estimates.

In general, forest carbon stocks broadly reflect other measures of forest resources such as stand age, volume, or stocking. Carbon summaries show: 1) most of the carbon is in organic carbon in forest soils, closely followed by live trees; 2) most carbon is in stands of 41 to 100 years; 3) specific stand-level carbon varies; and 4) overall forest carbon in Wisconsin has increased over the past 5 years.

Tree Species Composition

Background

Forest composition is dynamic, changing over time both within stands of trees and across forested landscapes. Many factors combine to influence forest composition including climate and soil; forest disturbances such as fires, storms, insects, diseases, and tree cutting; regenerative ability of tree species; and forest management decisions. Change in forest composition is usually very slow but can be abrupt and drastic if conditions change rapidly due to disease or disturbance. The species of trees within a forest can influence or be influenced by the composition of other plants and animals.

What we found

Number of trees: The estimated number of growing-stock trees (≥5 inches d.b.h.) on timberland has increased by 2.1 percent since 1983. In 2014, red maple was the most abundant tree species in Wisconsin's forests with 256 million growing-stock trees (12 percent of all stems), followed by sugar maple and quaking aspen, both at around 220 million (10 percent of all stems; Fig. 36). The number of red maple growing-stock trees has increased by 35 percent since 1983. Other relatively abundant species that have increased in number since 1983 include eastern white pine, red pine, and black ash (increases of 105 percent, 42 percent, and 39 percent, respectively).

In contrast, the number of growing-stock trees of several common tree species have shown large declines since 1983. These include paper birch, northern red oak, balsam fir, and quaking aspen (-61 percent, -26 percent, -18 percent, and -18 percent, respectively).

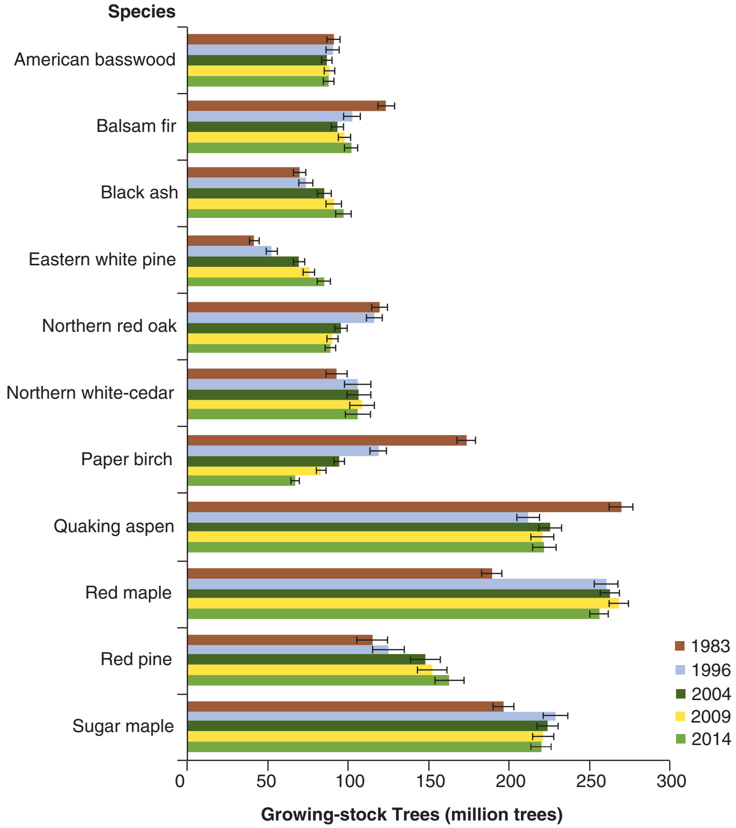


Figure 36.—Number of growing-stock trees on timberland for select species, Wisconsin, 1983 to 2014. Error bars represent the 68 percent confidence interval.

Volume of trees: In 2014, sugar maple has the largest volume of growing-stock trees on timberland at 2.4 billion cubic feet (Fig. 37). Between 1983 and 2014, the total volume for all species increased by 39 percent. Since 2009, several common species have increased in volume by more than 10 percent, including eastern white pine (16 percent), red pine (12 percent), black ash (11 percent), green ash (11 percent), and white ash (10 percent). Common tree species showing larger declines in volume over the last 5 years include paper birch (-18 percent), jack pine (-16 percent), northern pin oak (-10 percent), and black oak (-10 percent).

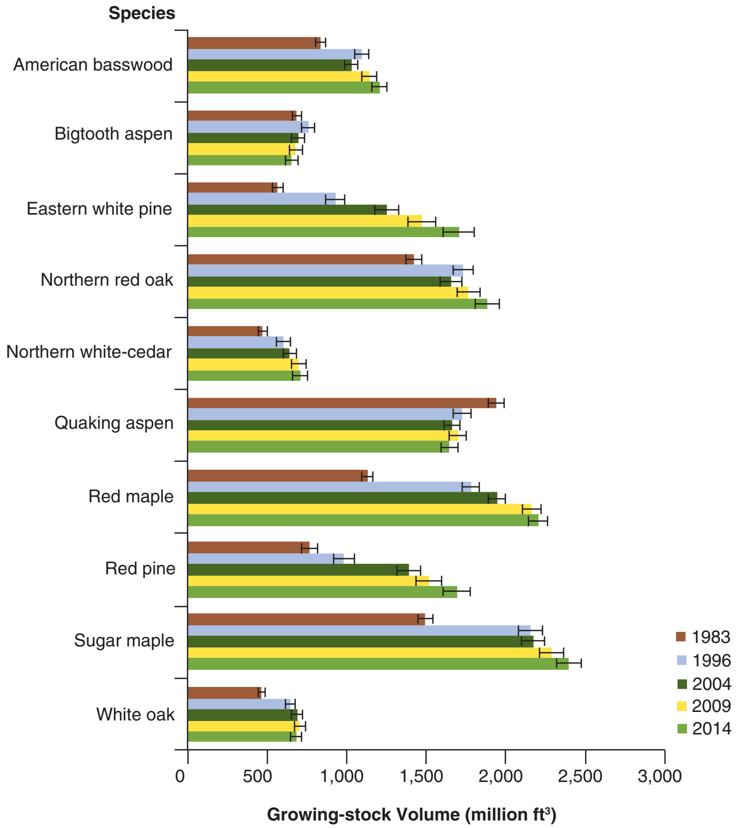


Figure 37.—Growing-stock volume on timberland for select species, Wisconsin, 1983 to 2014. Error bars represent the 68 percent confidence interval.

Comparison of aspen and maples: The aspen and maple species groups account for one-third of all growing-stock volume. Maples are increasing in volume while aspens have been declining. Bigtooth aspen and quaking aspen have decreased 15 percent and 6 percent, respectively, since 1996 while sugar maple and red maple have increased 7 percent and 20 percent, respectively.

The ratio of total growth to volume is about equal among the species groups (Fig. 38) while the percentage mortality for aspen is 7 to 10 times higher and the percentage removal is 2 to 3 times higher than the maples (Fig. 39). This same relationship holds for absolute volumes of mortality and removals.

Aspen volume has decreased steadily since 1983, probably a result of natural forest succession, mortality, and high levels of removal. Growth of quaking aspen adds 45 million cubic feet per year but mortality and harvests remove 99 million cubic feet per year, over twice the volume growth. Similarly growth of bigtooth aspen adds 19 million cubic feet per year but mortality and harvest remove 35 million cubic feet per year. The ratio of removals to growth is greater than 100 percent for aspen, which means that more trees are being harvested than are being replaced by growth. Aspen volume in unharvested stands increased 26 percent between 2004 and 2014, in contrast to a decrease of 66 percent of aspen volume on harvested stands.

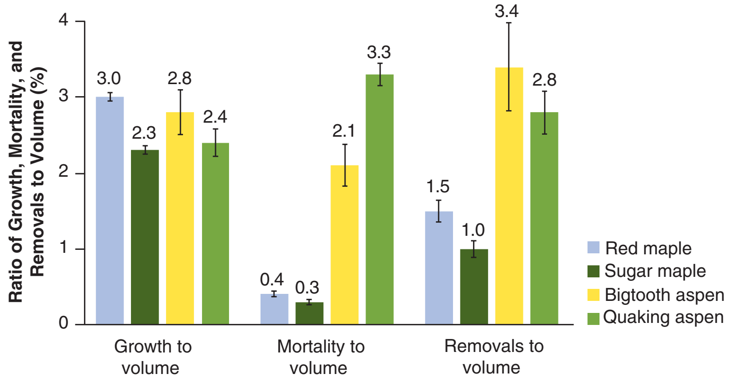


Figure 38.—A comparison of the growth, mortality, and removals to volume for select species on Wisconsin timberland. Error bars represent the 68 percent confidence interval.

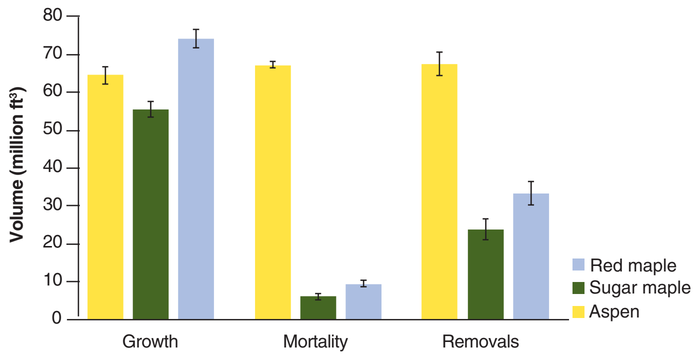


Figure 39.—A comparison of growth, mortality, and removals by species on timberland. Error bars represent the 68 percent confidence interval.

What this means

The dominance of certain tree species is constantly changing but certain trends stand out from the data. For instance, succession to shade-tolerant and longer-lived species will take place in the absence of major disturbance such as fire, storms, or large-scale logging. In Wisconsin's forests, tree species that depend on disturbance to regenerate are decreasing in number and/or volume. These include quaking aspen, bigtooth aspen, jack pine, and paper birch. Species that are more shade tolerant—and typically follow the early successional species—are increasing in number and volume. These include sugar and red maples, red and white oaks, balsam fir, eastern white pine, and American basswood.

There has also been a large increase in red pine volume since 2009 primarily in middle to large sized stands, probably due to increased plantation planting prior to 1996. Area of planted seedling/sapling red pine has decreased substantially since 1996 and has remained statistically unchanged since 2004. Additionally, if aspen continues to experience high levels of harvest and mortality, we can expect to see sharply lower volumes in the future.

Given the current trends, there will likely be an increase in shade tolerant species, a decrease in species dependent on disturbance for regeneration, and a decrease in species susceptible to diseases or pests. The elms, jack pine, butternut, northern pin oak, and black oak are species that currently require monitoring for various disease and pest impacts. As new pests appear or established ones become more widespread, species such as white, green, and black ash (emerald ash borer), as well as American beech (beech bark disease) and red pine (*annosum* root rot), may begin to decline in number and volume.

Sawtimber Volume and Quality

Background

Sawtimber volume and quality are important indicators of the present and future economic value of Wisconsin's forests. This resource not only provides direct economic benefit through sawtimber and veneer sales but also supports wood-using secondary industries such as furniture and millwork manufacturing. As Wisconsin's forests mature, trees increase in diameter and volume.

Tree grade is based on tree diameter and the presence (or absence) of defects such as knots, decay, and curvature. Trees grades range 1 through 5 with quality inversely related to grade number. The value of sawtimber varies greatly by species and tree grade.

A sawtimber tree may go from a lower grade log (grade 3, 4, or 5) to grade 1 or 2 due to an increase in diameter. The increase in economic value can be significant, as the value of a grade 1 log may be over twice the value of a grade 3 log. The quantity of sawtimber by grade needs to be measured to accurately gauge the economic value of timber.

What we found

Sawtimber volume, estimated to be 69.5 billion board feet in 2014, has increased steadily since 1956 (Fig. 40). The sawtimber volume of most economically valuable species groups increased between 1996 and 2014: 40 percent for hardwoods and 56 percent for softwoods. Several species, including northern pin oak, red pine, silver maple, and white ash increased in sawtimber volume by more than 75 percent (Fig. 41). Jack pine, paper birch, and aspen, which are early successional species, have declined substantially in the last two decades. Jack pine sawtimber volume has decreased 40 percent since 1996.

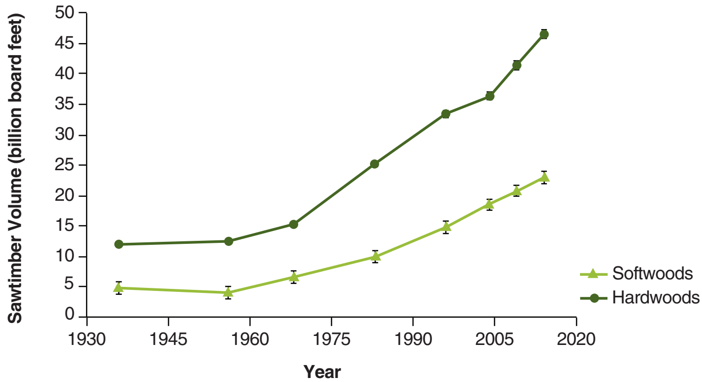


Figure 40.—Volume of sawtimber on timberland by year for softwoods and hardwoods, Wisconsin. Error bars represent the 68 percent confidence interval.

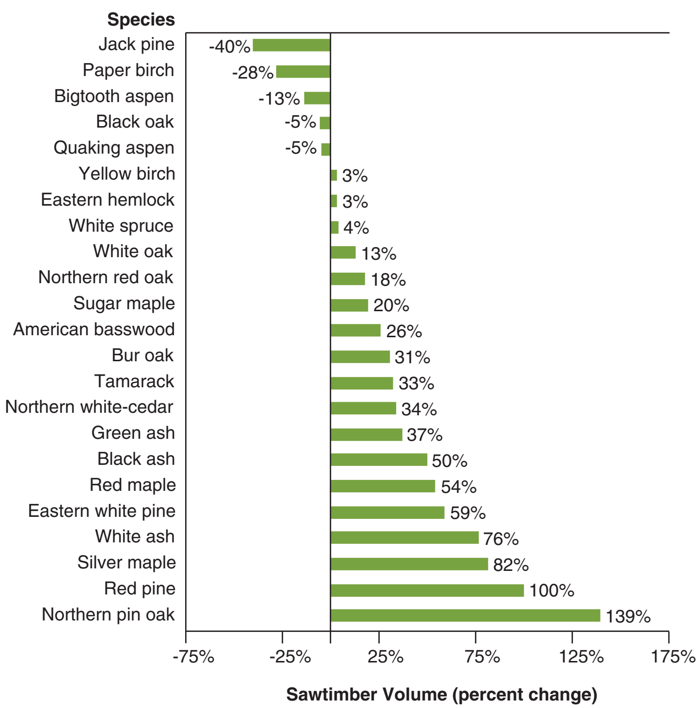


Figure 41.—Change in sawtimber volume on timberland by species, Wisconsin, 1996 to 2014.

Since 2004, net growth and removals have decreased while mortality has increased (Fig. 42). Average annual mortality has increased 43 percent since 2004. Overall there is an increase in the ratio of mortality to volume, a reduction in the ratio of growth to volume, and a reduction in the ratio of removals to volume (Fig. 43).

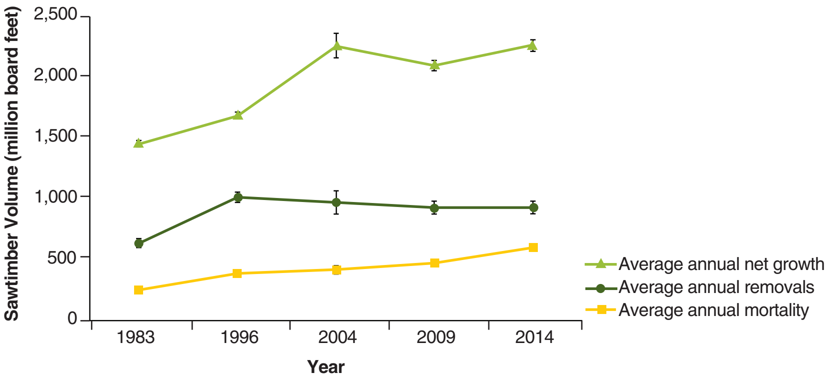


Figure 42.—Average annual net growth, mortality, and removals for sawtimber volume by year, Wisconsin. Error bars represent the 68 percent confidence interval.

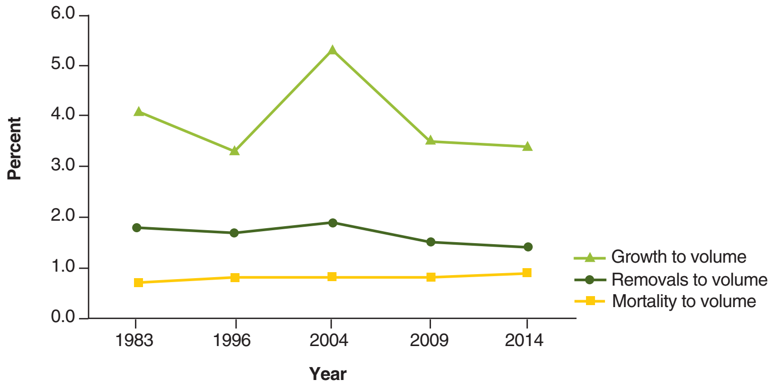


Figure 43.—The ratio of growth, mortality, and removals to volume by inventory year, Wisconsin.

The volume of some valuable species, such as black walnut and black cherry, has doubled since 1996. Volume of grade 1 and 2 sawtimber has increased from 20.6 billion board feet in 2004 to 29.5 billion board feet in 2014 (Fig. 44), a 43 percent since 2004. In comparison, the lower grade (grades 3, 4, and 5) sawtimber increased 10 percent. Several important hardwood species, such as northern red oak, American basswood, and red maple, have experienced large increases in volume of grade 1 and 2 sawtimber between 2004 and 2014 (Fig. 45). Bigtooth and quaking aspen, however, have seen decreases in volume.

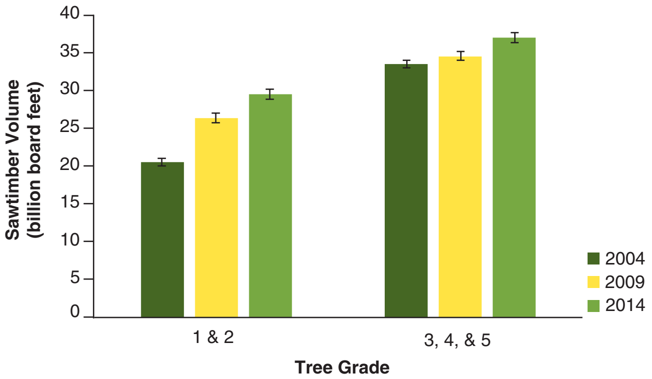


Figure 44.—Sawtimber volume by grade and inventory year, Wisconsin. Error bars represent the 68 percent confidence interval.

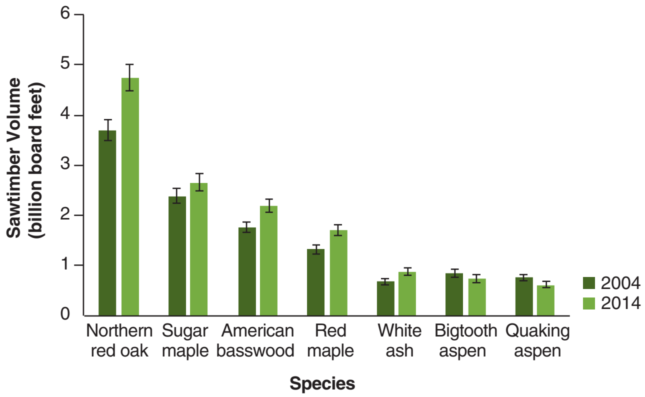


Figure 45.—Volume of grade 1 and 2 sawtimber by tree species and year, Wisconsin. Error bars represent the 68 percent confidence interval.

What this means

The sawtimber resources of Wisconsin's forests have increased since the 1950s especially in grade 1 and 2. As our forests age, tree size and volume will increase but growth rates may slow. Low rates of removal may compensate for higher mortality rates, ensuring a steady increase in the supply of sawtimber on Wisconsin timberland.

Regeneration Status

Background

The composition and abundance of tree seedlings drives the sustainability of forest ecosystems in the early years of stand development and sets the stage for future composition and structure, and hence, the viability of timber and ecosystem services provided. Ecosystem services provided by forests, such as soil conservation, watershed protection, scenic beauty, and personal enjoyment, are important reasons why forest regeneration and other forest attributes bear careful monitoring (Wisconsin Department of Natural Resources 2002).

The previous 5-year FIA inventory report for Wisconsin listed a number of positive trends in the volume and size of the State's forest (Perry et al. 2012). Poor oak regeneration and decreased volume for species that rely on disturbance to regenerate were mentioned as issues to watch. Also, aspen harvests were found to be unsustainable over the long term. It was found that the maturing forest is producing a wealth of resources, but a shift toward shade tolerant species (maples) and away from shade intolerant species (aspen) during the stand initiation stage of development is occurring.

Forest systems of Wisconsin face a number of regeneration stressors, e.g., herbivory, invasive plants, insects, diseases, and climate change. As stands that make up these systems mature and undergo stand replacement disturbances, it is imperative to know the condition of the regeneration component. Regeneration data are critically important for understanding and projecting future forest characteristics that ultimately determine sustainability of the full suite of forest values available.

Early successional young forest habitat provides unique plant biota and landscape heterogeneity (Greenberg et al. 2011). Some prime examples of wildlife that depend on young forest are golden-winged warbler (*Vermivora chrysoptera*), American woodcock (*Scolopax minor*), and cotton-tail rabbit (*Sylvilagus floridanus*) (Gilbart 2012, Wildlife Management Institute 2014). The vitality of Wisconsin's young forest depends directly on the condition of the regeneration component. This is important because it was previously found that the area of young forest is decreasing and the regeneration of light-demanding species is a concern.

To fill the need for more detailed information on regeneration, the Northern Research Station's FIA program (NRS-FIA) added protocols to collect regeneration data on a subset of sample plots (Phase 2-plus plots) during the growing season (McWilliams et al. 2015). The results in this report are based on measurements of 184 plots measured from 2012 to 2014. Field crews measure all established tree seedlings less than 1 inch d.b.h. by length class and assess the impact of browsing in the area surrounding the plot. The regeneration indicator data improve NRS-FIA's ability to evaluate this important aspect of forest health and sustainability. The results presented here for Wisconsin reflect only three of the seven panels of measurements that will eventually comprise the first full baseline dataset for the regeneration indicator. The full dataset will facilitate more detailed analyses, e.g., more species-specific details, and improve the level of statistical confidence in the estimates.

What we found

As Wisconsin's forest stands continue to age, the young forest acreage is becoming a concern as old forests increasingly dominate. Since 1983, the area of young forest (0-20 years old) decreased from about 22 percent of Wisconsin's forest land to 13 percent, a loss of 1.3 million acres of young forest habitat. Over the same period, the area of forest 60 years and older increased by 78 percent or 3.6 million acres. It should be noted that the aspen/birch and spruce/fir forest-type groups typically have more young forest than some other groups. These two groups contribute to 15 percent of the State's forest area and over one-third of the young forest.

Sixty-nine percent of plots had medium (52 percent) or high (17 percent) levels of browse impact on understory plants (Fig. 46A). Nearly one-third of the plots had low browse levels (this category includes no browse). Most of the plots with medium browse impact are randomly distributed (Fig. 46B). High browse levels were most common in the Northern Forest and Central Farmland Deer Management Zones designated by the Wisconsin Department of Natural Resources (2014).

The number of seedlings is estimated at 108.2 billion, or a statewide average of 6,400 seedlings per acre. About 56 percent of the seedlings are less than 1 foot tall, 36 percent are 1.0 to 4.9 feet, and 8 percent are 5.0 feet and taller (Figs. 47). High densities of seedlings were most common in the northwestern region (Fig. 48). This region also has most of the aspen/birch and spruce/fir forests that are typified by high seedling densities.

Maple is the most common seedling genera with 46 percent of the population (Fig. 49). Ash ranks second with 11 percent. All the other genera have less than 10 percent of the seedling population. The top five seedling species are red maple (30 percent), sugar maple (14 percent), black ash (6 percent), black cherry (5 percent), and balsam fir (4 percent). There is also an abundance of species that are not capable of achieving high canopy status, such as American hornbeam, serviceberry species, and chokecherry.

Comparing species abundance by size class highlights potential pathways for future canopy dominants. Prospective "gainers" are those species with relatively high percentages of stems in the regeneration pool of seedlings and saplings compared to larger trees. Sugar maple, red maple, and the "other" group are the most apparent gainers (Fig. 50). Prospective "losers" are species with lower percentages in the regeneration pool than the adult pool. The list of potential losers includes red pine, eastern white pine, red oaks, white oaks, and American basswood. The distribution of stem abundance by size class is out of balance for these species with seedlings, saplings, and young adults rare compared to older adults.

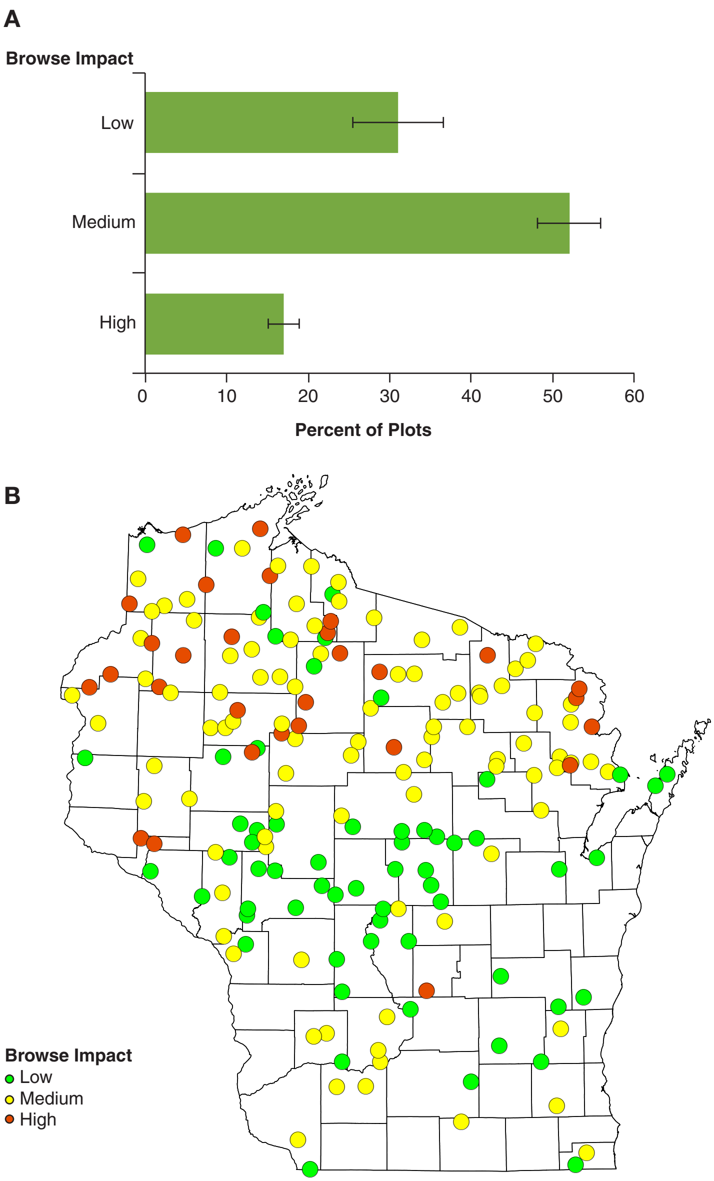


Figure 46.—Proportion of plots by browse level (A) and distribution of forested P2+ sample plots on forest land by level of browse impact (B), Wisconsin, 2012 to 2014. High and very high browse impact classes are combined in both A and B. Error bars represent the 68 percent confidence interval. Plot locations are approximate.

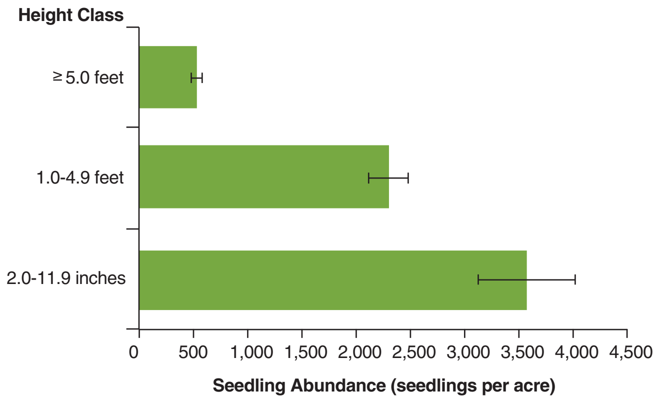


Figure 47.—Seedling abundance on forest land by seedling height class, Wisconsin, 2012 to 2014. Error bars represent the 68 percent confidence interval.

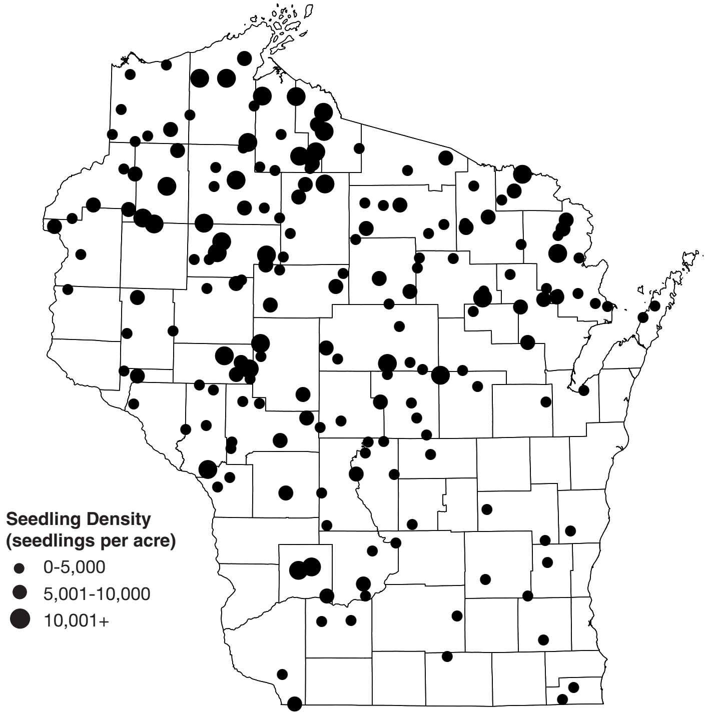


Figure 48.—Distribution of P2+ sample plots on forest land by seedling density, Wisconsin, 2012-2014. Error bars represent the 68 percent confidence interval. Plot locations are approximate.

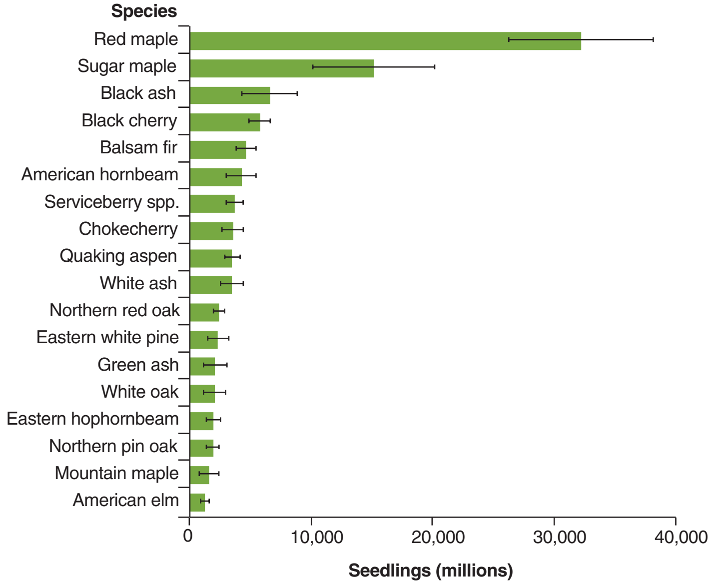


Figure 49.—Number of seedlings on forest land by species for species with at least 1-percent of the total number of seedlings, Wisconsin, 2012-2014. Error bars represent the 68 percent confidence interval.

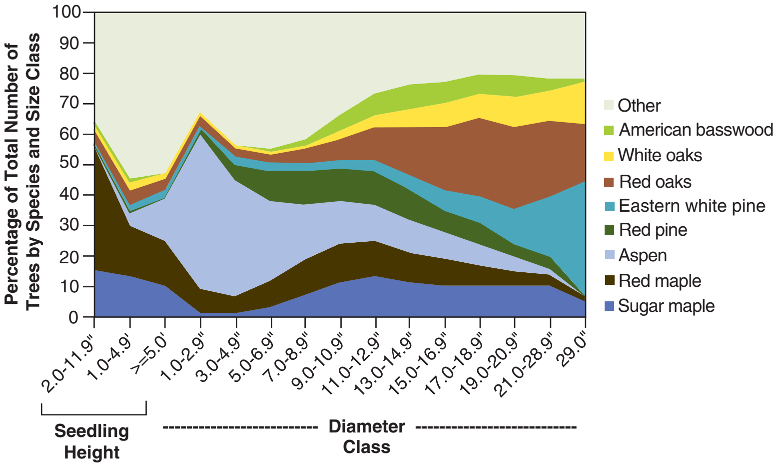


Figure 50.—Species composition for seedlings, dominant/codominant live saplings, and growing-stock trees on forest land for species with the greatest aboveground biomass, Wisconsin. Seedling estimates are for 2012-2014 and sapling and tree estimates are for 2010-2014.

What this means

Wisconsin forests face a variety of forest health risks and regeneration is an integral factor. Deer browse is a major factor affecting regeneration in the eastern United States (Russell et al. 2001, White 2012). In Wisconsin, hunters contribute an estimated $2.5 billion to the economy (U.S. Fish and Wildlife Service and U.S. Census Bureau 2014). With nearly 70 percent of the plots having at least medium browse impact, it is 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 that occurs in more populated areas of the State (Augustine and deCalesta 2003).

The most noteworthy issue found in the results is a proliferation of sugar maple and red maple seedlings and saplings. Both sugar and red maple are mesophytic and shade tolerant, which gives them an advantage during the regeneration phase in stands with low light on a wide variety of sites. These phenomena have created an imbalance in the distribution of trees by size class where maple seedlings dominate the seedling and sapling size classes at the expense of other species that are shade intolerant and more site specific.

Oak regeneration is problematic in the eastern United States and management challenges, such as lack of fire and over-browsing, have been described by Holt and Fischer (1979). The imbalance in size class is particularly apparent in oak/hickory forests, the most common forest-type group in the State on approximately one-quarter of the forest land. The long-term future of oak-dominated forests will depend on management strategies that establish oak seedlings and foster development of saplings and adults using stand-tending prescriptions that forestall development of shade tolerant species (Abrams 1992).

Maple/beech/birch is the second most important forest-type group in Wisconsin with almost 23 percent of the forest land. The future of the group appears to be favorable because of the large population of maple seedlings and saplings that could eventually replace today's stands.

The aspen/birch forest-type group accounts for nearly 18 percent of the forest land and Wisconsin's pulp and paper industry relies on aspen for a sustainable supply of raw material. It would appear that the lack of small aspen trees implies an impending shortage of the aspen resource. Although the short-term supply of aspen should be adequate, the long-term future of the group will require an influx of seedlings at some point.

Stocking

Background

Stocking values are a measurement of the occupancy of land by trees in relation to a desired level. When a stand is fully stocked, the site potential is fully utilized. In overstocked stands, trees are crowded, growth is reduced, there is little to no available growing space, and mortality increases. Poorly stocked stands lack a sufficient number of trees and regeneration is a concern. Stocking values vary by species and change with tree size since the values are determined by the number of trees per acre and their diameters. As stands mature, the number of trees per acre decreases and stand volume increases.

What we found

Wisconsin has over 6.8 million acres, or 41 percent of timberland, that are fully stocked (Fig. 51). This is similar to what is found in neighboring Michigan (48 percent fully stocked stands) and Minnesota (42 percent). Additional stocking categories in Wisconsin are medium stocked (38 percent), poorly stocked (12 percent), overstocked (8 percent), and nonstocked (1 percent). Since 2004 the area of fully stocked timberland has decreased slightly, however the acreage of medium stocked trees has increased. Combining medium and fully stocked timberland results in a gradual increase in acreage over the past 10 years. The area of poorly stocked and nonstocked timberland has remained relatively stable.

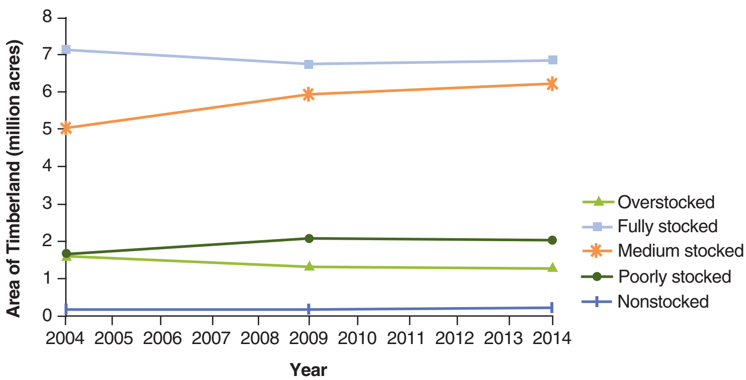


Figure 51.—Level of stocking on timberland by year, Wisconsin.

Stocking levels vary by forest-type group (Fig. 52). Various factors, such as physiography, soil fertility, and moisture, can affect stocking values. Forests in hydric (wet) and xeric (dry) sites often have lower stocking. The elm/ash/cottonwood forest-type group is often found on hydric sites with reduced stocking. Those forest-type groups with the most fully stocked stands, such as aspen/birch and maple/beech/birch, are more common on mesic (moderate moisture) sites. Overstocked stands can be an artifact of limited utilization due to operability, wildlife, or legal constraints.

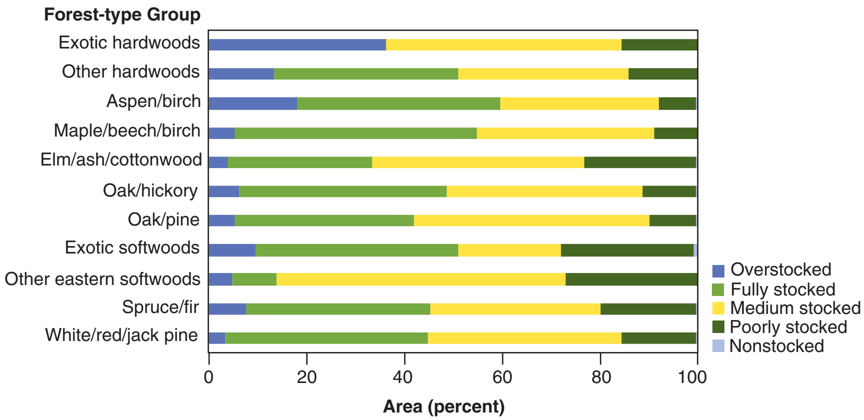


Figure 52.—Level of stocking on timberland by forest-type group, Wisconsin, 2014.

What this means

Fully stocked stands represent the largest area of any group. Poorly stocked and nonstocked areas represent areas of management opportunities as they are areas with minimal growth. It is important to monitor these trends to keep the forests healthy. Forest management can help promote vigor and growth to help provide a future flow of quality timber products as well as wildlife habitat and recreational areas.

Tree Growth

Background

The components of forest change—growth, removals, and mortality—are important indicators of sustainability and help us understand what is influencing net change in volume. Growth is reported as average annual net growth and is the annual change in volume of sound wood in live trees greater than or equal to 5 inches diameter plus the volume of trees entering this class through ingrowth, minus the volume lost from natural causes (mortality).

What we found

The growth of growing-stock trees on timberland in Wisconsin has increased since 1983 (Fig. 53). In 2014, the average annual net growth is nearly 576 million cubic feet, an increase of almost 34 million cubic feet since the last inventory. Since 2009, the four most voluminous species are red pine, eastern white pine, red maple, and sugar maple, however red pine has the greatest average annual net growth, replacing red maple at the top of the list (Fig. 54). Another change is that white oak is no longer one of the 10 most voluminous species as black ash enters the list of the top 10 species. It is important to note that these shifts in ranking can occur due to relatively minor changes in stocking.

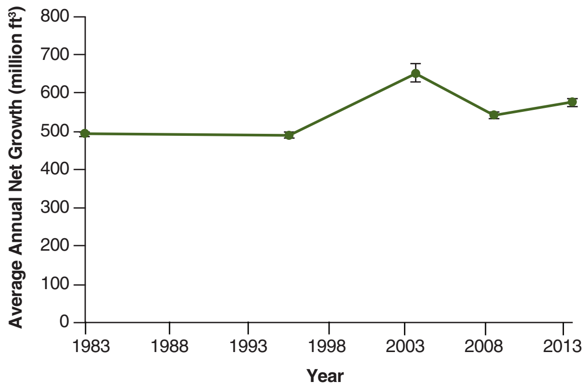


Figure 53.—Average annual net growth of growing-stock trees on timberland by year, Wisconsin. Error bars represent the 68 percent confidence interval.

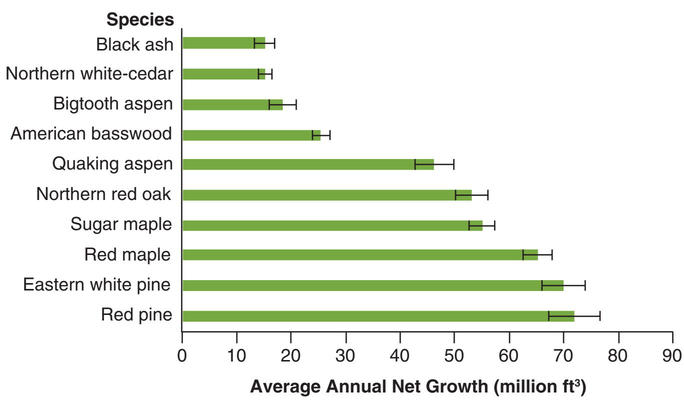


Figure 54.—Average annual net growth for the 10 most voluminous species of growing-stock trees on timberland, Wisconsin, 2014. Error bars represent the 68 percent confidence interval.

What this means

Wisconsin's forest growth has consistently outpaced removals. This is important to ensure future resource availability. While most of the species of high volume remained the same, it will be important to continue monitoring their abundance. Information on mortality and removals help identify the changing forest composition. It is important to remember these three components of change—growth, mortality, and removals—provide information for trees 5 inches d.b.h. or greater. Healthy and adequate regeneration is another vital forest component that must be monitored as the forests face mounting pressures including browse, climate change, and invasive species such as earthworms, plants, and insects.

Tree Mortality

Background

Mortality can be caused by insects, disease, adverse weather, natural successional processes, competition, fire, old age, and human or animal activity; most often, mortality is the result of a combination of these factors. Tree volume lost as a result of land clearing or harvesting is not included in mortality estimates.

What we found

The average annual mortality of growing-stock trees on Wisconsin's timberland has been increasing since the mid 1960s. However, the rate of increase has slowed since 1996 (Fig. 55). The average annual mortality for all species in 2014 is approximately 233 million cubic feet, a considerable increase over the 2009 inventory.

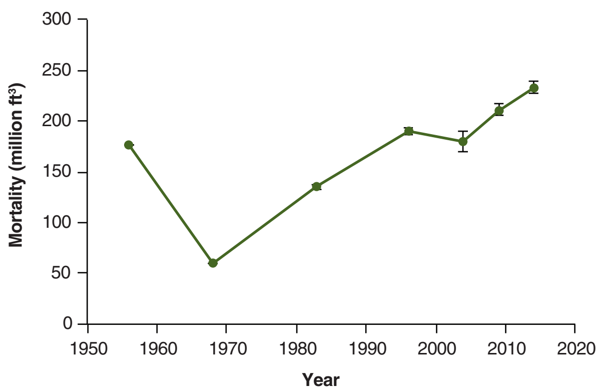


Figure 55.—Average annual mortality of growing-stock trees on timberland by year. Error bars show 68 percent confidence interval.

Of the 10 most voluminous species, quaking aspen, bigtooth aspen, red maple, northern red oak, and basswood, have the highest annual mortality volume in 2014. Quaking aspen mortality is over 53 million cubic feet per year, substantially higher than in 2009 (Fig. 56).

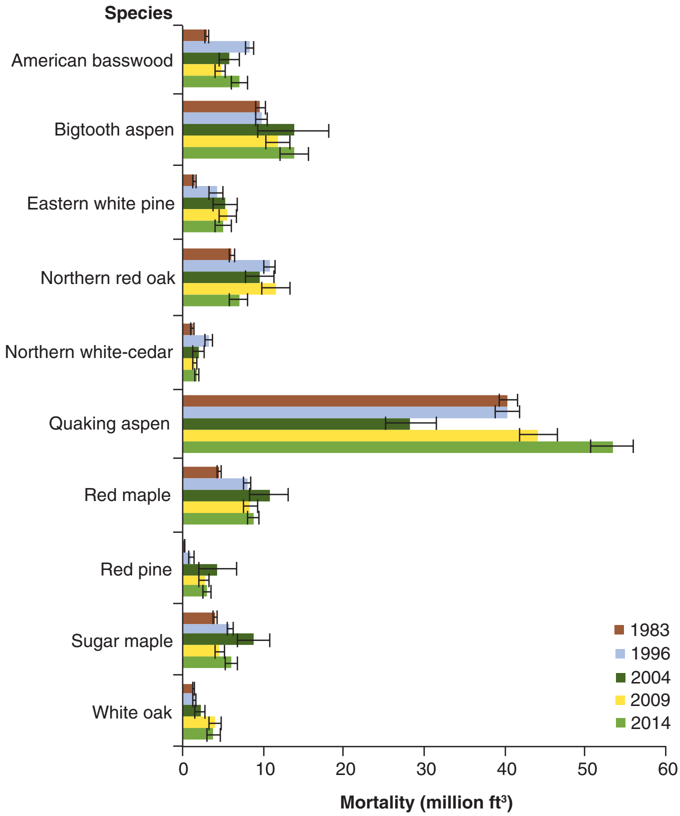


Figure 56.—Average annual mortality of growing stock on timberland for the 10 most voluminous species by year, Wisconsin. Error bars show 68 percent confidence interval.

On timberland, the average annual mortality as a percentage of total growing-stock volume averages just over 1 percent for all species. Quaking aspen (3.2 percent) and bigtooth aspen (2.1 percent) have the highest mortality-to-volume ratio among the 10 most voluminous species. Considering only the species of interest from Figure 56, red pine, sugar maple, northern white-cedar, and eastern white pine have mortality-to-volume ratios under 0.3 percent, the lowest in the group (Fig. 57).

The average annual mortality rate of growing-stock trees on timberland as a percentage of growing-stock volume is fairly consistent across landowner groups. The highest mortality rate is for National Forest land at 1.13 percent and lowest for private lands at 1.07 percent. The State and county lands are at 1.10 percent.

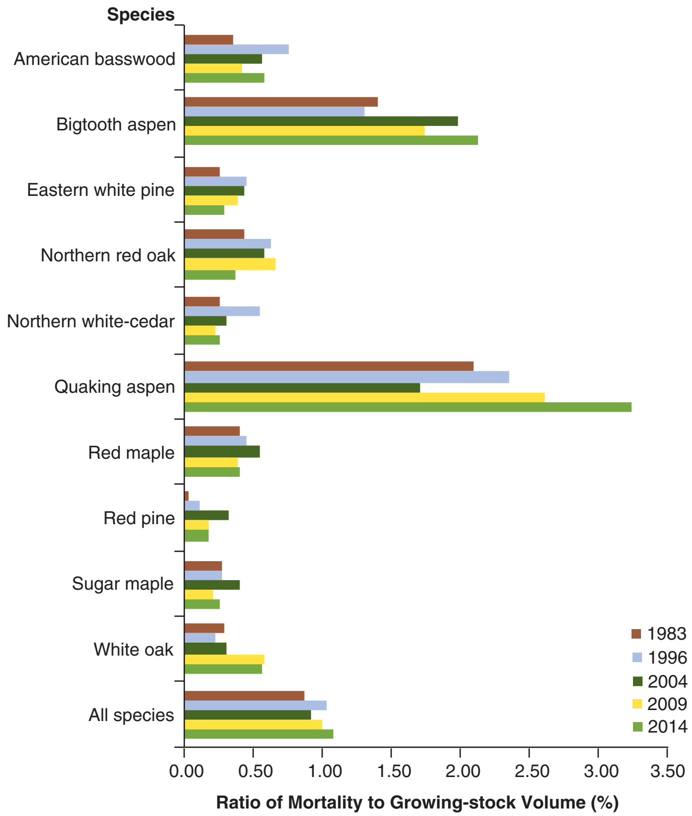


Figure 57.—Ratio of mortality to growing-stock volume on timberland for select species by year, Wisconsin.

Sugar maple, red maple, and aspen account for one-third of all growing-stock volume in Wisconsin's forests. Maples, however, are increasing in volume while aspens have been declining. Average annual mortality for maple species generally hasn't changed a lot since 1996, while average annual mortality for aspen is much higher and has risen considerably since 2004. The percentage mortality is 7 to 10 times higher for aspens than for maples.

The volume of aspen has decreased steadily since 1983, probably a result of natural forest succession, mortality, and high levels of removals. The ratio of mortality/removals to growth is greater than 100 percent, meaning more aspen is dying and being harvested than is being replaced by growth.

What this means

Tree mortality across Wisconsin continues to increase, but the rate of increase may be slowing. Mortality is a natural process in forest stands as they develop and changes over time from early successional forests to longer-lived species in climax communities. Quaking aspen and bigtooth aspen are short-lived pioneer species that colonize openings, grow quickly, and then senesce as the shade-tolerant, longer-lived species grow underneath. For this reason, it is not surprising that these species have the highest mortality rates among the top 10 commercially important species in Wisconsin. Tree mortality is an important component of forest processes and of overall forest health. However, there is concern for aspen since mortality and removals are exceeding annual growth which could present a problem in the future if this trend continues.

Tree Removals

Background

Trees cut by harvesting or land clearing are considered removals. Trees are removed from timberland for a variety of reasons. Changes in the quantity and species of timber removed can affect land use as well as future species composition. In addition, the quality or grade of trees removed affects the future availability of high quality sawtimber. Because removals are generally observed on a limited number of plots, the estimates for removals show greater variance than those for growth, mortality, or area.

What we found

Removals of growing-stock and sawtimber increased after 1983 but have remained steady since 1996 (Fig. 58). However, the percentage of volume that was removed decreased after 2004 as removals trended down and volume increased substantially (Fig. 59).

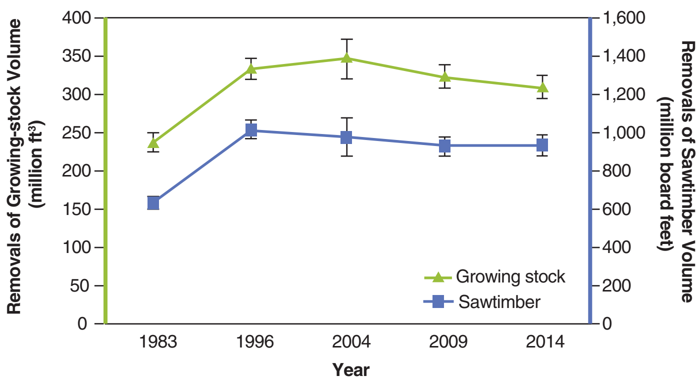


Figure 58.—Removals of growing stock (left axis) and sawtimber (right axis) by year. Error bars represent the 68 percent confidence interval.

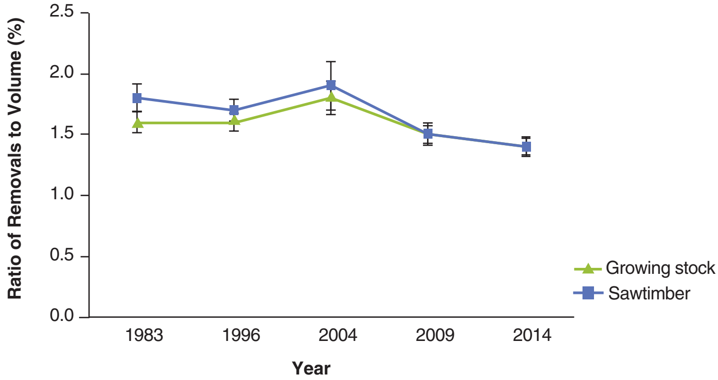


Figure 59.—The ratio of removals to volume for growing stock and sawtimber on timberland by year, Wisconsin. Error bars represent the 68 percent confidence interval.

Quaking aspen and red pine remained the species with the largest volume of growing-stock and sawtimber removals followed by red maple, sugar maple, bigtooth aspen, and northern red oak (Figs. 60A, 60B). Since 2004, there has been an increase in growing-stock removals of red pine (130 percent), black oak (79 percent), and northern pin oak (108 percent). Decreases in removals of other species, such as quaking aspen, sugar maple, northern red oak, eastern white pine, paper birch, jack pine, and white oak, have all been over 20 percent.

Removing trees can have a long-term or even lasting effect on species composition and land use. For instance, after harvesting, timberland is more likely to change forest type or convert to nonforest. Stands that were harvested between the 2009 and 2014 inventories were 53 percent more likely to convert to nonforest after harvest and 25 percent more likely to change forest types than stands that were not harvested (Fig. 61). The aspen/birch forest-type group shows a much higher rate of conversion to nonforest after harvest (5 percent of acreage) compared to nonharvested stands (1 percent of acreage).

Removals of high quality sawtimber can affect future supply. The volume of high grade sawtimber (grades 1 and 2) has increased 28 percent since 2007 while the volume of the lower grades (grades 3, 4, and 5) has remained about the same (Fig. 62A). However removals of high grade timber have decreased 26 percent while removals of lower grades have increased 14 percent (Fig. 62B). This suggests that the volume of high quality sawtimber is increasing and lower grade sawtimber is being harvested more than the higher grades.

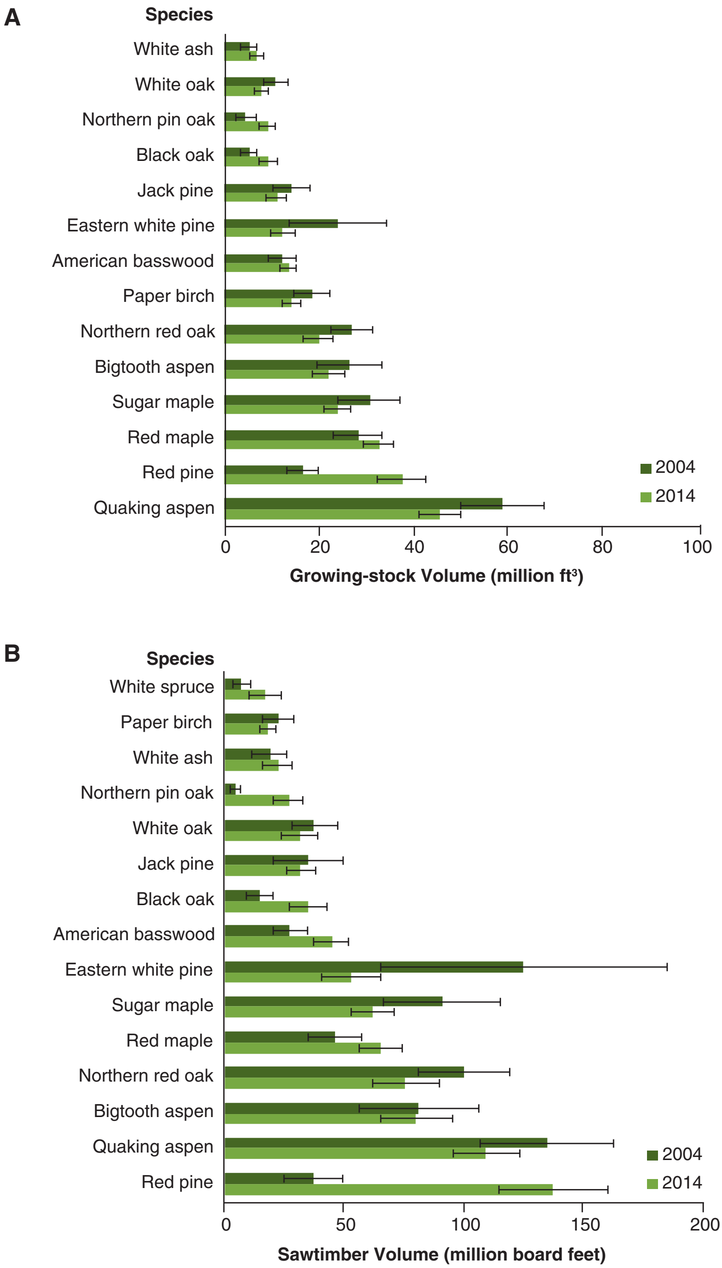


Figure 60.—Volume of removals of growing-stock (A) and sawtimber (B) for select species, Wisconsin, 2014. Error bars represent the 68 percent confidence interval.

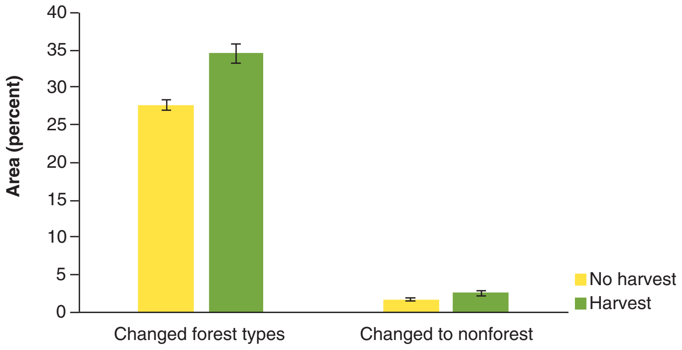


Figure 61.—The percentage of area that changed forest type or changed to nonforest between 2004 and 2014 by harvest category. Error bars represent the 68 percent confidence interval.

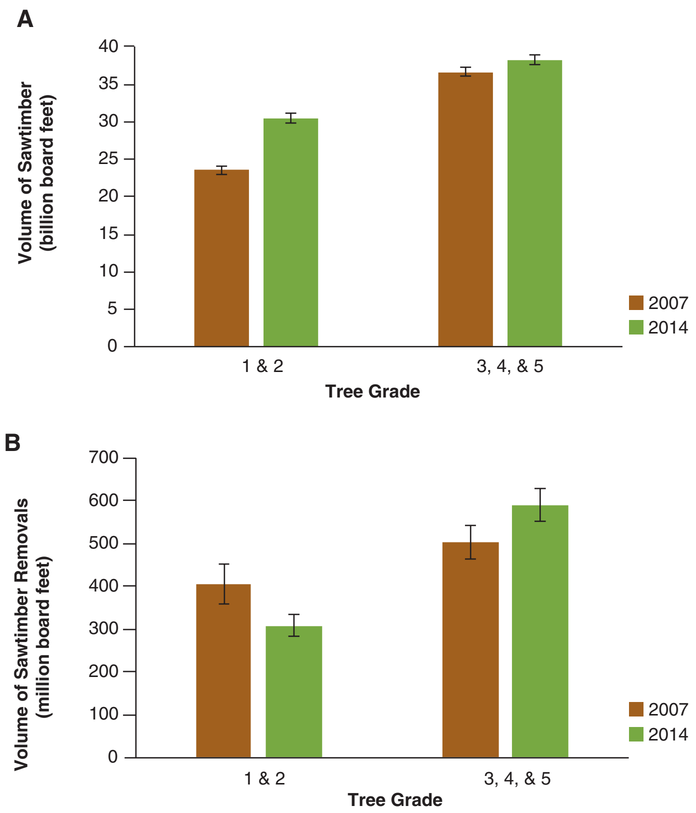
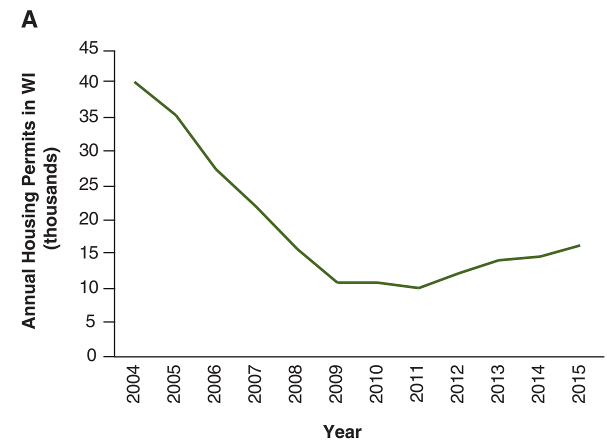


Figure 62.—The volume of sawtimber on forest land by grade category and year (A) and volume of removals of sawtimber on forest land (B) by grade category and year, Wisconsin. Error bars represent the 68 percent confidence interval.

What this means

Tree removals have remained unchanged in the last 10 years despite increasing volume. In addition, removals of high grade sawtimber have decreased in the last 7 years while removals of low grade timber have increased. One possible explanation is the fall in demand for lumber driven by the economic downturn at the end of 2008 and the subsequent decrease in housing construction and other wood-based manufacturing. Housing permits hit a low in 2009 at the beginning of the economic recession and began to recover in 2012 (Fig. 63A). Sawtimber prices are affected by demand from home construction and manufacturing and are reflected in harvesting activity. Sawtimber prices for major sawtimber species bottomed out in 2009 and began to recover in 2012 (Fig. 63B). If this trend continues, we should see an increasing demand for timber and a subsequent rise in tree removals.



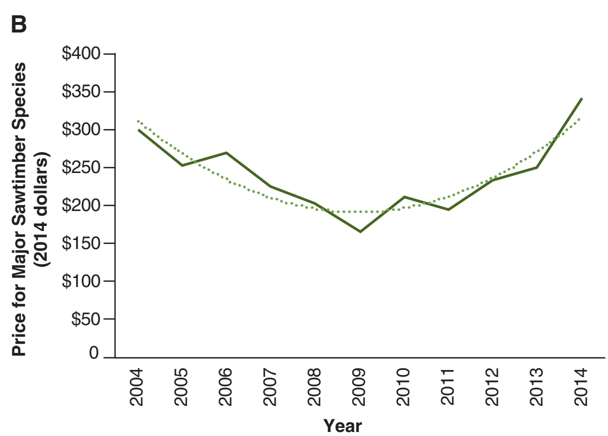


Figure 63.—Number of annual housing permits issued in Wisconsin (A) and price trends of major sawtimber species (B).

Growth-to-Removals Ratio

Background

A primary measure of forest sustainability is the net annual growth-to-removals (G/R) ratio. The G/R ratio is annual net growth divided by removals where net growth is equal to gross growth minus mortality. A ratio greater than 1.0 indicates that net annual growth of the species exceeds annual removals and this removal rate is sustainable. A ratio less than 1.0 indicates that growth is less than removals and this species will not be sustained if removals continue at this level over time.

What we found

The annual G/R ratio of growing-stock trees on Wisconsin's timberland fluctuated from 1956 to 2014, varying from about 1.3 to 2.2 (Fig. 64). The annual G/R ratio for all species in 2014 is 2.22. Among the top 10 species by volume, bigtooth aspen is the only species to have a G/R ratio less than 1.0 (0.90) (Fig. 65). Species with G/R ratio greater than 3.0 are northern white-cedar (8.44), eastern white pine (6.68), and northern red oak (3.05).

The annual G/R ratio of growing-stock trees on timberland varies by landowner class. The ratio is highest for Federal lands (3.11), followed by private landowners (2.48), State (2.27), and county and other local governments (1.36). The G/R ratios for Federal, State, and county and local governments have decreased since 2009 (4.7, 2.8, and 1.5 in 2009, respectively), while the ratio increased on privately held lands (1.9 in 2009).

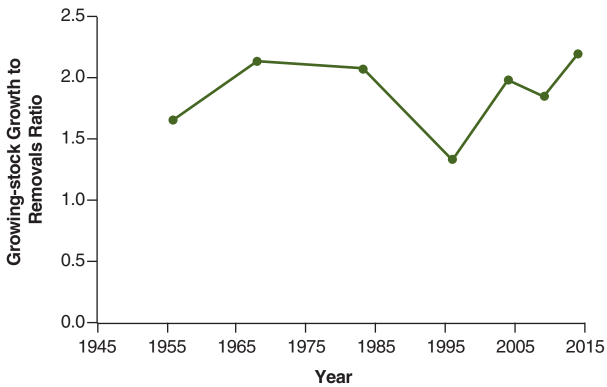


Figure 64.—Ratio of growth–to-removals (G/R) of growing stock on Wisconsin timberland by year.

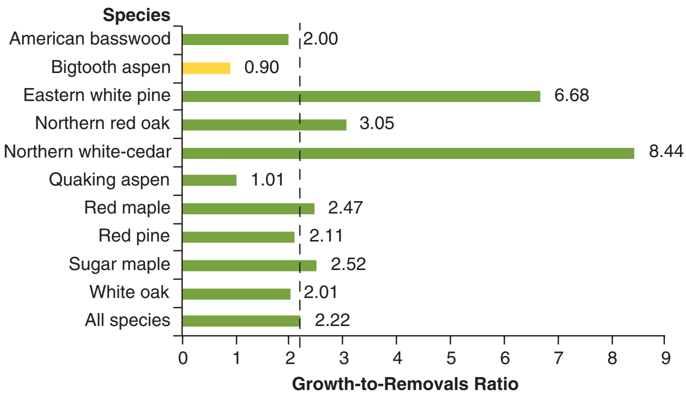


Figure 65.—Growth-to removals ratio for the 10 most voluminous tree species of growing-stock trees, Wisconsin, 2014.

What this means

The statewide G/R ratio of 2.2 in 2014 confirms that net annual growth exceeded removals and is an indicator that harvest and land cover change removals are generally sustainable if continued at this rate. The G/R ratio increased from 2009 to 2014 (1.8 to 2.2), due to a 12 percent increase in growth and a 6 percent decrease in removals. Both quaking aspen and bigtooth aspen have high removal to volume ratios. Quaking aspen also has seen its G/R ratio increase (0.95 to 1.01 between 2009 and 2014) due to increasing growth and decreasing harvest. With quaking and bigtooth aspen, high mortality rates reduce their net growth values. As a result, current aspen harvest levels are only marginally sustainable over the long term. However, aspen harvest levels have been declining and will probably continue to decline as a result of global competition in the paper and pulp industries and the downturn in the economy. As noted previously, aspen are short-lived, early successional species that will be replaced by later successional forest types over time regardless of harvest intensity. Of the three components of change (growth, removals, and mortality), removals are the most directly tied to human activity and as a result are the most responsive to changing economic conditions.

G/R ratios for different ownership types have been changing. Over the last several years, many industrial lands have changed hands, some staying in industrial ownership and some going to other ownership classes. This may have led to lower harvest removals on lands that are no longer in industrial ownership and led to lower overall harvest removals on private lands.

Wildlife Value

Background

All stages of forest development provide habitat for wildlife and plant species that depend on forests at some point in their lives. As forests mature, certain stages of forest will become less common across the landscape as others become more common. In addition, certain types of forests or species dominance will fade as the canopy closes and sunlight-demanding or early successional species are replaced by shade tolerant ones. In the absence of natural disturbance, harvesting and artificial regeneration are required to maintain young forests in the landscape. If left mostly undisturbed, mature or middle-aged stands will begin to show the characteristics of old growth. As large and old trees die, small trees will fill gaps in the canopy created by these trees. Saplings that would normally be restricted to the understory by an unbroken canopy are now released to grow in these gaps. In addition, coarse woody debris will accumulate as large trees fall and slowly decay.

What we found

Forests are becoming more diverse. Areas in very young (<21 years old) and very old (>100 years old) forest stands have increased for the first time since 1996 (Fig. 66). The areas of small diameter and large diameter stands have increased as well (Fig. 67). Acreage in small diameter (seedling/sapling) stands is beginning to increase for the first time in decades and, with the exclusion of the aspen type which has been declining, this increase was noteworthy in 2014. Since 2004, there has been a 25 percent increase in large diameter stands as well.

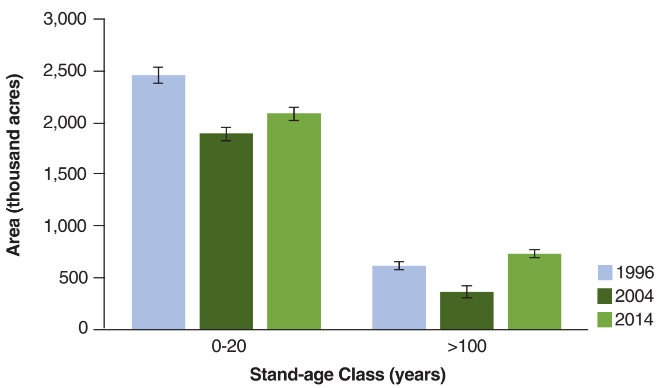


Figure 66.—Timberland area of young (0-20 years) and old (>100 years) forests by inventory year. Error bars show the 68 percent confidence interval.

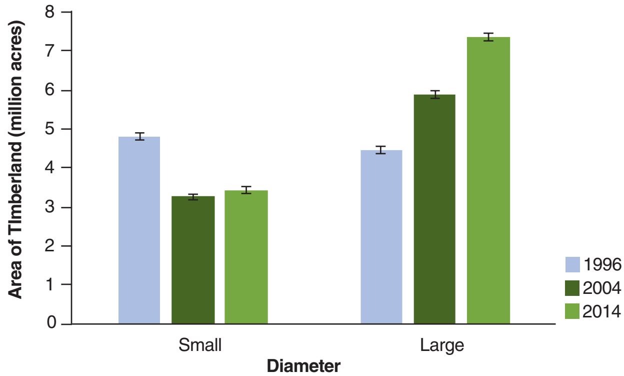


Figure 67.—Timberland area of small diameter and large diameter stands by year, Wisconsin. Error bars show the 68 percent confidence interval.

Older stands are becoming diverse as characteristics of old growth develop in stands over 80 years old. These characteristics include larger average tree diameter, a greater number of large snags (Fig. 68A), an increase of saplings in the canopy (Fig. 68B), and an increase in coarse woody debris (Fig. 68C). The number of large snags (>17 inches d.b.h.) increased 62 percent after 2009 but only in stands over 80 years old. There have been notable increases in the number of canopy saplings in both 2009 and 2014 but only in stands over 80 years old. In addition, the volume of coarse woody debris has doubled in stands over 80 years old but remained unchanged or decreased in younger stands.

Early successional species such as aspen, jack pine, and paper birch are experiencing higher mortality and lower regeneration. These species often depend on major disturbances to regenerate and consequently, they are slowly disappearing as late successional forests increasingly dominate. Areas in aspen, jack pine, and paper birch forest types have decreased 15 percent since 1996 due primarily to a 31 percent decrease in area of small diameter stands (Fig. 69).

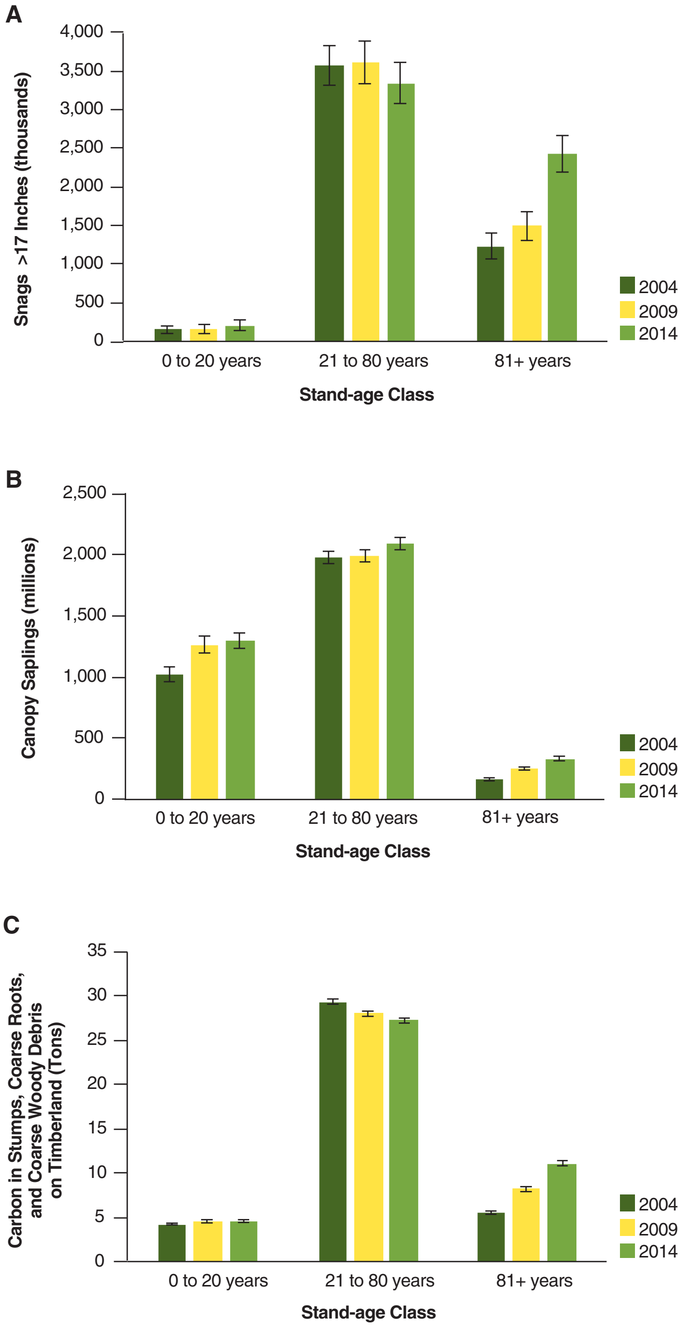


Figure 68.—The number of large (>17 inches) snags (A), canopy saplings (B), and amount of carbon in coarse woody debris, stumps, and roots (C) by stand age class and year, Wisconsin. Error bars show the 68 percent confidence interval.

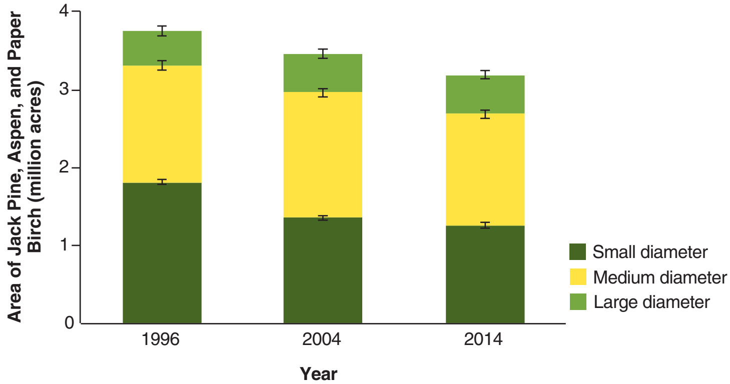


Figure 69.—Area of early successional forest types (jack pine, aspen, and paper birch) by stand-size class and year, Wisconsin. Error bars show the 68 percent confidence interval.

What this means

Early successional cover types such as aspen and jack pine have been declining, probably due to high levels of removal, mortality, succession, changing disturbance regimes, and land use. The expansion of areas with older and larger diameter trees indicates a maturing hardwood forest. This generally favors tree species that can regenerate under an existing canopy or shady conditions, such as red maple, and a reduction in early successional species like birch, aspen, and jack pine, which require timber harvesting or other disturbances to regenerate successfully. Overall, Wisconsin's forest land is becoming more diverse with regard to age class and size class. As acreage of younger and older stands increases, this may help support a diverse array of wildlife that depend on various stages of stand development.

Acreage of old forest and large diameter trees is increasing and, as would be expected, these older stands are developing more structural complexity such as increased snags and coarse woody debris. These structural characteristics provide important habitat for a variety of wildlife. However, these structural characteristics do not show comparable increases in younger stands. This may be due to the fact that young trees are healthier and less likely to become snags large enough to be useful as wildlife habitat. In addition, past harvesting practices may not have emphasized retention of snags and coarse woody debris as a management objective. As a result, the young stands that replaced the old may be lacking this structural diversity.

Standing Dead Trees

Background

Standing dead trees provide critical habitat components for many forest associated wildlife species. Standing dead trees that are large enough to meet habitat requirements for wildlife are referred to as snags. Several species of greatest conservation need (SGCN) in Wisconsin utilize snags and/or cavity trees. Some examples include northern flying squirrel (*Glaucomys sabrinus*), red-headed woodpecker (*Melanerpes erythrocephalus*), black-backed woodpecker (*Picoides arcticus*), northern long-eared bat (*Myotis septentrionalis*), and silver-haired bat (*Lasionycteris noctivagans*) (Wisconsin Department of Natural Resources 2015b). Bat species prefer large, spreading, snags with the bark intact. In addition, many of the more common forest wildlife species including eastern gray squirrel (*Sciurus carolinensis*) and raccoon (*Procyon lotor*), benefit from the presence of large trees, cavity trees, and snags.

Snag size is important. While small snags are useful for birds like boreal chickadees (*Poecile hudsonicus*) and prothonotary warbler (*Protonotaria citrea*) (species of special concern in Wisconsin), many large birds require bigger snags for nesting sites as well as foraging. Woodpeckers, such as the pileated (*Dryocopus pileatus*) or red-headed (*Melanerpes erythrocephalus*) woodpecker, can require snags over 17 inches d.b.h. Large snags not only last longer they often have a rotted heartwood cavity which provides ideal nesting habitat. Large snags afford more space for large broods and better thermal insulation for over-wintering birds and mammals. These large trees can also provide perches for birds of prey such as eagles and ospreys.

The species of snag is also important. Softwood snags can provide easy forage for insectivorous birds and softer heartwood for cavity formation. Some softwood snags, such as eastern white pine and eastern hemlock, can last a very long time. Hardwood snags of species such as oak and sugar maple can reach very large sizes and provide durable nesting and den sites which can be used year after year.

A snag density of at least three 12-inch d.b.h. snags per acre and one 15-inch d.b.h. snag per acre has been suggested in the Northeast in order to provide habitat for woodpeckers, flickers, and several bat and owl species (Connecticut Department of Energy and Environmental Protection 2015). Scott and Oldemeyer (1983), working in ponderosa pine forests, suggest maintaining at least two or three snags per acre over 19 inches d.b.h. for large cavity nesters such as the pileated woodpecker.

What we found

There are over 248 million snags (5 inches d.b.h or greater) in Wisconsin's forests and 64 percent of all timberland (10 million acres) has at least one snag per acre. Ninety-one percent of snags are less than 13 inches in diameter.

There are nearly 6 million snags over 17 inches in diameter. This number has increased 20 percent in the last 10 years and 13 percent since 2009 (Fig. 70). About one-third are oaks with fewer aspen, eastern white pine, and American elm. Of these large snags, about half have been standing for at least 5 years. These long-standing snags are mostly eastern white pine, oak, or eastern hemlock.

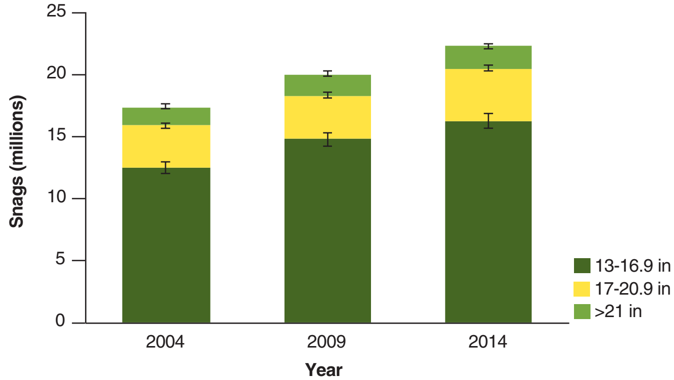


Figure 70.—Number of snags on timberland by diameter class and year, Wisconsin. Error bars show the 68 percent confidence interval.

Between 2004 and 2014, there was a meaningful increase in the number of snags of several species (Fig. 71). These included quaking aspen, balsam fir, American elm, northern pin oak, tamarack, slippery elm, white spruce, and bitternut hickory. Many of these species were negatively affected by drought in northern Wisconsin from 2005 to 2009 (Fig. 72). Mortality increased 57 percent for these species between 2004 and 2014, with 68 percent of this increase occurring between 2004 and 2009. It is important to remember that the maps of Figure 72 represent the average of each 5-year span and that each year within the time frame is independent.

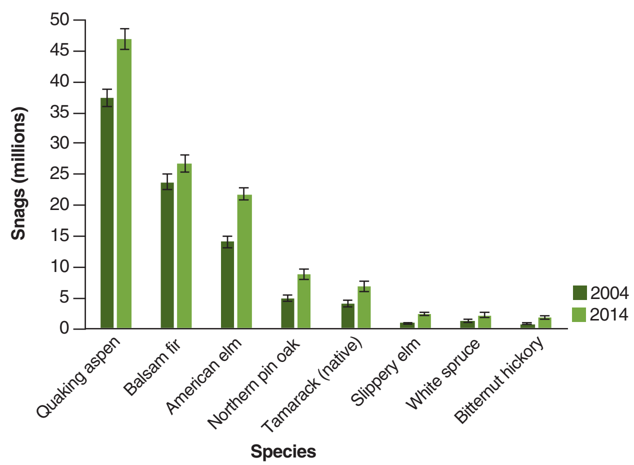
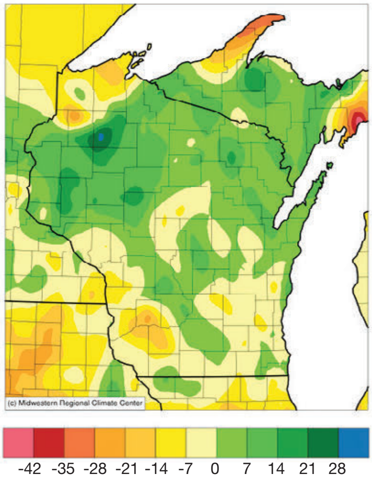


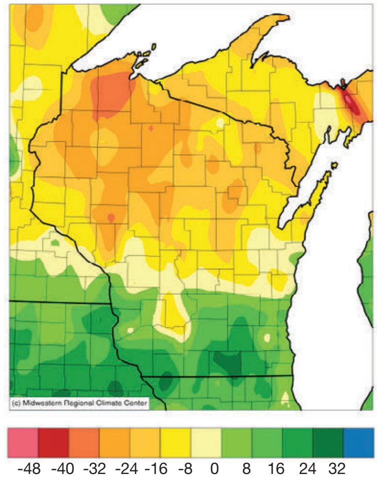
Figure 71.—Species showing a significant increase in the number of standing dead trees by inventory year. Error bars show the 68 percent confidence interval.

Accumulated Precipitation (in): Departure from 1981-2010 Normals

January 01, 2000 to December 31, 2004



January 01, 2005 to December 31, 2009



January 01, 2010 to December 31, 2014

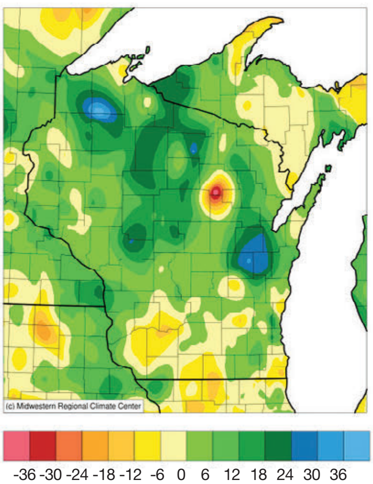


Figure 72.—Areas of Wisconsin that experienced a departure from normal cumulative precipitation by year.

Source: Midwestern Regional Climate Center, http://mrcc.isws.illinois.edu/CLIMATE/welcome.jsp (accessed September 2015).

In 2014, 1.3 million acres (7.8 percent) of timberland meet the minimum snag density for large cavity dwellers (at least one snag per acre over 15 inches d.b.h. and three snags per acre over 12 inches d.b.h.). This acreage is a small percentage of the total but is increasing every year. About 40 percent of this timberland is oak/hickory forest type and 30 percent is maple/beech/birch.

In Wisconsin, the number of large snags is increasing and the amount of timberland with at least one very large snag per acre (over 19 inches in diameter) is increasing as well. There are currently 420,000 acres (2.5 percent of all timberland) with at least one very large snag per acre.

What this means

Standing dead trees or snags are important sources of food and habitat for many birds and mammals of all sizes. Large, older snags are much rarer but provide crucial nesting and perch sites for large birds, many of which are species of special concern or threatened in Wisconsin, including the red-headed woodpecker, the black-backed woodpecker, the long-eared owl, the common goldeneye, and the barn owl. Most of these birds require cavity trees greater than 12 to 15 inches d.b.h.

Very large snags (19 inches d.b.h. or larger) are particularly valuable, accommodating a variety of wildlife. Larger wildlife species require larger trees, while smaller species can still use the large snags. Additionally, large cavity trees tend to remain available for a longer time. Some long-lived wildlife species will use this resource seasonally over a period of years and some species will use the same resource across generations.

The Urban Forest

Background

The urban forest (trees in and around communities) provides numerous benefits to the health of the surrounding environment and those who inhabit it. These benefits include energy reduction, pollution removal, and carbon sequestration. Trees in and immediately surrounding Wisconsin's urban areas provide annual functional values greater than $150 million: $26.8 million in carbon sequestration, $47.6 million in pollution removal (ozone, particulate matter, nitrous oxide, etc.), and $78.9 million in reduced building energy use (Nowak et al. 2017). These values tend to rise with increased size and number of healthy trees. Sustaining forest health and longevity is critical to sustaining these benefits through time.

Until recently, relatively little was known about Wisconsin's urban forests. In 2002, a partnership between the U.S. Forest Service and the Wisconsin Department of Natural Resources resulted in a pilot study and inventory of the composition and condition of the State's urban forests and the benefits they provide. The inventory was repeated in 2012, but for a different area and sampling design. The area sampled changed as 1) urban area increased between 2002 and 2012; and 2) the 2012 study focused solely on plots located in urban areas that did not meet the traditional FIA definition of forest, as opposed to the 2002 study that sampled all plots in urban areas, regardless of whether or not they fit the FIA definition of forest. The sampling design changed with the inclusion of microplots in the 2012 inventory that were absent in the 2002 pilot study. These four microplots are located at 90, 180, 270, and 360 degrees from plot center and have a 6.8 foot radius. The microplots are where the saplings are sampled.

What we found

The 2012 study collected data from 185 urban field plots. Urban areas were delimited using the 2000 U.S. Census definition of urban land (U.S. Census Bureau 2015). The inventory included trees on all land uses (e.g., residential, commercial/transportation). Residential was the dominant land use, covering 46.3 percent of urban areas (Table 1). The sampled area contains an estimated 42.8 million trees, with an estimated total structural/replacement value of $19.3 billion, including $507 million in carbon storage value (Wisconsin Department of Natural Resources 2016). The average number of trees per acre in Wisconsin's urban areas is 45.9, and residential land had the highest tree density (68.6 trees/acre) (Fig. 73). Average tree size is 5.4 inches d.b.h. and of the 65 different species found in the study, the most common are common lilac, northern white-cedar, and apple species (Fig. 74).

Table 1.—Land use distribution based on urban plots, Wisconsin, 2012

Land use	Area	
	acres	*percent*
Residential	432,000	46.3
Commercial/transportation	170,000	18.2
Institutional/parks	137,000	14.7
Agriculture/other	88,000	9.5
Forest	74,000	7.9
Wetland	32,000	3.4
Total Urban	933,000	100

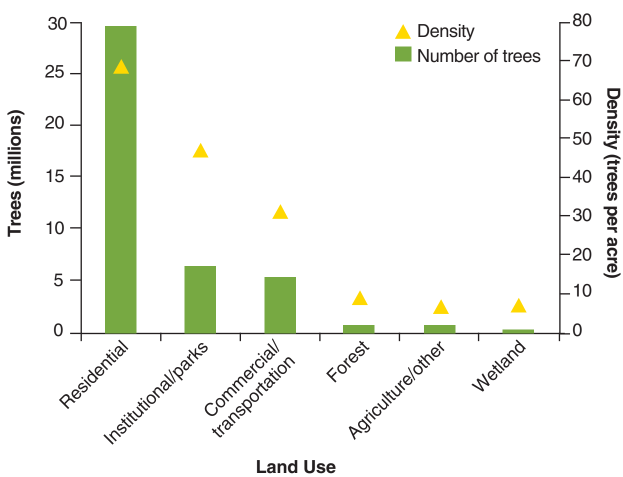


Figure 73.—Urban tree population and density by land use type, Wisconsin, 2012.

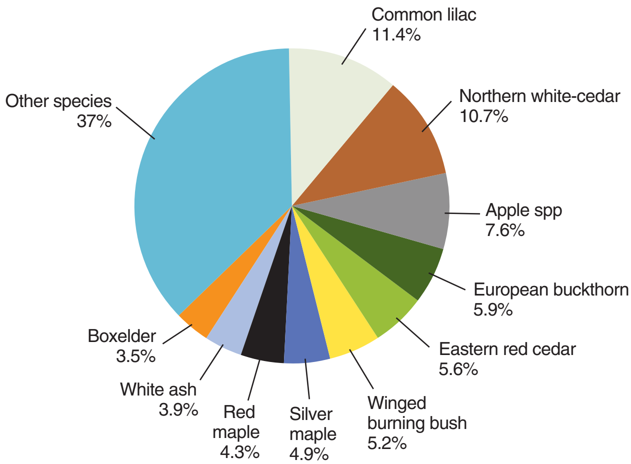


Figure 74.—Urban woody species composition, Wisconsin, 2012.

Crown condition and damage indicated the urban forests of Wisconsin generally are healthy and vigorous, with 1.1 percent of trees classified as dead. The most common tree damage is trunk/bark inclusion (32.8 percent of all trees), cankers or signs of decay (19.5 percent), and wounds or cracks (5.3 percent).

Urban forests are a mix of native tree species that were planted, seeded in, or existed prior to the development of the city and exotic species that were introduced by residents or other means. Fourteen tree species observed are classified as invasive in Wisconsin (Wisconsin Department of Natural Resources 2015a) and comprise about 20 percent of the population (8.4 million trees). The most common invasive species are common buckthorn, winged burning bush, and Norway maple (Table 2).

Table 2.—Invasive urban tree species in Wisconsin, 2012

Scientific name	Common name	Percent of the Urban Population	Number of Trees
Rhamnus cathartica	common buckthorn	5.9	2,545,755
Euonymus alata	winged burning bush	5.2	2,223,535
Acer platanoides	Norway maple	2.5	1,082,477
Pinus sylvestris	Scotch pine	2.5	1,052,645
Ulmus pumila	Siberian elm	2.1	893,236
Morus alba	white mulberry	0.7	309,064
Pyrus calleryana	Callery pear	0.4	189,442
Robinia pseudoacacia	black locust	0.2	92,667
Elaeagnus angustifolia	Russian olive	0.1	56,193
		19.6	8,445,014

The urban forest is vulnerable to pests, particularly emerald ash borer (EAB; *Agrilus planipennis*), which poses a risk to the ash of Wisconsin's urban forests. There are an estimated 3.2 million ash trees larger than 1 inch d.b.h. in urban areas with an associated structural/replacement value of $2.2 billion. These are conservative estimates that do not consider the cost to remove dead trees and stumps, nor the lost environmental, social, and economic services provided by the trees.

Ninety-one remeasured plots were used to estimate change in urban trees between 2002 and 2012. This change analysis was only conducted on urban plots for trees greater than 5 inches in d.b.h. because of differences in sampling design between the two inventories. Of the 91 plots, 67 plots had trees greater than 5 inches in 2002.

The average number of trees greater than 5 inches d.b.h. dropped by 2.6 trees per plot. Analyzing change by species was restricted due to limited sample size for individual species (e.g., many species were only measured on one plot). Species that had increases in the number of trees greater than 5 inches were silver maple and species classified as unknown (Table 3). Species with decreases were white ash, Kwanzan cherry, red mulberry, and sugar maple (Table 3).

Table 3.—Species with statistically significant changes in number of trees per plot

Scientific name	Common name	n	Change[a]	Wilcoxon[b] p value	t-test[c] p value
Acer saccharinum	silver maple	9	2.22	0.008*	0.002*
NA	unknown	10	1.5	0.043*	
Acer saccharum	sugar maple	7	-1.43	0.031*	0.008*
Morus rubra	red mulberry	5	-2.6	0.125	0.049*
Prunus serrulata	Kwanzan cherry	3	-4.33	0.25	0.096**
Fraxinus americana	white ash	10	-5.4	0.062**	

n = number of plots with given species (sample size)
[a] average change in number of trees per plot
[b] Wilcoxon signed rank test
[c] t-test (if species was normally distributed)
* statistically significant difference at alpha = 0.05
** statistically significant difference at alpha = 0.10

As EAB continues to spread in Wisconsin, management decisions and activities of communities and the public are changing because of the actual or anticipated arrival of EAB. While the insect itself likely contributed to the observed per-plot decrease in average number of white ash trees greater than 5 inches d.b.h., preemptive removals of ash by municipalities and private homeowners and replacement with different species likely contributed as well (Table 3). For more information on the statewide effects of EAB, please see the Forest Health Indicators section.

What this means

The urban forests of Wisconsin provide substantial social, economic, human health, and environmental benefits to nearly 4 million people on a daily basis. The trees offer various benefits such as shade (reduce cooling), food (fruit), carbon storage, pollution reduction through sequestration and runoff mitigation, and habitat for various wildlife (e.g., birds and squirrels). The structural and age diversity of the urban forest provides various wildlife benefits and offers habitat and forage for many urban species. The urban forest is a valuable resource that must be conscientiously managed over time to fully realize all of the benefits it provides.

Health Indicators

Firewood. Photo by Christie L. Kurtz, used with permission.

Tree Crown Health and Damage

Background

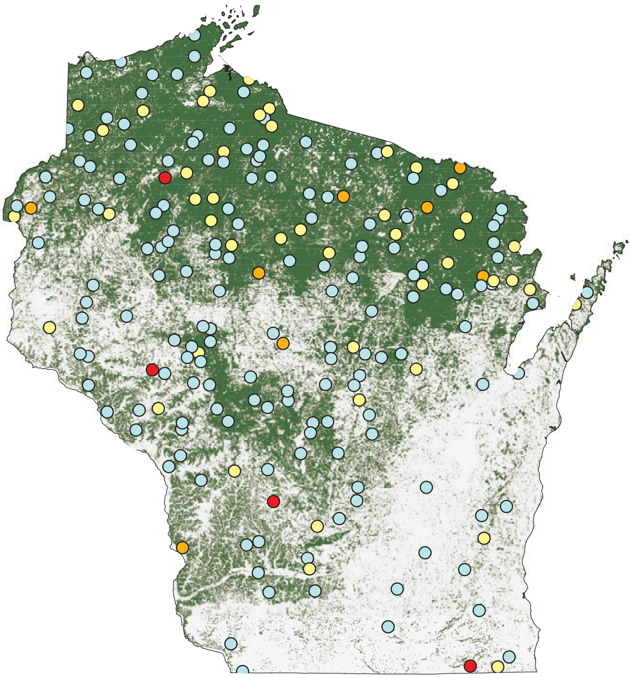
The crown condition of trees is influenced by various biotic and abiotic stressors. Biotic stressors include native or introduced insects, diseases, invasive plant species, and animals. Abiotic stressors include drought, flooding, cold temperatures or freeze injury, nutrient deficiencies, the physical properties of soils that affect moisture and aeration, and toxic pollutants. Crown dieback is collected in the summer on a subset of P2 plots (see Gormanson et al. 2017 for explanation of 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 a 5-inch d.b.h. or greater. Up to two of the following types of damage can be recorded: insect damage, cankers, decay, fire, animal damage, weather, and logging damage. If more than two types of damage are observed, decisions about which two are recorded are based on the relative abundance of the agent prioritized and recorded based on location of the damaging agents (U.S. Forest Service 2010).

What we found

The incidence of poor crown condition is uncommon across Wisconsin with very few plots comprised of trees having greater than 20 percent of the basal area with poor crowns (Fig. 75A). The species with the highest proportion of live basal area containing poor crowns is black ash (9 percent) (Table 4), and plots having relative proportions of black ash with poor crowns are concentrated in the northern part of the State (Fig. 75B). Conversely, all other species have a very low occurrence of poor crowns. Additionally, the proportion of quaking aspen basal area with poor crowns dropped from 20.9 percent in 2009 to 3.1 percent in 2014 (Table 4).

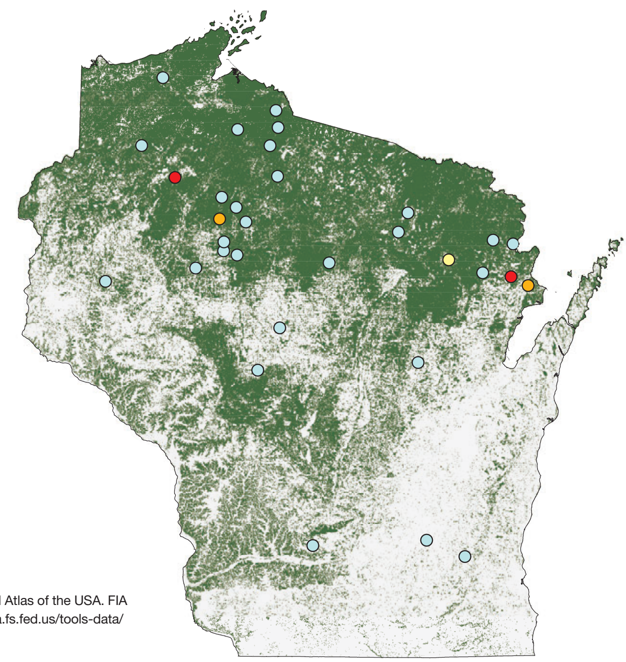
A



Percent of Basal Area with Poor Crowns

- 0
- 1-10
- 11-20
- >20
- Nonforest
- Forest

B



Percent of Basal Area with Poor Crowns

- 0
- 1-10
- 11-20
- >20
- Nonforest
- Forest

Projection: Wisonsin State Plane Central, NAD83.
Sources: U.S. Forest Service, Forest Inventory and Analysis Program, 2009, 2014.
Geographic base data are provided by the National Atlas of the USA. FIA data and tools are available online at http://www.fia.fs.fed.us/tools-data/
Cartography: R.S. Morin. Oct. 2015

Figure 75.—Percentage of live basal area of trees with poor crowns, for all species (A) and black ash (B), Wisconsin, 2014. Plot locations are approximate.

Table 4.—Percentage of live basal area with poor crowns, Wisconsin, 2009 and 2014

Species	Percent of Basal Area with Poor Crowns	
	2009	2014
Red pine	0.3	0.0
Eastern white pine	0.0	0.0
Northern white-cedar	8.7	2.5
Red maple	1.3	3.8
Sugar maple	4.1	0.7
Black ash	8.0	8.6
Quaking aspen	20.9	3.1
White oak	1.4	0.0
Northern red oak	3.4	0.0
American basswood	1.2	0.2

Average crown dieback ranges from less than 1 percent for eastern white pine and red pine to nearly 8 percent for black ash (Table 5). The proportion of the trees that die increases with increasing crown dieback (Fig. 76). Nearly 35 percent of trees with crown dieback greater than 20 percent during the 2009 inventory were dead in the 2014 inventory.

Table 5.—Crown dieback statistics for live trees (>5 inches d.b.h.) on forest land by species, Wisconsin, 2014

Species	Trees	Crown Die Back				
		Mean	SE	Minimum	Median	Maximum
	number	---------------------------- *percent* ----------------------------				
Black ash	184	7.7	1.4163	0	0	99
Quaking aspen	386	2.6	0.4774	0	0	99
Red maple	495	2.5	0.3994	0	0	99
White oak	68	2.4	0.3848	0	0	15
Sugar maple	389	2.3	0.2695	0	0	75
Northern white-cedar	463	1.5	0.2121	0	0	35
American basswood	181	1.5	0.5653	0	0	99
Northern red oak	147	1.2	0.1966	0	0	10
Eastern white pine	213	0.2	0.0871	0	0	15
Red pine	523	0.1	0.0301	0	0	10

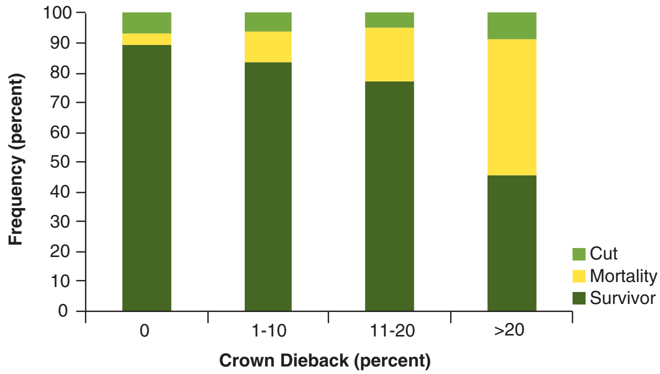


Figure 76.—Crown dieback distribution by tree survivorship for remeasured trees, Wisconsin, 2014.

Damage was recorded on approximately 21 percent of the trees in Wisconsin, but there is considerable variation between species. The most frequent damage on all species is decay (12 percent of trees), but it ranges from 1 percent on red pine to 20 percent on northern white-cedar and red maple. Notably, insect damage is present on more than 15 percent of eastern white pine and sugar maple trees. The occurrence of all other injury types was very low (Fig. 77).

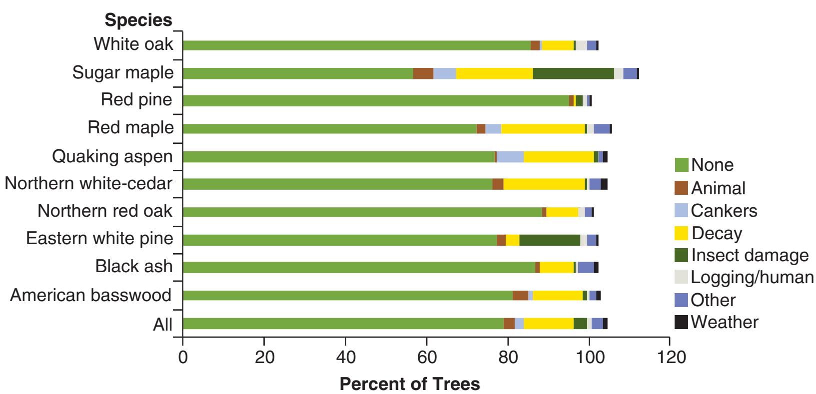


Figure 77.—Percentage of trees with damage, Wisconsin, 2014. Note that columns do not sum to 100 because multiple damages can be recorded on trees.

What this means

The trees of most major species in the forests of Wisconsin are generally in good health. As in most eastern forests, decay is the most commonly observed damage in Wisconsin's forests. This is not unusual given that nearly half of Wisconsin's forests are large diameter stands composed of mature trees. The high occurrence of insect damage on sugar maple trees is likely due to the sugar maple borer (*Glycobius speciosus*), which can cause lumber defects but rarely causes mortality (Hoffard and

Marshall 1978). The high incidence of eastern white pine insect damage is related to field crews' observations of deformed stems likely caused by the native white pine weevil, *Pissodes strobi* (Peck). Although the weevil damage does not typically kill trees, the form and quality of saw logs is impacted as evidenced by the increasing proportion of damaged trees that fall into tree grades 3, 4, and 5 (Fig. 78) (Morin et al. 2016).

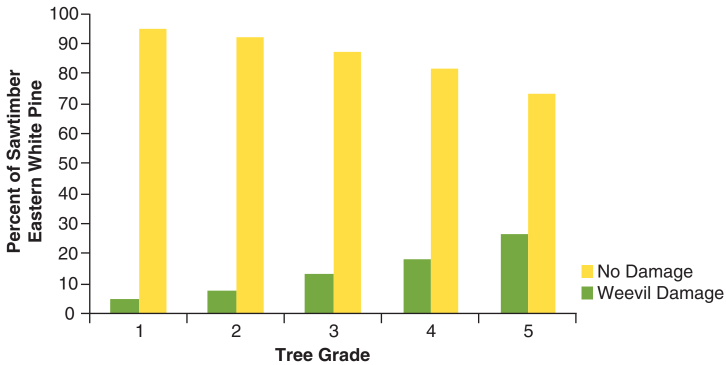


Figure 78.—Percentage of sawtimber-size eastern white pine trees by tree grade and white pine weevil status, Wisconsin, 2014.

The health of tree crowns in American beech, eastern hemlock, and ash species should be monitored closely because of likely future impacts of beech bark disease, hemlock woolly adelgid (*Adelges tsugae*), and emerald ash borer, respectively.

Forest Insects and Diseases

Background

Insects and diseases are a natural part of Wisconsin's forest ecosystem. Impacts by both native and exotic insects and diseases continue to affect forest resources in the State. In addition, environmental factors such as drought and flooding have put even greater pressure on our forests and have contributed to the impacts of insect and diseases.

What we found

Between 2009 and 2014, Wisconsin experienced a number of extreme weather events that aggravated problems caused by pests and diseases. Prolonged flooding in the spring and summer of 2010 added stress to numerous tree species. Drought was a major factor, stressing trees and predisposing them to decline or mortality caused by insects and diseases. The drought of 2012 was severe to extreme in many parts of Wisconsin. In the subsequent years, conditions remained abnormally dry in southern Wisconsin and severe in western counties. Extremely cold conditions in the winter of 2013 and 2014 also impacted some forest tree species. Some forest health problems are directly related to environmental stress, such as tamarack mortality, bur oak dieback, and mortality from repeated defoliation. Other forest health issues, such as annosum root rot, beech bark disease, emerald ash borer (discussed in a separate section), and gypsy moth defoliation are probably not related to environmental stresses.

Annosum Root Rot: Annosum root rot, caused by the fungus, *Heterobasidion irregulare*, causes a decay of the roots and lower stem and often kills infected trees. Annosum root rot is considered one of the most destructive diseases of managed conifer stands in the northern hemisphere. In Wisconsin, red and eastern white pine plantations have been the most severely affected. Other conifer species may also be impacted by this disease. Airborne spores of annosum infect fresh cut stumps usually after a thinning or harvest. Once established in the stump, the fungus spreads to adjacent living trees via grafted root systems, causing a "pocket" of dying trees.

Annosum root rot was first detected in Wisconsin in 1993 in Adams County in central Wisconsin. By 2009, twenty counties in Wisconsin were confirmed with the disease. Between 2009 and 2014, annosum was detected in four additional counties: Taylor and Oconto Counties in 2010, Marinette County in 2011, and Grant County in 2014 (Fig. 79). Once annosum is established in a plantation, it can exist for decades in roots and stumps and continue to spread.

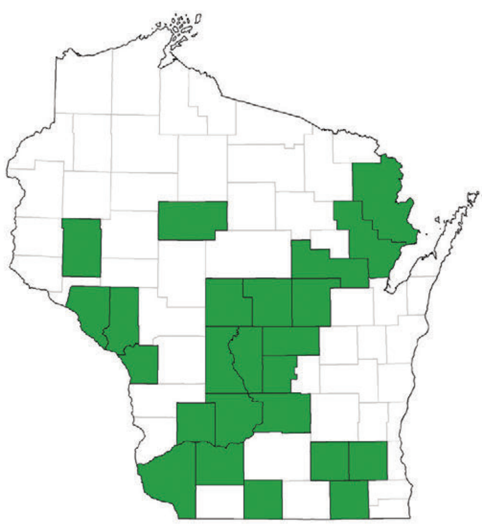


Figure 79.—Counties where annosum root rot has been detected in Wisconsin through 2014.

In Wisconsin, the acreage of conifer plantations that are due for thinning or harvesting has grown in the last two decades, increasing the risk of new infection on untreated stumps. The area in planted red pine over 40 years old has almost tripled since 1996 and increased 50 percent in the last decade (Fig. 80). There are over a half-million acres of pine over 20 years old within 25 miles of a known annosum infection (Fig. 81). This is almost half of all pine acreage in the State over 20 years of age. This land accounts for 1.25 million cubic feet of pine volume that may be threatened by annosum infection.

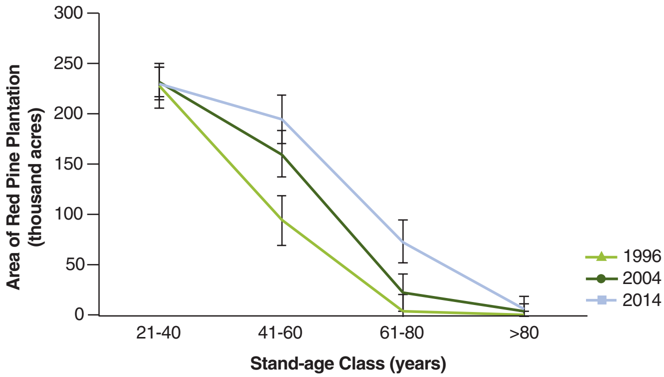


Figure 80.—Area of red pine plantations in Wisconsin by stand age and inventory year. Error bars show the 68 percent confidence interval.

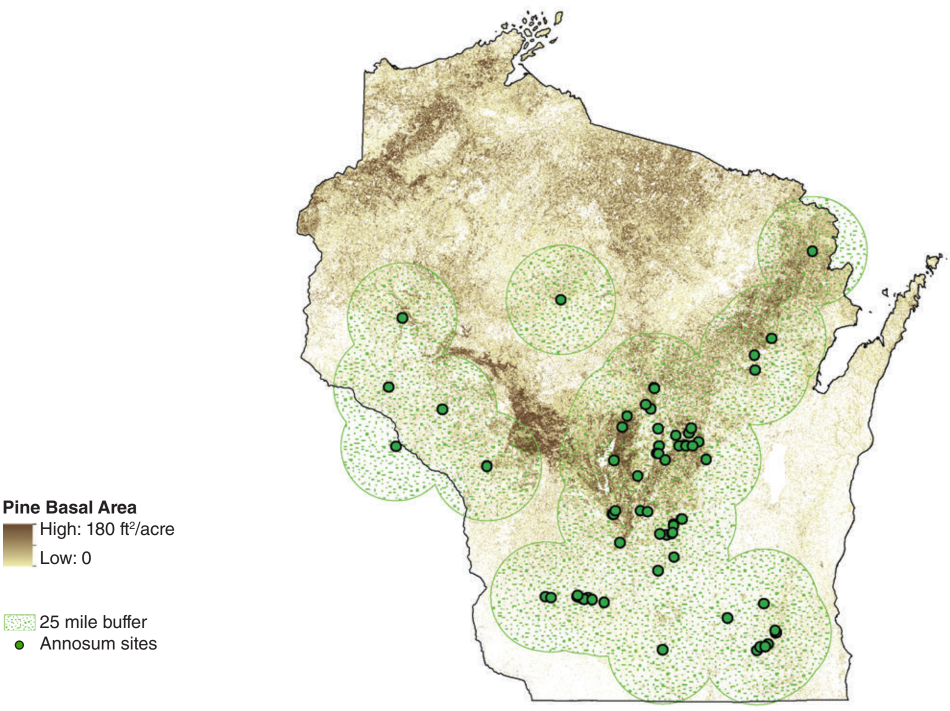


Figure 81.—Annosum infections sites, 25 mile buffer zones around the infection sites, overlying a map of the basal area of pine throughout Wisconsin.

Beech Bark Disease: Beech bark disease, a disease of American beech, is caused by the beech scale insect *Cryptococcus fagisuga* and one of several species of canker-causing fungi in the genus *Neonectria*. Initially trees become heavily infested with cottony scales. This is referred to as the "advancing front." This front is followed by canker infections, often years later, which enter the tree using wounds created by the scale and cause top dieback and mortality. This second front is referred to as the "killing front" where "beech snap" often occurs in which the upper trunk of the beech tree will break.

Beech scale was first detected in 2009 in Door County. Beech scale is now widespread throughout most of the native range of beech in Wisconsin. Surveys in 2014 found that scale populations remained very low in most parts of the native range of beech with the exception of Door County (Fig. 82). Continued expansion of high scale numbers (the advancing front) did continue in Door County with several new areas detected. Localized mortality occurred and some salvage harvesting was undertaken in some areas in Door County. The localized damage area (the killing front), however, did not expand between 2013 and 2014. In Wisconsin, there are an estimated 3 million American beech 5 inches d.b.h. or larger on forest land.

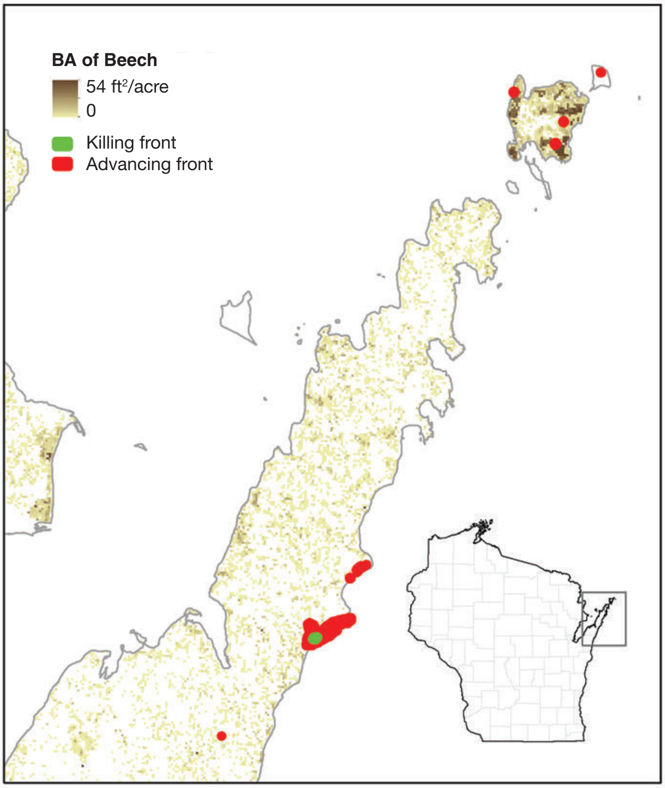


Figure 82.—The killing front and advancing front of beech bark disease in Door County, Wisconsin, 2014.

Bur Oak Dieback and Mortality: Reports and observations of declining and dead bur oak in southern Wisconsin were received periodically between 2009 and 2014. A number of factors appeared to be involved, including Armillaria root rot (*Armillaria* spp.) and two-lined chestnut borer (*Agrilus bilineatus*), both common native organisms of Wisconsin forests.

Bur oak blight has been confirmed in a number of counties and may be playing a small role, along with periodic oak tatters (a leaf disorder) and damaging spring frost injury. Oak wilt has not been considered a major factor and was rarely confirmed as an issue on impacted bur oak at sites visited. The drought of 2012 in southern Wisconsin (Fig. 83) likely caused additional stress and predisposed trees to attack by Armillaria and two-lined chestnut borer, both frequently observed at these sites. FIA data indicates that there was an increase in the ratio of mortality to volume between 2004 and 2014 in southwest, central, and southeast Wisconsin as well as statewide (Fig. 84). Southwest Wisconsin has approximately 29 percent of the volume of bur oak, but experienced 52 percent of the bur oak mortality from 2009 to 2014.

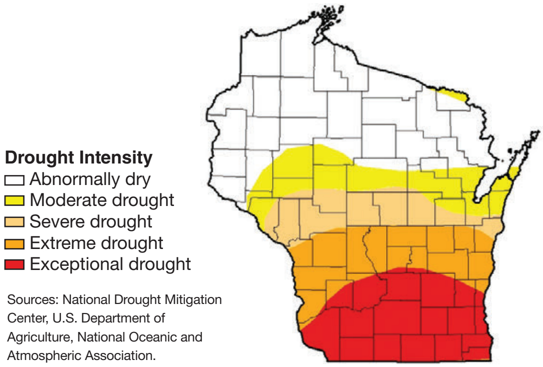


Figure 83.—Long-term drought status as of summer of 2012 in Wisconsin.

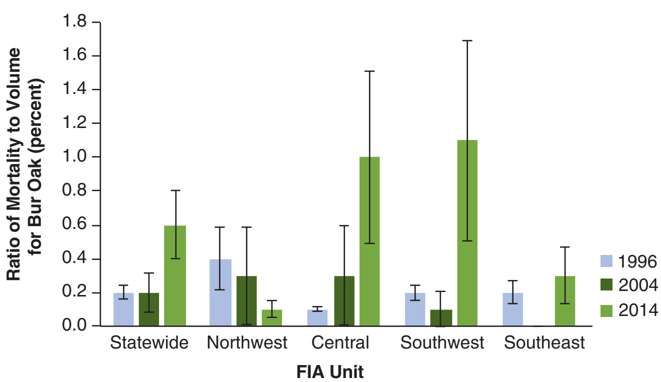


Figure 84.—The ratio of mortality to volume for bur oak in Wisconsin by survey unit and year. Error bars represent the 68 percent confidence interval.

Gypsy Moth: Gypsy moth, *Lymantria dispar*, is a major defoliator of hardwood and conifer forests. The invasive insect was first detected in the eastern part of the State in the mid 1970s. By 1989, gypsy moth had established populations along Wisconsin's eastern shore from Milwaukee to Green Bay. It is currently well established in eastern and central parts of Wisconsin and continues to establish in western parts of the State. It is important for land managers to have accurate maps showing where forest resources will be most at risk to gypsy moth in order to help plan for suppression activities. In Wisconsin, the most abundant preferred species are aspen, birch, and oaks. These species occur in relatively high density throughout the State (Fig. 85). The gypsy moth quarantine includes 50 of Wisconsin's 72 counties, requiring inspection or certification of wood products and outdoor household items before moving them from quarantined areas to nonquarantined areas (WDNR, n.d.). The 2014 gypsy moth quarantine map (Figure 86) shows quarantined counties in the State. Wisconsin's Department of Natural Resources and Department of Agriculture, Trade and Consumer Protection are part of a national gypsy moth quarantine program to limit the rate of western and southern establishment of gypsy moth in the northeast United States.

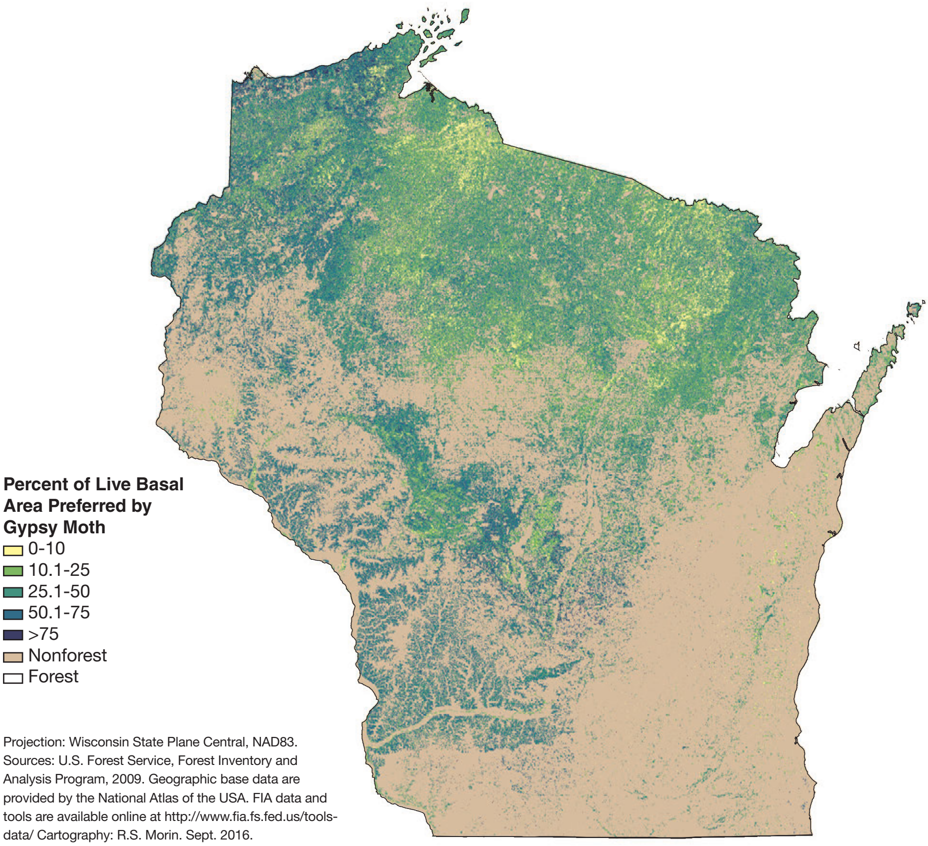


Figure 85.—Percent of live basal area of tree species preferred by gypsy moth, Wisconsin, 2009.

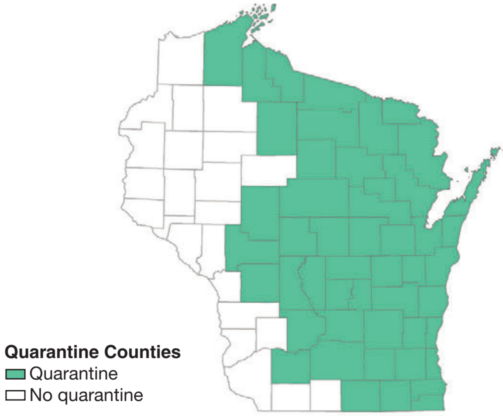


Figure 86.—Wisconsin counties under quarantine for gypsy moth, 2014.

Gypsy moth populations have been variable since 2001 when the first damaging levels appeared in Wisconsin. The population has since cycled between periods of outbreak populations for 1 to 2 years followed by several years of subsidence. The forested area impacted by gypsy moth increased through 2003 then collapsed and slowly built up to a peak of over 340,000 acres of defoliation in 2010 (Table 6). However, a wet spring in 2010 caused widespread development of the fungal caterpillar disease *Entomophaga miamiaga,* which helped limit the 2010 defoliation to only light to moderate damage. The population subsequently crashed in the late instar caterpillar phase. The nucleopolyhedrosis virus (NPV) was commonly found in association with fungal outbreaks. Despite gypsy moth impacting the forests of Wisconsin for over 40 years, the gypsy moth population has remained relatively low through 2014 (Fig. 87).

Table 6.—Acres of gypsy moth defoliation since 2001

Year	Acres
2001	2,700
2002	33,000
2003	65,000
2004	20
2005	1
2006	0
2007	22,994
2008	8,659
2009	3,620
2010	346,749
2011	0
2012	14,500
2013	12,248
2014	<200

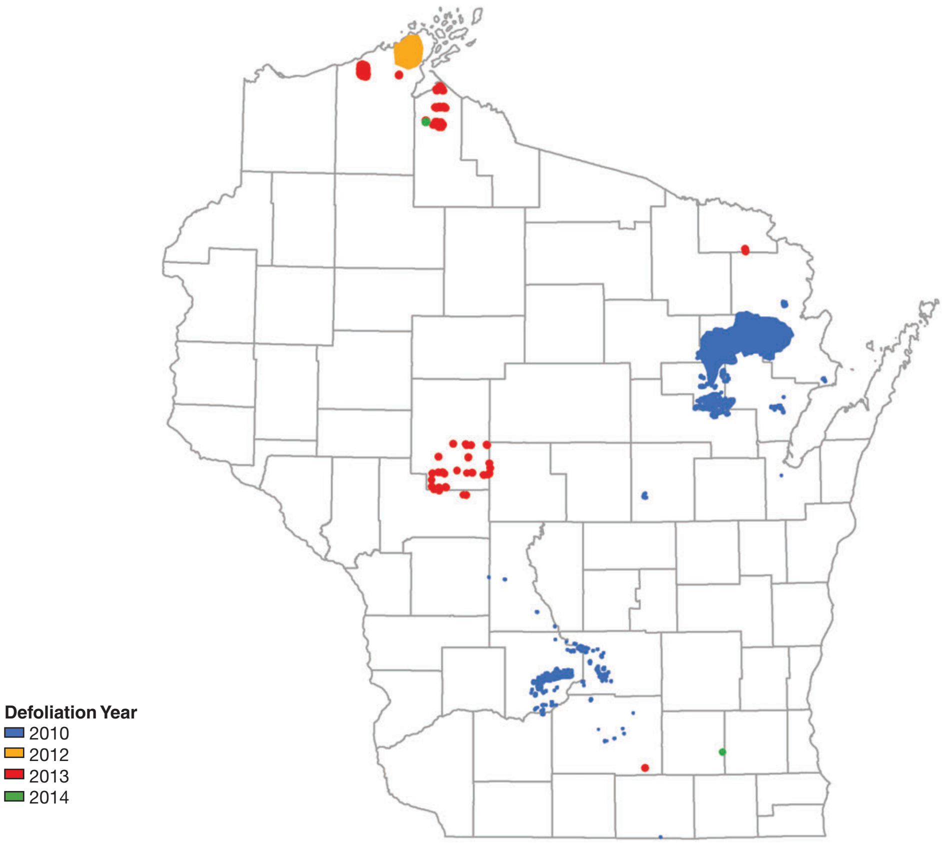


Figure 87.—Areas of gypsy moth defoliation by year in Wisconsin.

Oak Wilt: Oak wilt, which is caused by the wilt fungus *Ceratocystis fagacearum*, is common in the southern two-thirds of Wisconsin. Periodic new detections have occurred between 2009 and 2014 in some of the previously oak wilt free counties of northern Wisconsin. Oak wilt was confirmed for the first time in Langlade and Oneida Counties in 2010, in Lincoln, Sawyer, and Vilas Counties in 2012, in Rusk County in 2013, and in Washburn County in 2014. As of 2014, oak wilt has been detected in 60 of Wisconsin's 72 counties. (Fig. 88). Species of the red oak group are highly susceptible to infection and Wisconsin forest land has almost 24 million black oak, 38.5 million northern pin oak, and nearly 90.9 million northern red oak 5 inches d.b.h. and larger.

Eastern Larch Beetle and Tamarack Mortality: Eastern larch beetle (*Dendroctonus simplex*) is a native pest of tamarack and attacks the main trunk, exposed roots, and large branches of stressed trees. If severe enough, the colonization of this beetle can kill the tree. Under certain conditions, widespread outbreaks of hundreds of acres may occur.

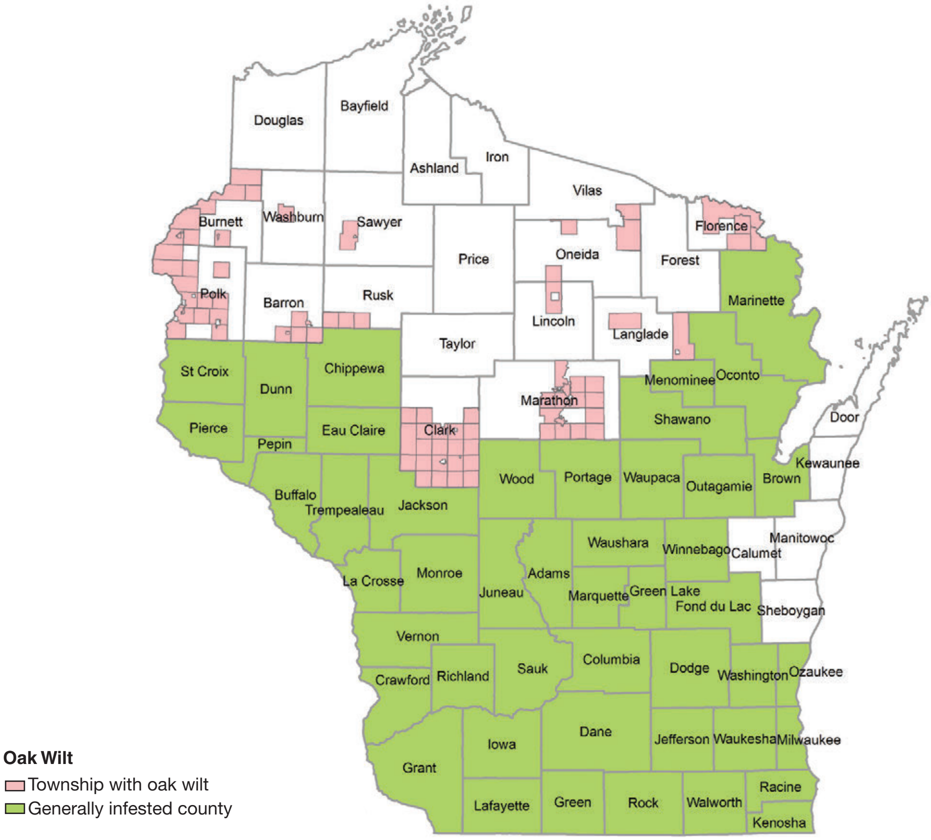


Figure 88.—Distribution of oak wilt in Wisconsin.

While eastern larch beetle has been causing noticeable mortality in parts of the State since 2000, insect populations remained relatively low from 2009 to 2011. Populations of eastern larch beetle began to increase in 2012, with 730 acres of infested tamarack in 2012 and 1,300 acres in 2013 (Fig. 89). This later damage was widely scattered and included sites in Burnett, Chippewa, Clark, Douglas, Florence, Jackson, Juneau, Langlade, Lincoln, Marinette, Oneida, Price, Rusk, Sawyer, Taylor, Vilas, and Washburn Counties. Eighty infested stands were mapped with seven larger than 40 acres. In 2014, a 356-acre stand in Chippewa County suffered moderate mortality. Additional scattered mortality was also observed in Oneida and Vilas Counties in 2014, indicating spread from some of the 2013 areas.

Eastern larch beetle has been causing noticeable mortality in parts of Wisconsin since 2000. Recent research in Minnesota suggests that eastern larch beetle may go through two generations in a single year, which could contribute to increased severity of outbreaks in the future (McKee and Aukema 2015).

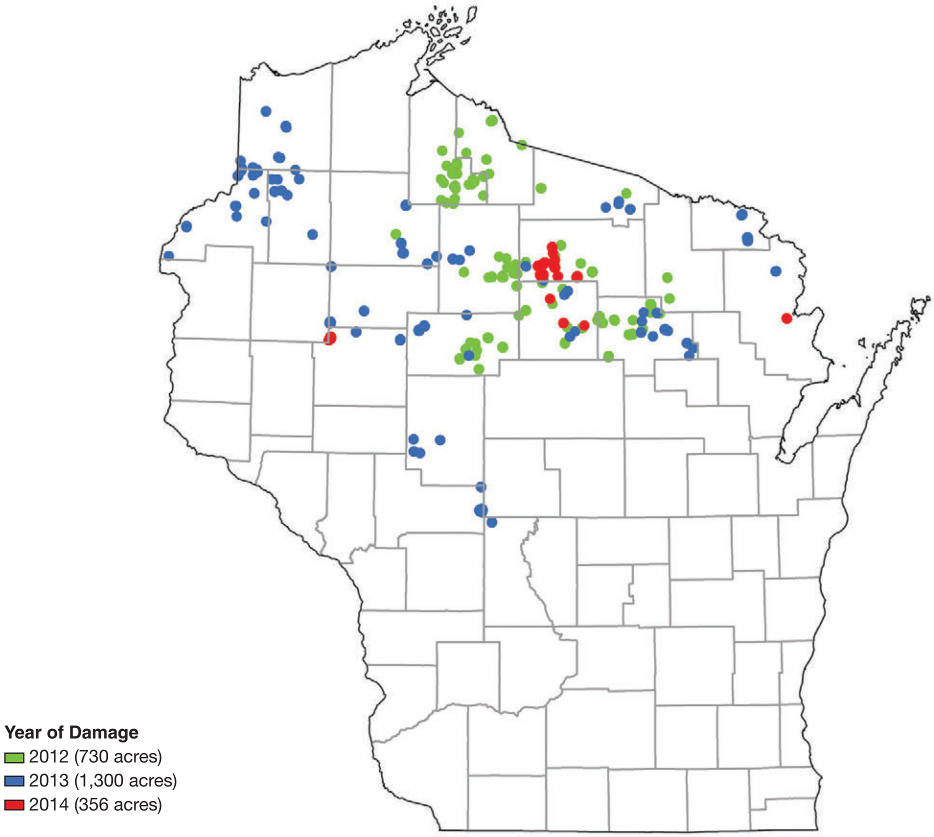


Figure 89.—Eastern larch beetle damage in 2012, 2013, and 2014, Wisconsin.

What this means

Several biotic and abiotic factors have impacted the health of Wisconsin's forests between 2009 and 2014. Severe drought, extended cold periods, and localized flooding all added to stress in the ecosystem thus exacerbating damage by both native and exotic pests. This included the first occurrence of beech bark disease in the State, the expansion of oak wilt into new counties, the spread of a major root rot pathogen in managed conifer plantations, and expected fluctuations in damage by gypsy moth.

Native forest pests typically undergo periodic outbreaks; damage from these outbreaks is likely to be exacerbated by future weather patterns. As invasive exotic insects and diseases expand to new areas of the State, they increase the risk to the health of Wisconsin forests.

Emerald Ash Borer

Background

Emerald ash borer is a nonnative pest of ash trees. EAB was first detected and identified in 2002 in the Detroit, MI, area and has since spread throughout the eastern half of the United States. EAB attacks all native species of ash, including green, white, black, and blue ash. Tree mortality occurs following the construction of larval galleries under the bark, which sever the flow of water and nutrients, thus girdling the tree. Due to rapid spread of this insect and little natural resistance of ash, Wisconsin's ash resource is at high risk for mortality due to EAB in both urban and rural forests throughout the State.

While systemic insecticides have been developed to treat individual trees, these treatments are not conducive for use in rural forests. Wisconsin continues to participate in releases of parasitoid wasps which attack both eggs and larvae in the hope that this might regulate the high populations of beetles building in ash trees.

In August 2008, EAB was first detected in eastern Wisconsin. A well-established population of EAB was found in the Newburg area in Ozaukee County that year and, based on dendrochronology studies, had likely been present since 2004 (Fig. 90). Later that year, EAB was detected on the far western side of Wisconsin, near Victory in Vernon County. New detections continued at a slow rate between 2008 and 2011 (Table 7). Beginning in 2012, there was a large increase in the number of EAB infestations. By 2014, widespread ash mortality was observed in eastern Wisconsin as well as scattered mortality in other parts of the State. Southeastern Wisconsin saw a large increase in mortality post EAB detection (Fig. 91). For more information on EAB in the urban forest, see "Urban Forests" on page 70.

What we found

There are nearly 173 million growing-stock ash at least 5 inches d.b.h. on timberland in Wisconsin. Ash is mostly a northern species and almost 60 percent of ash volume occurs in northeast and northwest Wisconsin. This bodes well for the ash resource, as less than 1 percent of EAB occurrences have been reported in central and northern Wisconsin. Nonetheless, the threat to ash is serious. Over 15 percent of all ash trees and 23 percent of sawtimber volume are located within 15 miles of a site where EAB has been found. In southeast Wisconsin, almost 70 percent of ash sawtimber volume occurs within 15 miles of an EAB positive location (Fig. 92).

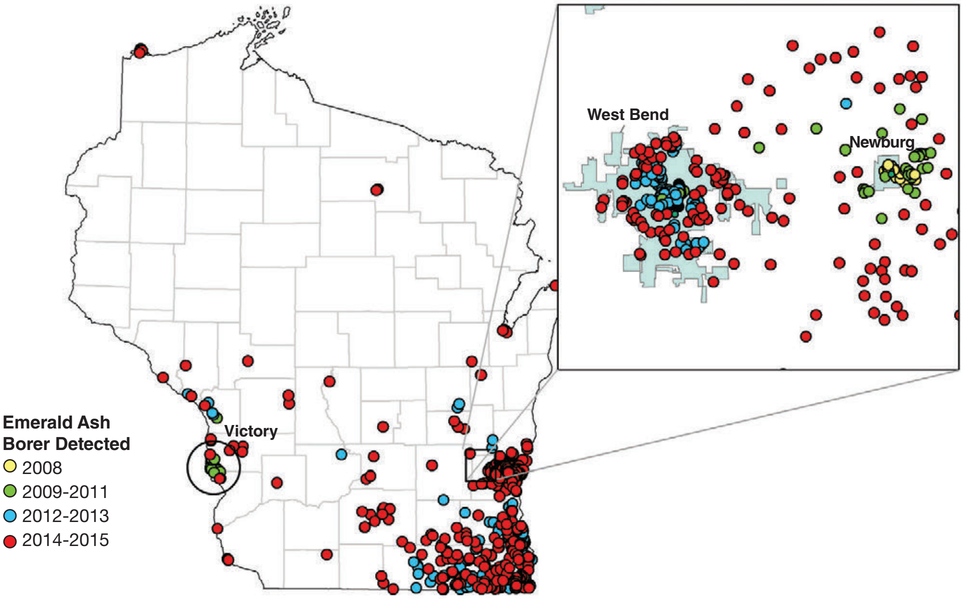


Figure 90.—Years and locations where emerald ash borer has been detected. Inset shows the Newburg area where EAB was first found in 2008. The Vernon County site is circled.

Table 7.—Number of emerald ash borer (EAB) municipal-level first detections

Year	Count
2008	2
2009	9
2010	2
2011	2
2012	16
2013	46
2014	51

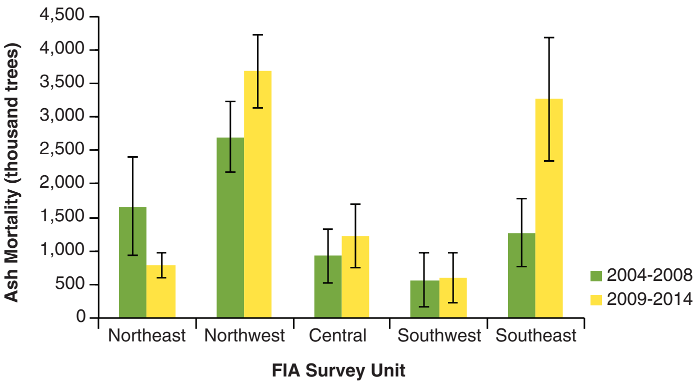


Figure 91.—Ash mortality, prior to EAB detection (2004-2008) and following EAB detection (2009-2014), by survey unit, Wisconsin.

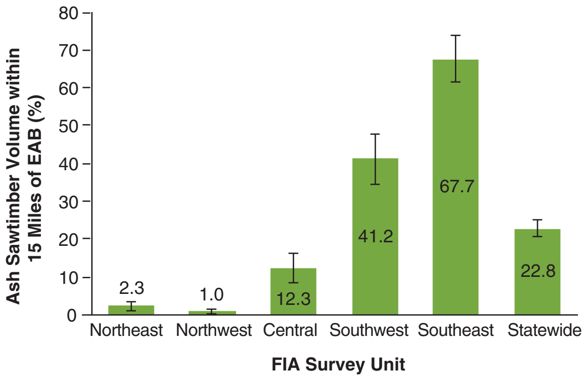


Figure 92.—Percent of ash sawtimber volume within 15 miles of EAB positive location by region of the State. Error bars represent the 68 percent confidence interval.

What this means

Although EAB has spread quickly in southern Wisconsin, it has not been detected in much of northern Wisconsin. Continued efforts aimed at reducing human assisted movement of infested ash materials will help slow EAB spread. Unfortunately, substantial damage to Wisconsin's ash resource is likely based on previous damage and spread, but these impacts will be variable depending on ash density. However, use of EAB parasitoids in areas with high EAB populations may decrease the impacts caused by this damaging insect. These parasitoids are a method of biological control used to reduce the EAB population by parasitizing the larvae.

Mitigating the EAB impacts will be especially challenging in lowland areas with high components of green and black ash, particularly with concerns of invasive plant establishment, such as reed canarygrass (*Phalaris arundinacea*). River corridor systems with a high ash component may also see high levels of tree mortality.

Quarantines to limit spread into new areas continue to be implemented at the county level and precautions have been developed to limit spread within quarantined areas. While quarantines limit EAB human-aided movement, ash logs may continue to move to mills under compliance agreements with Wisconsin Department of Agriculture, Trade, and Consumer Protection. These compliance agreements include steps to destroy infested material before the beetle emergence period in the spring and summer.

Invasive Plant Species

Background

Invasive plant species (IPS) often form dense colonies that limit light, nutrient, and water availability. They can be detrimental to native forest ecosystems by threatening ecological diversity, increasing forest management costs through their impact on forest tree regeneration and growth, and limiting management options. Some invasive plants are alternate hosts for insects and diseases that can cause devastating impacts. These plants may also provide beneficial qualities such as offering habitat, aesthetic beauty, and herbal or medicinal qualities. Despite the positive qualities, the management, monitoring, and removal of these aggressive plants costs billions of dollars annually. Because of the implications caused by invasive plants, it is important to increase awareness through informing and educating individuals.

What we found

Data were collected on 811 P2 invasive plots from 2009 to 2014. Twenty species and one nonspecific genus were identified in Wisconsin's forests in 2014 (Fig. 93, Table 8); this is an increase from the 17 species between 2007 and 2009. The three most common IPS were nonnative honeysuckles (*Lonicera* spp.), common buckthorn (*Rhamnus cathartica*), and reed canarygrass, each tallied on more than 100 plots. One or more IPS were found on 343 plots (Fig. 94), and it is becoming common to find two or more species occurring on the same plot (48 percent versus 21 percent in 2009) with an average of 1.9 species tallied per plot that had any IPS present. In fact, two plots had seven different species and 16 plots had five or more IPS tallied on them.

What this means

Although IPS represent a minority of species in Wisconsin's forests, they are a forest health concern because they can out-compete native plant species, including trees, and threaten ecological diversity by altering natural plant communities. The increase in range and number of IPS since 2009 is alarming, but not unexpected. While efforts to control or contain some IPS have been somewhat successful, most efforts have not had a great impact. In September of 2009, Wisconsin enacted the invasive species rule (Wis. Adm. Code chapter NR 40; http://dnr.wi.gov/topic/invasives/classification.html), which makes it illegal to possess, transport, transfer, or introduce certain invasive species in Wisconsin without a permit. It is hoped that this will inhibit the spread of existing IPS, and prevent the introduction of IPS that are not yet established in Wisconsin.

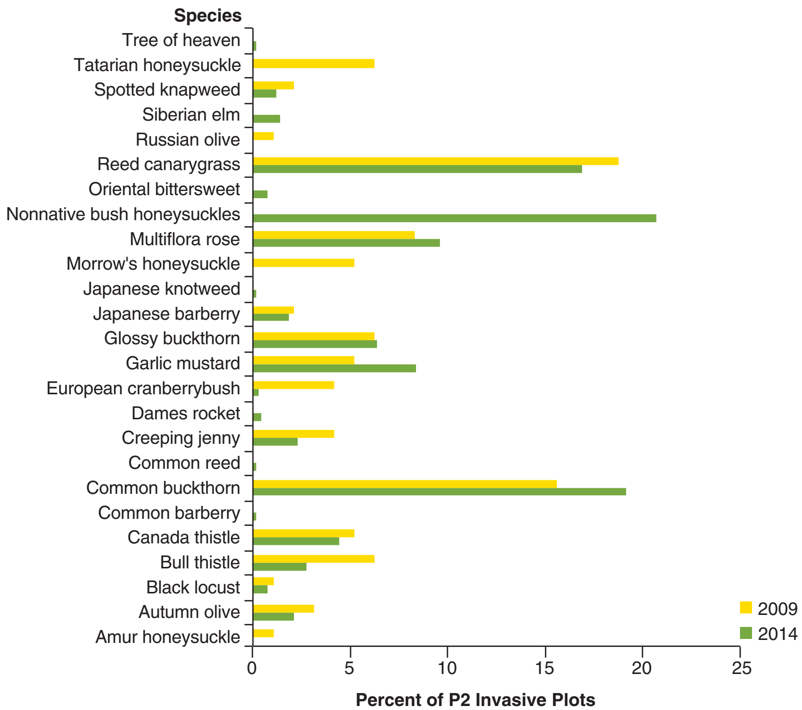


Figure 93.—Occurrences of invasive plant species monitored by FIA on P2 invasive plots, by year, Wisconsin.

Table 8.—List of invasive plants found in Wisconsin, of those monitored by FIA, 2014

Common name	Latin name
Tree of heaven	*Ailanthus altissima*
Garlic mustard	*Alliaria petiolata*
Japanese baberry	*Berberis thunbergii*
Common barberry	*Berberis vulgaris*
Oriental bittersweet	*Celastrus orbiculatus*
Spotted knapweed	*Centaurea stoebe*
Canada thistle	*Cirsium arvense*
Bull thistle	*Cirsium vulgare*
Autumn olive	*Elaeagnus umbellata*
Glossy buckthorn	*Frangula alnus*
Dames rocket	*Hesperis matronalis*
Nonnative bush honeysuckles	*Lonicera* spp.
Creeping jenny	*Lysimachia nummularia*
Reed canarygrass	*Phalaris arundinacea*
Common reed	*Phragmites australis*
Japanese knotweed	*Polygonum cuspidatum*
Common buckthorn	*Rhamnus cathartica*
Multiflora rose	*Rosa multiflora*
Black locust	*Robinia pseudoacacia*
Siberian elm	*Ulmus pumila*
European cranberrybush	*Viburnum opulus*

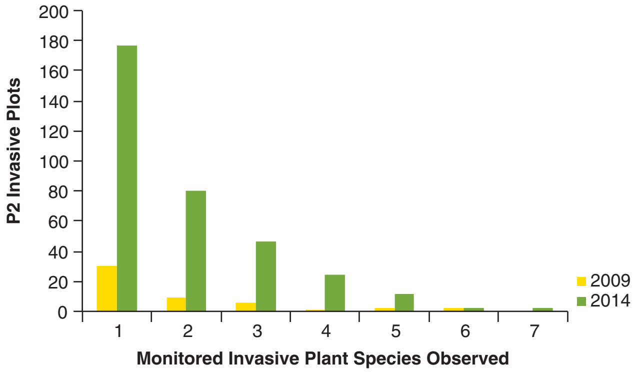


Figure 94.—Number of monitored invasive plant species observed per P2 invasive plot, by year, Wisconsin.

Forest Economics

Red pine plantation. Photo by Cassandra M. Kurtz, U.S. Forest Service.

Growing-stock Volume

Background

Wisconsin's forests are vital to the State's economy by providing raw material to paper and lumber mills, recreational opportunities for tourism, and ecosystem functions such as water filtration and erosion control. Since Wisconsin's forests were cutover in the late 19th century, these forests have aged: trees have gotten bigger and shade-tolerant species have replaced more intolerant species. In addition, introduced pests and diseases have caused some tree species to decline in number.

What we found

The total volume of growing stock on Wisconsin timberland has increased steadily since 1938 and currently stands at 21.6 billion cubic feet. The volume of softwood has increased in each inventory since 1983 (Fig. 95). Hardwood volume remained unchanged between 1996 and 2004 but has increased since then (Fig. 95).

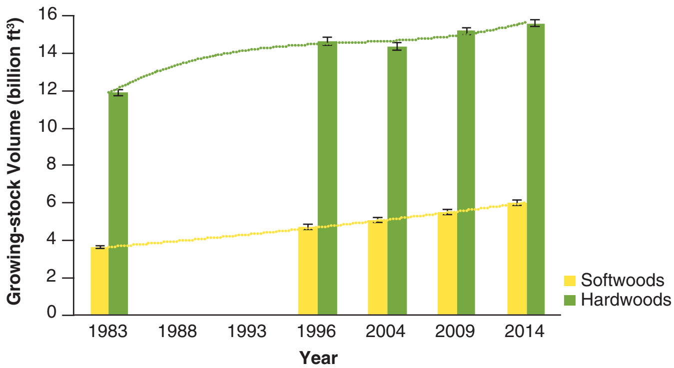


Figure 95.—Volume of growing stock by species group and year, Wisconsin; trend lines are superimposed. Error bars estimate the 68 percent confidence interval.

Over the last two decades, certain species have increased in volume and others have decreased or remained unchanged (Fig. 96). The volume of eastern white pine, red pine, and northern pin oak have increased by more than 60 percent while the volume of red maple, black ash, and white ash have increased by over 20 percent. Northern pin oak, white ash, red pine, and eastern white pine have had large increases in every inventory since 1983.

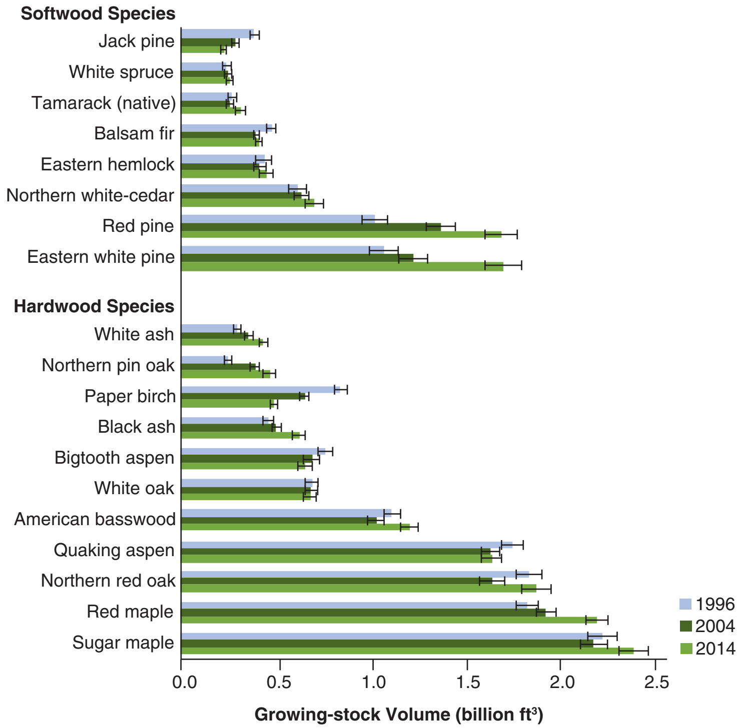
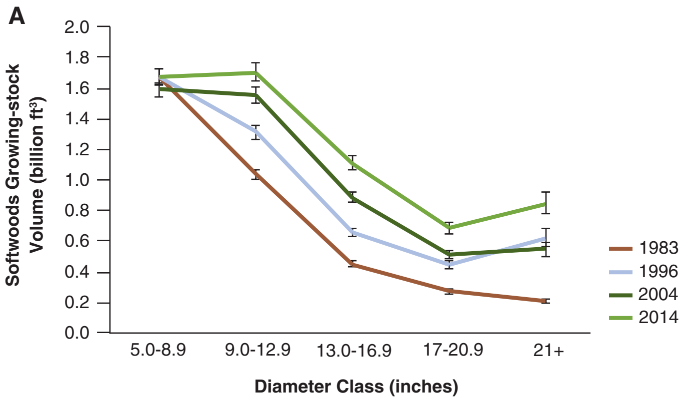


Figure 96.—Growing-stock volume by species and year, Wisconsin. Error bars represent the 68 percent confidence interval.

In the last 20 years, bigtooth aspen, butternut, black oak, and balsam fir have decreased with paper birch and jack pine decreasing over 40 percent. Aspen, paper birch, and jack pine are species which depend on disturbance to regenerate. The lack of fire and other stand-altering disturbance may have led to a decrease in the volume of these species.

The volume in large diameter softwood (Fig. 97A) and hardwood (Fig. 97B) trees has increased steadily since 1983. Softwood volume has increased in all size classes from poles to large sawtimber whereas volume in hardwoods has decreased for trees under 9 inches in diameter and increased sizably for trees over 13 inches. About one quarter of all volume is in trees over 17 inches d.b.h.



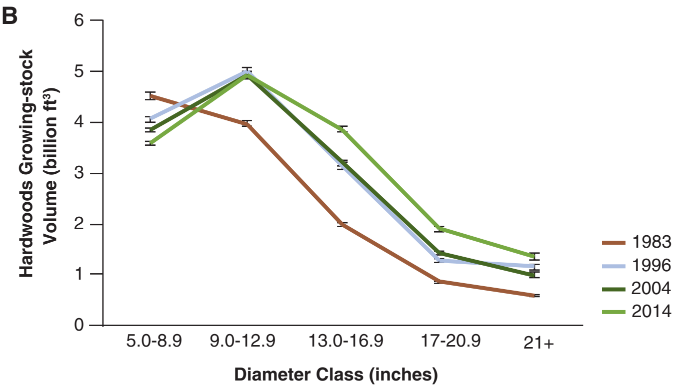


Figure 97.—Volume of growing stock for softwoods (A) and hardwoods (B) by diameter class and year, Wisconsin. Error bars represent the 68 percent confidence interval.

What this means

Most of the major commercial species have increased substantially over the last few decades with the exception of aspen, paper birch, and jack pine. The volume of saw log and pulpwood species, such as sugar maple, red maple, red pine, ash species, and northern red oak, have increased steadily while other important timber species, such as aspen, paper birch, and jack pine, have decreased substantially in volume since 1996. However, species such as red maple, white and black ash, and eastern white pine are increasing dramatically in volume and may serve to replace aspen and paper birch in the future as these species diminish in importance. These changes have important implications for wildlife habitat and forage and mill utilization.

Timber Product Outputs

Background

The harvesting and processing of timber products produces a stream of income shared by timber owners, managers, marketers, loggers, truckers, and processors. In 2012, the wood products and paper manufacturing industries (North American Industry Classification System codes 321 and 322) in Wisconsin employed 46,500 people, with an average annual payroll of $2.3 billion, and a total value of shipments and receipts of $17.5 billion (U.S. Census Bureau 2012). To better manage the forests of the State, it is important to know the species, amounts, and locations of timber being harvested. Surveys of Wisconsin's wood-processing mills are conducted periodically to estimate the amount of wood volume that is processed into products. This is supplemented with the most recent surveys conducted in surrounding states that processed wood harvested from Wisconsin. All of the primary wood processors in Wisconsin were canvassed in 2008 and 2013 to determine the amount of wood that was processed by Wisconsin's wood processors to determine the products that were processed by species and by country, state, and county of origin.

What we found

The 238 primary wood products mills in Wisconsin processed 307.4 million cubic feet of industrial roundwood in 2013.[1] Wisconsin forest land had 308.1 million cubic feet of industrial roundwood harvested, which supplied raw material for the primary wood processors in Wisconsin, surrounding states, and Canada. Fifty-three percent of the industrial roundwood harvested went to pulp mills, 29 percent went to saw mills, and 12 percent was used by composite panel mills (Fig. 98). Other products harvested included veneer logs, industrial fuelwood (including pellets), cabin logs, excelsior, post, poles, pilings, and other miscellaneous products.

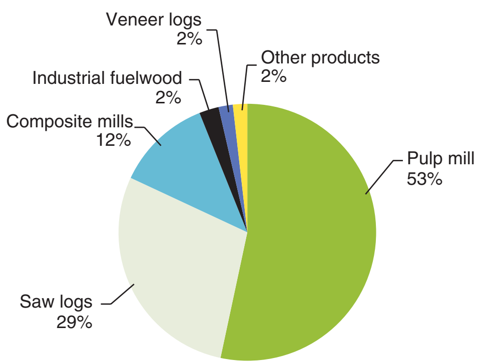


Figure 98.—Industrial roundwood and fuelwood production by product, Wisconsin, 2013.

[1] Manuscript in preparation. Haugen, D.E. Wisconsin Timber Industry, a research note to be published by U.S. Forest Service, Northern Research Station.

Aspen/balsam poplar accounted for more than one-fifth of the volume of industrial roundwood harvested (Fig. 99). Other important species groups harvested where hard maple, red pine, red oak, and soft maple. In 2013, the process of harvesting industrial roundwood, 122.2 million cubic feet of harvest residues were left on the ground. More than 85 percent of the harvest residue came from non-growing-stock sources (logging slash), such as crooked or rotten trees, nonforest trees, tops and limbs, and dead trees (Fig. 100). The processing of industrial roundwood by the State's primary wood-using mills generated another 2.4 million green tons of wood and bark residues. Nearly 50 percent of the mill residues generated were used for industrial fuelwood, and almost 25 percent was used by the pulp and composite panel mills for paper or particleboard products. Only 1 percent of the remaining mill residues were not used for other products such as residential fuelwood, mulch, animal bedding, or other miscellaneous uses (Fig. 101).

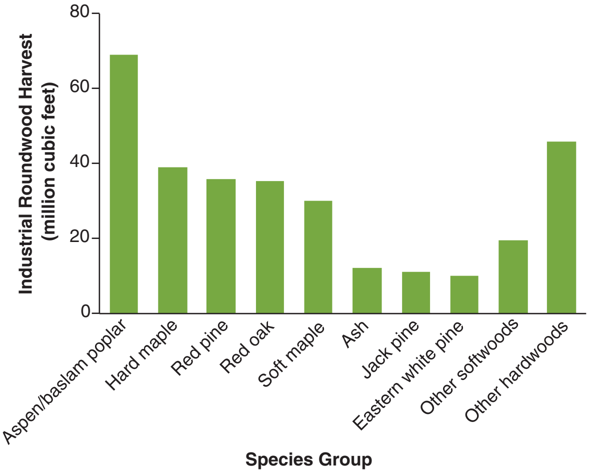


Figure 99.—Volume of industrial roundwood harvested by species group, Wisconsin, 2013.

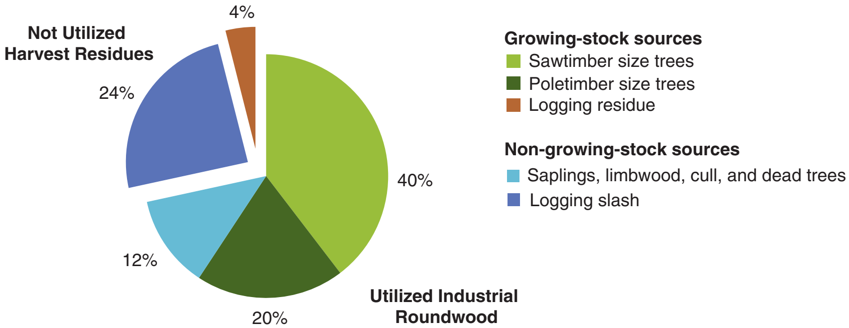


Figure 100.—Harvest residue generated by industrial roundwood harvesting by growing stock and non-growing-stock sources, and used for product and harvest residue, Wisconsin, 2013.

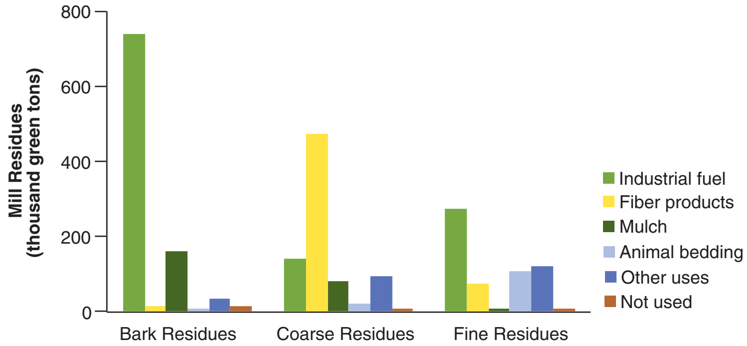


Figure 101.—Disposition of mill residues generated by primary wood-using mills, Wisconsin, 2013.

What this means

The need for wood products is likely to increase, placing a greater demand on the resource. An important consideration for the future of the primary wood-products industry is its ability to retain industrial roundwood processing facilities. The number of wood-processing mills has been steadily declining. The loss of processing facilities makes it harder for landowners to find markets for the timber harvested from management activities on their forest land.

Another important issue is the volume of harvest residues that are generated in the State that go unused. Between 2003 and 2013, five pulp and composite panel mills closed in Wisconsin. These mills can use smaller diameter material than saw mills or veneer mills, which leads to better utilization of the timber resource. Industrial fuelwood or increased pulpwood markets could lead to better utilization of merchantable trees. The use of logging slash for industrial fuelwood at cogeneration facilities and pellet mills could also result in better utilization of the forest resource.

Future Forests of Wisconsin

Background

This section focuses on anticipated changes to the forests of Wisconsin 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 roughly 352,000 acres of forest land to be converted to urban land (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 utilized 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 storylines and storyline variations. They are identified by their storyline identifier (A1B, A2, or B2) followed by a hyphen and then their storyline variation (C, BIO, or EAB).

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. Utilizes the CGCM3.1 climate model (Canadian Centre for Climate Modelling and Analysis, n.d. b).

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

3) B2—A trend toward local self-reliance and stronger communities. Community-based solutions to social problems. Energy systems differ from region to region, depending on the availability of natural resources. The need to use energy and other resources more efficiently spurs the development of less carbon-intensive technology in some regions. Utilizes the CGCM2 climate model (Canadian Centre for Climate Modelling and Analysis, n.d.a).

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 storylines, A1B, A2, and B2.

2) BIO—Increased harvest and utilization of woody biomass for energy variation; available for all storylines, A1B, A2, and B2.

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

What we found

The anticipated declines in forest land, which total in the hundreds of thousands of acres, reverses the trend of increasing forest area in Wisconsin since the 1968 inventory (Fig. 102). Specifically, over the next 50 years forest land area is projected to decline from an estimated 16.7 million acres in 2010 to 15.9 million acres (-5 percent) in 2060 under scenario A1B-C; to 16.1 million acres (-4 percent) under scenario A2-C; and to 16.3 million acres (-2 percent) under scenario B2-C. Only three scenarios are represented in Figure 102 as the climate model and variations on the storylines do not impact the area of forest land under 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 less forest land over the time period.

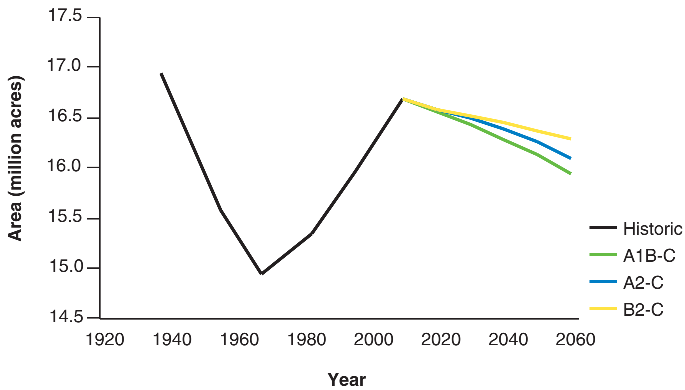


Figure 102.—Projected forest land area by climate change and demographic scenario, Wisconsin, 2010-2060.

The area in the elm/ash/cottonwood forest-type group decreases under all scenarios from the historic level in 2010 but the decrease is largest under scenario A2-EAB (Fig. 103). Overall only 6 percent of the live tree volume in Wisconsin is in ash species, however, ash species constitutes 29 percent of the volume in the elm/ash/cottonwood forest type group. The loss of the ash component in the elm/ash/cottonwood forest-type group is partially offset by increases in other associated species within the elm/ash/cottonwood forest-type group.

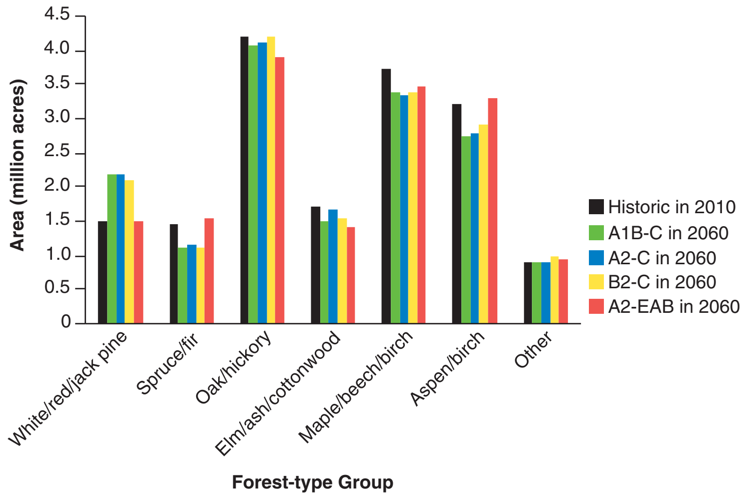


Figure 103.—Projected forest land area by forest-type group, 2010 and by climate change and demographic scenario in 2060.

The impacts of EAB are more pronounced in Figure 104. Live tree volume on forest land decreases for the A2-EAB scenario from 2020 to 2030 while the volume estimates for scenarios A1B-C, A2-C, and B2-C continue to increase. Of the three high biomass utilization scenarios only scenario A1B-BIO has a decline in volume from 2020 to 2030. Not until 2060 do all three high biomass utilization variation scenarios (A1B-BIO, B2-BIO, and A2-BIO) have lower levels of live tree volume than the A2-EAB scenario. The volume under all scenarios is projected to decline from 2030 to 2050 at which point the three standard scenarios (A1B-C, A2-C, and B2-C) and the A2-EAB scenario are projected to increase in volume (despite losses in forest land area) while the three high biomass utilization scenarios are projected to show large decreases in volume from 2050 to 2060. The area of forest land is expected to decrease but the volume per acre is expected to increase under the standard scenarios as forests continue to mature. Scenarios with high biomass utilization expect increasingly high removals (Fig. 105) and volume per acre is expected to decrease.

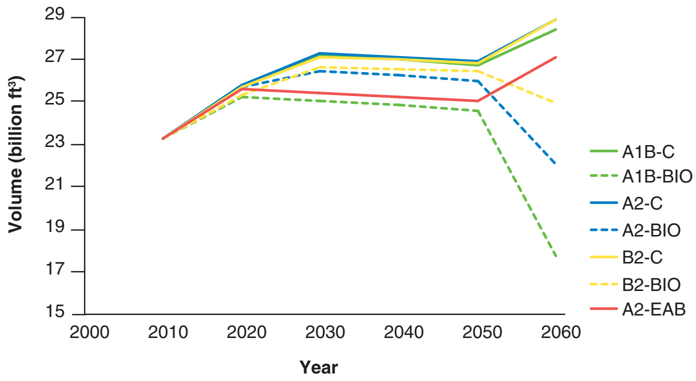


Figure 104.—Live tree volume on forest land by climate change and demographic scenario, Wisconsin, 2010-2060.

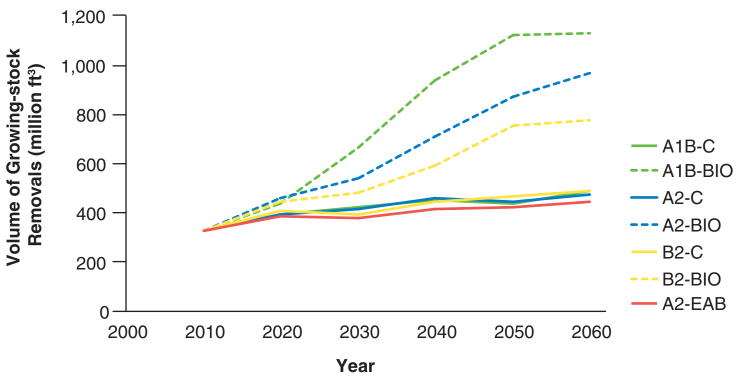


Figure 105.—Average annual growing-stock removals on timberland in Wisconsin by climate change and demographic scenario, 2010-2060.

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 (Fig. 102) reverses the upward trend of forest area over the past six decades. The loss of from 2 to 5 percent of forest land, depending on scenario, is somewhat offset by increases in volume. Harvest rates under the high biomass utilization scenarios (Fig. 105) have a large impact on volumes for those scenarios after 2050.

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Appendix

Appendix 1. Tree Species

The following are tree species that were found on sample plots, Wisconsin, 2014. This is not a complete list of tree species known in Wisconsin.

Common Name	Scientific name	Number of trees
Balsam fir	*Abies balsamea*	13,809
Eastern redcedar	*Juniperus virginiana*	427
Tamarack (native)	*Larix laricina*	4,365
Norway spruce	*Picea abies*	140
White spruce	*Picea glauca*	2,294
Black spruce	*Picea mariana*	4,668
Blue spruce	*Picea pungens*	4
Jack pine	*Pinus banksiana*	4,917
Red pine	*Pinus resinosa*	10,907
Eastern white pine	*Pinus strobus*	7,128
Scotch pine	*Pinus sylvestris*	309
Douglas-fir	*Pseudotsuga menziesii*	1
Northern white-cedar	*Thuja occidentalis*	8,479
Eastern hemlock	*Tsuga canadensis*	2,508
Boxelder	*Acer negundo*	2,434
Black maple	*Acer nigrum*	31
Red maple	*Acer rubrum*	23,438
Silver maple	*Acer saccharinum*	1104
Sugar maple	*Acer saccharum*	18,178
Mountain maple	*Acer spicata*	114
Norway maple	*Acer platinoides*	1
Ohio buckeye	*Aesculus glabra*	1
Common serviceberry	*Amelanchier arborea*	15
Roundleaf serviceberry	*Amalanchier sangiunea*	1
Yellow birch	*Betula alleghaniensis*	3,003
River birch	*Betula nigra*	111
Paper birch	*Betula papyrifera*	7,999
American hornbeam, musclewood	*Carpinus caroliniana*	1,018
Bitternut hickory	*Carya cordiformis*	1,429
Shagbark hickory	*Carya ovata*	1,392
Northern catalpa	*Catalpa speciosa*	2
Hackberry	*Celtis occidentalis*	274
Flowering dogwood	*Cornus florida*	1
Cockspur hawthorn	*Crataegus crus-galli*	13
Downy hawthorn	*Crataegus mollis*	3
American beech	*Fagus grandifolia*	278
White ash	*Fraxinus americana*	3,008

(Appendix continued on next page.)

(Appendix 1. continued)

Common Name	**Scientific name**	**Number of trees**
Black ash	*Fraxinus nigra*	8,053
Green ash	*Fraxinus pennsylvanica*	3,616
Honeylocust	*Gleditsia triacanthos*	21
Butternut	*Juglans cinerea*	184
Black walnut	*Juglans nigra*	605
White mulberry	*Morus alba*	60
Red mulberry	*Morus rubra*	125
Eastern hophornbeam	*Ostrya virginiana*	3,099
Balsam poplar	*Populus balsamifera*	385
Eastern cottonwood	*Populus deltoides*	179
Bigtooth aspen	*Populus grandidentata*	6,096
Quaking aspen	*Populus tremuloides*	25,948
Silver poplar	*Populus alba*	4
Pin cherry	*Prunus pensylvanica*	249
Black cherry	*Prunus serotina*	4,783
Chokecherry	*Prunus virginiana*	300
Canada plum	*Prunus nigra*	10
American plum	*Prunus americana*	39
White oak	*Quercus alba*	3,197
Swamp white oak	*Quercus bicolor*	193
Northern pin oak	*Quercus ellipsoidalis*	4,622
Bur oak	*Quercus macrocarpa*	2,005
Chinkapin oak	*Quercus muehlenbergii*	14
Northern red oak	*Quercus rubra*	6,525
Black oak	*Quercus velutina*	2,726
Black locust	*Robinia pseudoacacia*	473
Peachleaf willow	*Salix amygdaloides*	38
Black willow	*Salix nigra*	291
Bebb willow	*Salix bebbiana*	101
White willow	*Saccharum alopecuroides*	1
American mountain-ash	*Sorbus americana*	3
American basswood	*Tilia americana*	6,633
American elm	*Ulmus americana*	6,010
Siberian elm	*Ulmus pumila*	77
Slippery elm	*Ulmus rubra*	818
Rock elm	*Ulmus thomasii*	72
Russian-olive	*Elaeagnus angustifolia*	6
Fir spp.	*Abies* spp.	1
Larch spp.	*Larix* spp.	2
Unknown dead hardwood		2

(Appendix continued on next page.)

(Appendix 1. continued)

Common Name	Scientific name	Number of trees
Other or unknown live tree		2
Mountain-ash spp.	*Sorbus* spp.	1
Willow spp.	*Salix* spp.	31
Apple spp.	*Malus* spp.	281
Serviceberry spp.	*Amelanchier* spp.	400
Hawthorn spp.	*Crataegus* spp.	373
Walnut spp.	*Juglans* spp.	1
Unknown dead conifer		3

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This report summarizes the third annual inventory of Wisconsin's forests, conducted 2009–2014. Wisconsin's forests cover 17.1 million acres with 16.6 million acres classified as timberland. Forests are bountiful in the north with Florence, Forest, Menominee, and Vilas Counties having over 90 percent forest cover. In the southeastern part of the State, forest cover is lowest with Dodge, Fond du Lac, Milwaukee, and Racine Counties having less than 10 percent forest cover. The sawtimber volume on timberland has been rising and is estimated to be 69.5 billion board feet. Oak/hickory is the predominant forest-type group, covering one-quarter of the forest land. The statewide growth-to-removal ratio on timberland is 2.2, indicating growth is outpacing removals. Additional information on Wisconsin's forests such as growth, mortality, species composition, ownership, diseases, invasive plant species, and forest economics is detailed in this report. Information on forest inventory methods, data quality estimates, and important resource statistics can be found online at https://doi.org/10.2737/NRS-RB-112.

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