USDA

United States Department of Agriculture

Missouri Forests 2013

Forest Service

Northern Research Station

Resource Bulletin NRS-108

Publication Date December 2016

Abstract

The third full cycle of annual inventories (2009-2013) of Missouri's forests, completed in 2013, reports that there are an estimated 15.5 million acres of forest land in the State. An estimated 60 percent of the forest land area is in sawtimber-size stands, 30 percent are pole timber size, and 10 percent are seedling/sapling size or nontstocked. The net volume of live trees on forest land increased by 4 percent, from 20.1 million cubic feet in 2008, to 21.0 million cubic feet in 2013. Average annual net growth of live trees on forest land decreased by more than 25 percent, from an average of 36 cubic feet per acre in 2008, to an average of 26 cubic feet per acre in 2013. This report includes additional information on forest attributes, land-use change, carbon, and forest health. In addition to this document, Missouri Forests 2013: Statistics, Methods, and Quality Assurance is online https://doi.org/10.2737/NRS-RB-108. It contains 1) descriptive information on methods, statistics, and quality assurance of data collection, 2) a glossary of terms, 3) tables that summarize quality assurance. A set of tables with estimates for a variety of forest resources and other information is also available at the same location.

Acknowledgments

The authors would like to thank the many individuals who contributed both to the inventory and analysis of Missouri's forest resources. Staff with key responsibility for data management, processing, and estimation included Chuck Barnett, James Blehm, Dale Gormanson, Mark Hatfield, Barb O'Connell, and Paul Sowers. Pre-field production staff included Daniel Kaisershot, Cassandra Olson, Lucretia Stewert, and Jeff Wazenegger. Staff with key responsibilities of collecting field data included Todd Bixby, Tyler Camfield, Joshua Carron, Thomas Goff, Jason Gould, Matt Hake, Glenda Hefty, Brent Hummel, Katherine Johnson, Joe Kernan, Adam Magnuson, Mike Maki, Steve Potter, Greg Pugh, Kirk Ramsey, Dave Roth, Krista Starn, Joel Topham, Brian Wall, and Mike Whitehill. Report reviewers included Francisco Aguilar, University of Missouri; and Doug Ladd, The Nature Conservancy.

Cover: Fall in Miller County. Photo by Missouri Department of Conservation, used with permission.

Manuscript received for publication September 2015.

Published by:
U.S. FOREST SERVICE
11 CAMPUS BLVD SUITE 200
NEWTOWN SQUARE PA 19073-3294

For additional copies:
U.S. Forest Service
Publications Distribution
359 Main Road
Delaware, OH 43015-8640

December 2016

Visit our homepage at: **http://www.nrs.fs.fed.us**

Printed on recycled paper

Missouri Forests 2013

Ronald J. Piva, Thomas B. Treiman, Brett J. Butler, Susan J. Crocker, Dale D. Gormanson, Douglas M. Griffith, Cassandra M. Kurtz, Tonya W. Lister, William G. Luppold, William H. McWilliams, Patrick D. Miles, Randall S. Morin, Mark D. Nelson, Charles H. Perry, Rachel Riemann, James E. Smith, Brian F. Walters, Christopher W. Woodall

Contact Author:
Ronald J. Piva
rpiva@fs.fed.us
(651) 649-5150

About the Authors

Ronald J. Piva, Dale D. Gormanson, and Brian F. Walters are foresters with the Forest Inventory and Analysis (FIA) program, Northern Research Station, St. Paul, MN.

Thomas B. Treiman is a natural resource economist with the Missouri Department of Conservation, Columbia, MO.

Brett J. Butler is a research forester with the Forest Inventory and Analysis Program, Northern Research Station, Amherst, MA.

Susan J. Crocker, Patrick D. Miles, Mark D. Nelson, and Christopher W. Woodall are research foresters with the FIA program, Northern Research Station, St. Paul, MN.

Douglas M. Griffith and Tonya W. Lister are foresters with the FIA program, Northern Research Station, Newtown Square, PA.

Cassandra M. Kurtz is an ecologist with the FIA program, Northern Research Station, St. Paul, MN.

William G. Luppold is an economist with the FIA program, Northern Research Station, Princeton, WV.

William H. McWilliams and Randall S. Morin are research foresters with the FIA program, Northern Research Station, Newtown Square, PA.

Charles H. Perry is a research soil scientist with the FIA program, Northern Research Station, St. Paul, MN.

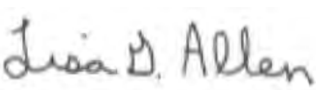
Rachel Riemann is a research forester/geographer with the FIA program, Northern Research Station, Troy, NY.

James E. Smith is a research plant physiologist with the FIA program, Northern Research Station, Durham, NH.

Foreword

Welcome to the third 5-year report from the U.S. Forest Service statewide forest inventory, Missouri Forests 2013. This inventory is conducted as a cooperative program between the Missouri Department of Conservation and the Forest Inventory and Analysis program of the U.S. Forest Service. Results of the inventory show that Missouri's forests have increased substantially since 1989. Missouri's forests are growing more wood than is being harvested. Missouri's forests support a forest products industry that contributes over $8 billion annually to the Missouri economy (2013 dollars) through jobs, personal income, product sales, and sales tax. In addition, Missouri's forests provide high quality wildlife habitat, clean and abundant water, clean air, and diverse outdoor recreation opportunities for both today's citizens and the next generation of Missourians. Missouri's forests are expanding and in good health. But they also face a variety of concerns: for example, ash is under attack from emerald ash borer and black walnut is threatened by thousand cankers disease. Land ownership parcelization and forest land conversion to other land uses result in smaller, fragmented forests. Missourians expect and need responsible management of our forests that will result in abundant renewable resources and improve the quality of forest habitats. Missouri Forests 2013 gives those who are interested in these issues a common set of scientifically gathered, statistically accurate numbers that we can use to make those responsible management decisions.

I trust this document will be informative and inspire you to join us in our pursuit to sustain Missouri's treasured trees and forests!



Lisa Allen

State Forester—Missouri Department of Conservation

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Highlights

On the Plus Side

- Seventy percent of the counties in Missouri reported an increase in forest land area since the last inventory. In 2013, 25 percent of the counties were at least 50 percent forested.
- Live tree and sapling biomass of forest land increased by 3 percent from 2008 to 2013, reaching a total of 641.4 million dry tons. Total forest ecosystem carbon stocks, estimated to be 830 million tons, also increased by 3 percent over the same time period.
- The volume of growing stock on timberland in Missouri is increasing nearly twice as fast as it is being removed. This indicates that there is potential for more intensive management on timberland, especially for less utilized species such as American sycamore and hackberry.
- There is low incidence of poor crown condition across Missouri, with no discernable spatial pattern. The only species with more than 4 percent of live basal area containing poor crowns are black walnut and scarlet oak. Black oak and scarlet oak had the highest average amount of crown dieback at 6.8 percent and 5.3 percent of basal area, respectively.
- In 2012, a canvass of the 397 primary wood-using industries of Missouri indicated that they received and processed 127.8 million cubic feet of industrial roundwood, 23 percent more than was processed in 2009. More than 90 percent of the industrial roundwood processed came from Missouri's forest land.
- There was 122.6 million cubic feet of industrial roundwood harvested from Missouri in 2012, an increase of 19 percent from 2009.
- About 98 percent of the mill residues generated from the processing of industrial roundwood were used for other secondary products such as charcoal, fiber products, and industrial and residential fuelwood.

Areas of Concern

- About 95 percent of Missouri's family forest owners do not have a management plan nor have they participated in most other traditional forest management planning or assistance programs. The average family forest owner in Missouri is 61 years old. This portends many acres of land passing on to the next generation in the not-too-distant future. It is uncertain who the future forest owners will be and what they will do with their land.

- Scarlet oak has been decreasing in all measurements. The number of trees on forest land has decreased by 20 percent between 2008 and 2013, and volume has decreased by 16 percent. Because of a high average annual mortality rate of 22.3 million cubic feet per year, net annual growth is only 0.2 million cubic feet per year. With an average annual removal rate of 15.6 million cubic feet per year, the volume of scarlet oak trees at least 5 inches d.b.h. is decreasing at a rate of 15.4 million cubic feet per year.

- Nearly 50 percent of the live trees at least 5 inches d.b.h. on forest land are oak species, but less than 20 percent of the seedlings are oak species. Shortleaf pine, which accounts for 4 percent of the live trees at least 5 inches d.b.h. on forest land, accounts for less than 1 percent of the seedlings found on Missouri's forest land. The exclusion of fire and low level of timber harvesting have likely allowed more shade tolerant species such as red maple to become more abundant in the understory.

- Average annual mortality of growing stock on timberland was 189.8 million cubic feet per year in 2013, an increase of 54 percent from 2008. Oaks have a number of insect and disease problems that are contributing to the increase. **Oak decline**—Species in the red oak group are particularly susceptible to oak decline, which develops when oak trees are under stress because of drought, physiological maturity, high stem density, or injuries caused by weather, and are subsequently attacked by pathogens or insects. The average annual mortality of red oaks in 2013 increased by nearly 20 percent over the 2008 inventory. **Rapid white oak mortality**—Unlike oak decline, the mortality tends to be rapid and affect white oaks on high quality sites. The average annual mortality of the white oak species group increased by 49 percent in 2013 over the 2008 inventory. **Bur oak blight**—Mature bur oaks in upland forest appear to be most at risk of severe symptoms. Bur oak blight has been found primarily in Iowa, but also in parts of northern Missouri. Average annual mortality for bur oak has increased from 98,000 cubic feet per year in 2008 to 1.4 million cubic feet per year in 2013.

- Multiflora rose was the most commonly observed invasive plant species and was found on 52 percent of the Phase 2 invasive plots surveyed. Japanese honeysuckle and nonnative bush honeysuckles were the next most commonly observed species and occurred on 9 percent and 6 percent of the plots, respectively. Invasive plants are able to alter forested ecosystems by displacing native species and impacting the fauna that depend on them.

- The growing-stock volume on timberland decreased from 16.6 billion cubic feet in 2008 to 16.4 billion cubic feet in 2013, a 2 percent decrease. Although oak species still maintain substantial growing-stock volumes, they had a 3 percent decrease in volume between 2008 and 2013. Meanwhile, less common species such as American beech, yellow-poplar, blackgum, and silver maple, combined for a 20 percent increase in growing-stock volume between 2008 and 2013.

Issues to Watch

- After increasing steadily between the 1972 and 2008 forest inventories, forest land and timberland area has leveled off at an estimated 15.5 million acres and 14.9 million acres, respectively. Much of the increase in the area of forest land and timberland between the 1972 and 2008 inventories was due to the reversion of marginal farmland back to forest land. But the recent increase in farm commodity prices has slowed the reversion back to forest land and timberland, and in some cases, has led to some clearing of forest land for crops. Only about 2 percent of the measurement plots experienced a forest loss or gain from 2008 to 2013, resulting in 450,000 acres of gross forest loss being offset by forest gains of the same magnitude.
- White oak, black oak, post oak, and northern red oak collectively, account for nearly half of the total volume of live trees at least 5 inches d.b.h. on forest land. But the 8 percent increase in volume for these four species from 2003 to 2013 is well below the State's total average increase of 16 percent for all species. Oak dominance in volume reflects large number of mature, overstory trees and a small number of oaks in the understory.
- Missouri's population increased by 7.0 percent between 2000 and 2010, to 6.0 million. During that same time period, the number of housing units increased by 11.1 percent. In recent decades this housing growth has occurred not only in increasing suburban rings, but also in rural areas. This can put additional pressure on forested areas even above the general increases in population and housing density.
- There are several forest insect and disease issues that should be closely monitored. **Emerald ash borer**—Ash trees greater than 1 inch d.b.h. account for almost 4 percent of the total tree species. Continued spread of emerald ash borer could have considerable impact on the health of ashes. **Gypsy moth**—About 66 percent of the live tree volume in Missouri is preferred by gypsy moth. Gypsy moth has not impacted the forest of Missouri yet, but moths have been captured as part of the Gypsy Moth Slow the Spread program. **Thousand cankers disease**—There are an estimated 114.9 million black walnut trees greater than 1 inch d.b.h. on forest land

in Missouri. Thousand cankers disease has not impacted the forest of Missouri yet, but it has the potential to cause extensive walnut mortality and dramatically impact Missouri's forest ecosystem and timber industry.

- A large component of future forest change will be the result of normal forest growth, aging, natural regeneration, and species succession. Projections of future forest conditions through the year 2060 predict that the following external forces will drive forest change: 1) population increases will likely cause some 550,000 acres of forest land to be converted to urban land; 2) unknown future economic conditions will affect forest products consumption, production, and harvest rates; 3) invasive species will spread and affect forest change; 4) changes in population, the economy, energy consumption, and energy production will jointly influence and be affected by changing climate conditions; and 5) climate change will likely affect patterns of forest growth and species succession.
- The regeneration indicator shows that maples, particularly red maple, are poised to expand in the future as stands undergo stand replacement disturbance. This means that silvicultural intervention may be required for establishing young oak regeneration. Very few shortleaf pine seedlings were observed, making this another species to monitor.

Background

Spring Creek Gap autumn. Photo by Missouri Department of Conservation, used with permission.

An Overview of Forest Inventory

What is a tree?

The Forest Inventory and Analysis (FIA) program within the U.S. Department of Agriculture, Forest Service, defines a tree as any perennial woody plant species that can attain a height of 15 feet at maturity. A complete list of the tree species recorded in this inventory can be found in the appendix.

What is a forest?

FIA defines forest land as land that is at least 10 percent stocked by trees of any size or formerly having had such tree cover and not currently developed for nonforest use. The area with trees must be at least 1 acre in size, and roadside, streamside, and shelterbelt strips must be at least 120 feet wide to qualify as forest land. Trees in narrow windbreaks, urban boulevards, orchards, and other nonforest situations are very valuable, too, but are not described in this report.

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

FIA classifies forest land into three categories: timberland, reserved forest land, and other forest land. In 2013, of the 15.5 million acres of forest land in Missouri, 97 percent is timberland, 2 percent is reserved forest land, and 1 percent is other forest land.

Timberland is forest land that is not reserved and meets minimum productivity requirements. Reserved forest land is land that has been withdrawn from timber utilization through legislation or administrative regulation. Most of the reserved forest land in Missouri is in the Mark Twain National Forest. The "other" forest land in Missouri is typically found on sites with poor soils where the forest is incapable of producing 20 cubic feet of wood per acre per year (sometimes referred to as unproductive forest land).

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 not considered reserved;

such lands are declared timberland if they meet minimum productivity requirements or "other" forest if they do not. Timberland does not include reserved forest land.

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), which 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 acreage, 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.

Where are Missouri's forests?

Missouri's geology, geography, and location at the boundaries of several ecological regions have combined to create a unique mix of ecosystems. Missouri's ecological classification system (ECS), modeled after the U.S. Forest Services' approach to ecological classification (Nigh and Schroeder 2002), is a hierarchical framework that helps describe the relationship between Missouri's natural communities and landscapes.

The ECS divides the State into four ecological sections (Fig. 1) and helps explain why Missouri has great species diversity. Each ecological section has unique geologic history, soils, topography, and weather patterns that have resulted in unique assemblages of plants and animals. The four sections are the Central Dissected Till Plains, Osage Plains, Ozark Highland, and Mississippi Alluvial Basin.

The Central Dissected Till Plains includes most of northern Missouri. Historically, much of this landscape consisted of prairie, but today, this area is mostly devoted to agriculture. Forests and woodlands make up a relatively small component and tend to be somewhat fragmented and isolated, but are generally highly productive. The Osage Plains, located in west-central Missouri, was historically dominated by prairie and extensive wetland complexes. Today, this section is also mostly devoted to agriculture. Forests and woodlands are found mostly on steeper slopes and valleys. The Ozark Highlands section, which makes up most of the southern half of the

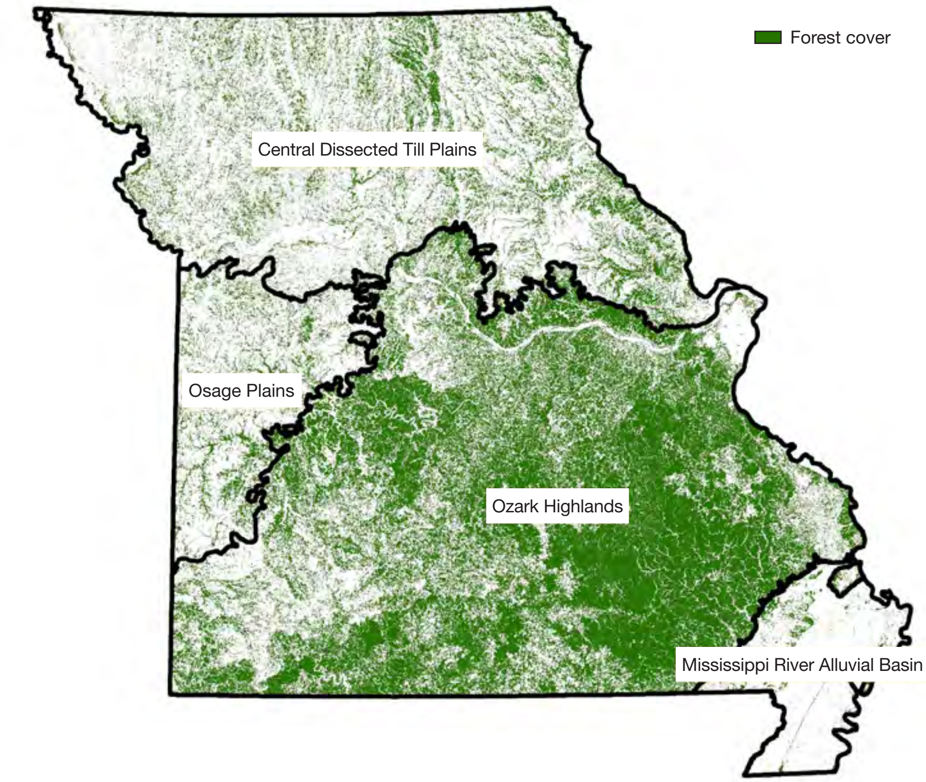


Figure 1.—Missouri's ecological sections and extent of forest cover. Map by Missouri Department of Conservation using 2001 National Land Cover Data and Missouri's Ecological Classification System data (Missouri Department of Conservation 2010).

State, is Missouri's most heavily forested section. Much of the area was historically in forest and woodland, and is still in forest and woodland cover today. The Mississippi Alluvial Basin is found in the extreme southeast corner—the "Bootheel." Historically, most of the area was poorly drained and consisted of marshes, swamps, and bottomland forest land. Most of this area has been drained and converted to cropland. However, there are still substantial but isolated patches of forested areas.

How many trees are there in Missouri?

There are about 8.2 billion trees at least 1 inch in diameter at breast height (d.b.h.; 4.5 feet above the ground) on Missouri's forest land. The exact number of trees is not known because the estimate is based on a sample of the total population. Trees were measured on 3,185 forest plots throughout the State (Fig. 2). For information on sampling errors, see "Missouri Forests 2013: Statistics, Methods, and Quality Assurance", available online at https://doi.org/10.2737/NRS-RB-108.

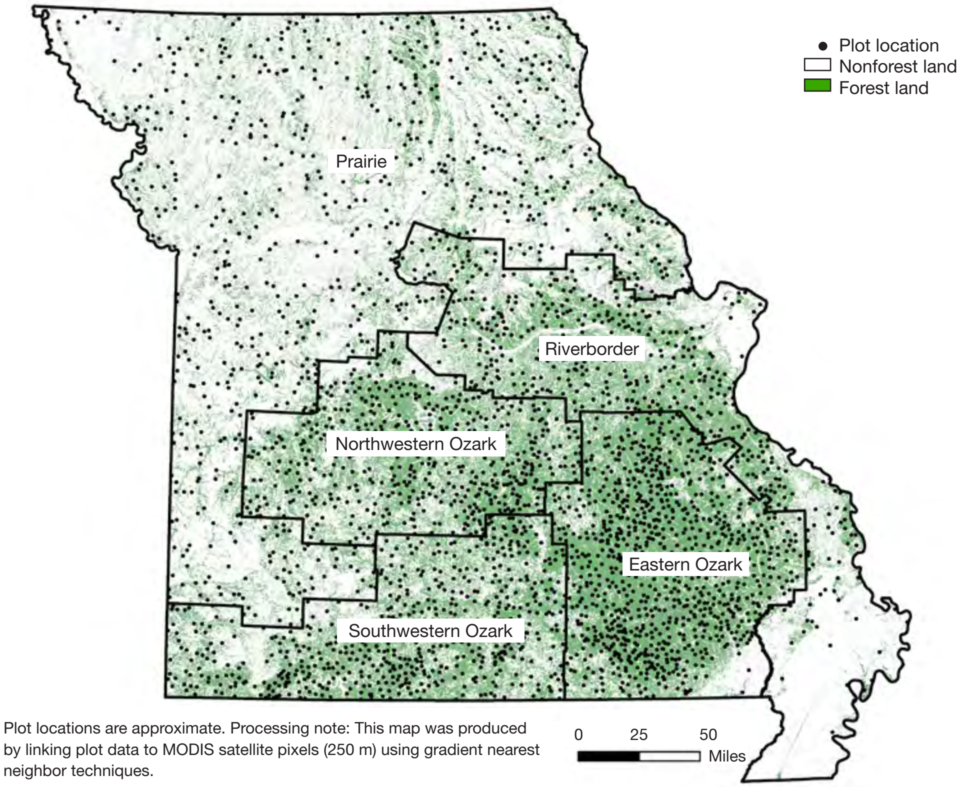


Figure 2.—Distribution of FIA plot locations, forest land, and FIA inventory units, Missouri, 2013. Plot locations are approximate.

How is a tree's volume estimated?

The volume of a tree can be precisely determined by immersing it in a pool of water and measuring the amount of water displaced. Less precise, but more efficient, is the method used by the Northern Research Station (NRS). In this method, 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 species group. Using these models, individual tree volume estimates can be produced based on species, diameter, and tree site index.

The same method was used to determine sawtimber volumes. FIA reports sawtimber volumes in International ¼-inch Rule board foot scale. To convert to Doyle or 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 developed estimates of specific gravity for a number of tree species (U.S. Forest Service 1999). These specific gravities were applied to estimates of tree volume to determine merchantable tree biomass (the weight of the bole). To estimate live biomass, the stump (Raile 1982), limbs, and bark (Hahn 1984) are added. Live biomass of roots or foliage is currently not reported. Forest inventories report biomass as green or oven-dry weight. Green weight is the weight of a freshly cut tree; oven-dry weight is the weight of a tree with 0 percent moisture content. On average, 1 ton of oven-dry biomass is equal to 1.9 tons of green biomass.

How are forest carbon pools estimated?

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 estimated based on stand and site characteristics (e.g., stand age and forest type).

How is data from different inventories compared?

Data from new inventories are often compared with data from earlier inventories to determine trends in forest resources. However, for comparisons to be valid, procedures used in the two inventories must be similar. As a result of FIA's ongoing efforts to improve the efficiency and reliability of the inventory, several changes in procedures and definitions have occurred since the last periodic inventory in 1989. While these changes will have little impact on statewide estimates of forest area, timber volume, and tree biomass, they may have significant impacts on plot classification variables such as forest type and stand-size class. Some of these changes make it inappropriate to directly compare annual inventories (2003, 2008, and 2013) data tables with those published for 1989 and earlier periodic inventories. Note that references to the 1947, 1959, 1972, and 1989 periodic inventories each refer to that single year of inventory, but references to the 2003 (1999 to 2003), 2008 (2004 to 2008), and 2013 (2009 to 2013) annual inventories each refer to the 5-year measurement period for those years.

A word of caution on harvest suitability and availability

FIA does not attempt to identify which lands are suitable or available for timber harvesting. Just because land is classified as timberland does not necessarily mean it is suitable or available for timber production. Forest inventory data alone are inadequate for determining the area of forest land available for timber harvest because laws, regulations, voluntary guidelines, physical constraints, economics, proximity to people, and ownership objectives may prevent timberland from being available for timber production.

How do we produce maps?

A geographic information system (GIS) and various geospatial datasets were used to generate the maps in this report. Unless otherwise indicated, forest resource data are from FIA and base map layers, e.g., state and county boundaries were obtained from the National Map (U.S. Geologic Survey 2016). Depicted FIA plot locations are approximate. Additional FIA data are available at http://fia.fs.fed.us/tools-data/. Sources of other geospatial datasets are cited within individual figures. All Missouri maps are portrayed in the Universal Transverse Mercator Coordinate System, Zone 16N, North American Datum of 1983.

Maps in this report were created using three different methods. The first used categorical coloring of Missouri's counties according to various forest attributes, such as forest land area. These are known as choropleth maps. An example of a choropleth map is Figure 3. The second method used a variation of the k-nearest neighbor technique to apply information from forest inventory plots to remotely sensed MODIS imagery (250 m pixel size) based on the spectral characterization of pixels and additional geospatial information. An example of a map produced using this methodology is Figure 1. The final procedure used colored dots to represent plot attributes at approximate plot locations. Figure 2 is an example of this type of map.

Forest Features

Mina Sauk Falls trail, Taum Sauk Mountain State Park. Photo used with permission of Missouri Department of Conservation.

Area

Background

Healthy Missouri forests provide a wealth of resources and services that are critical to a vibrant society, including wildlife habitat, watershed protection and flood control, groundwater recharge, recreational and scenic amenities, pollinator resources, and a diversity of forest products. Quantifying the amount of land occupied by forests is crucial to assessing the current status and trends in forest ecosystems. Fluctuations in the forest land base may indicate changing land use trends or forest health conditions. Ninety-seven percent of Missouri's forest land is defined as timberland, so timberland trends correspond closely with forest land trends.

What we found

The forest land area of Missouri is currently estimated at 15.5 million acres, almost 35 percent of Missouri's total land area. Ninety-seven percent is timberland, two percent is reserved forest land, and 1 percent is other forest land. The Eastern Ozark Forest Inventory Unit has 28 percent of the State's forest land. More than 70 percent of the land area in the Eastern Ozark Unit is covered by forests (Fig. 3). Both the Northwestern Ozark Unit and the Southwestern Ozark Unit are more than 50 percent forested. Nearly one-third of the land area in the Riverborder Unit is forest land, and 17 percent of the land area in the Prairie Unit is forest land.

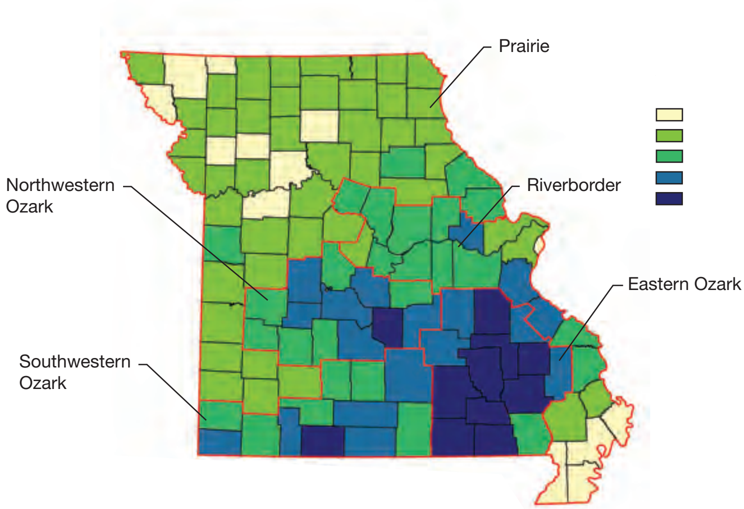


Figure 3.—Area of forest land as a percentage of county land area, Missouri, 2013.

Forest land area increased from 15.4 million acres in 2008 to 15.5 million acres in 2013 (Fig. 4). Timberland area remained at the 2008 level of 14.9 million acres. Reserved forest land increased from 315,000 acres in 2008 to 332,000 in 2013, an increase of 5 percent. Other forest land area posted the largest increase with 165,000 acres in 2008 and 211,000 acres in 2013, a 28 percent increase.

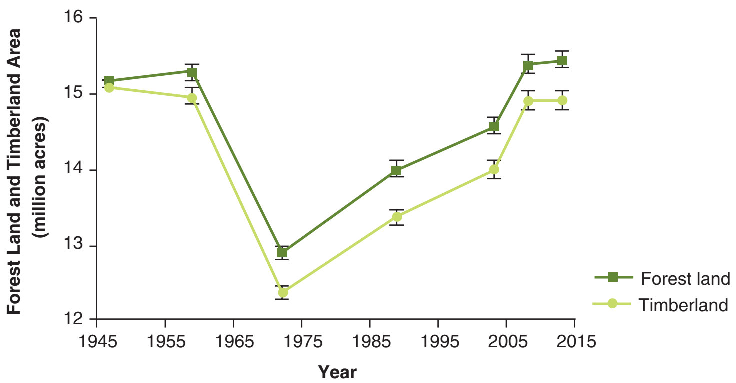


Figure 4.—Area of forest land and timberland by inventory year, Missouri. Error bars represent a 68 percent confidence interval around the estimated mean.

What this means

Forest land area in Missouri has been steadily increasing since the 1972 forest inventory. In 2013, 29 of the State's 114 total counties (25 percent) were at least 50 percent forested. Between 2003 and 2013, 70 percent of the counties reported an increase in forest land area (Fig. 5). Change in forest land area of Missouri is mainly driven by human activities (or lack thereof). Among them, changes in the agricultural economy and development of forest land for urban or residential uses that encourage or discourage shifts from or to forested uses are two of the most prominent. The declining farm economy of the 1960s and 1970s resulted in the reversion of marginal farmland back to forest. But, the increase in farm commodity prices in recent years has slowed the reversion back to forest land, and in some cases, led to some clearing of forest land for crops. While marginal farmland fluctuates between forest land and nonforest land, the clearing of forest land for urban or residential uses is, for the most part, permanent.

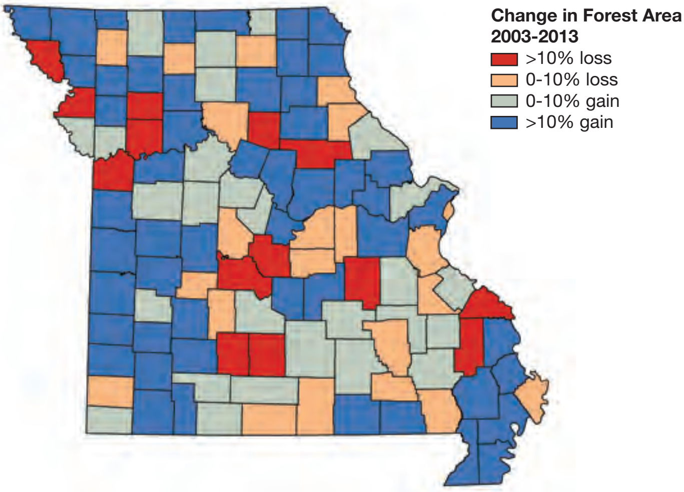


Figure 5.—Change in the area of forest land by county, Missouri, 2003 to 2013.

Land Use Change

Background

Although the total area of forest land in Missouri has remained relatively stable between 2008 and 2013, some areas of the State have experienced forest loss, while others have seen increases in forest land. To better understand Missouri's forest land dynamics, it is important to explore the underlying land use changes occurring in the State.

FIA characterizes land area using several land use categories which can be generalized to these classes: forest, rangeland, agriculture (including pasture and cropland), developed land, water, and other (including undeveloped beach, barren areas, wetlands, ice, or snow). The conversion of forest land to other uses is referred to as gross forest loss, and the conversion of nonforest land to forest is known as gross forest gain. The magnitude of the difference between gross loss and gain is defined as net forest change. By comparing the land uses on current inventory plots with the land uses recorded for the same plots during the previous inventory, we can characterize forest land use change dynamics. Understanding land use change dynamics is essential for monitoring the sustainability of Missouri's forest resources and helps land managers make informed policy decisions.

What we found

Missouri is dominated by agricultural land uses, which cover about 55 percent of the State's area (Fig. 6). Other nonforest areas in the State include developed land (including rights-of-way, 8 percent) and water (2 percent). About 34 percent of Missouri was forested in 2013. Most of the FIA plots in Missouri either remained forested or stayed in a nonforest use (33 percent and 65 percent, respectively), and only 2 percent of plots experienced either a forest loss or gain from 2008 to 2013 (Fig. 7).

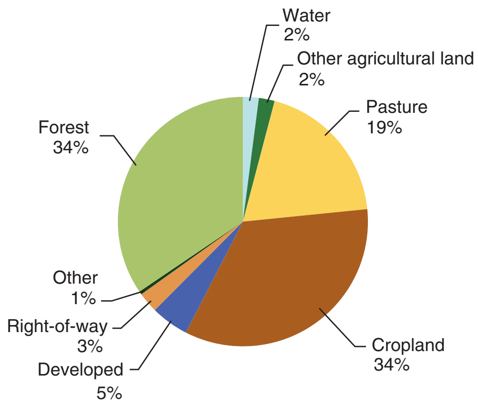


Figure 6.—Land use composition, Missouri, 2013.

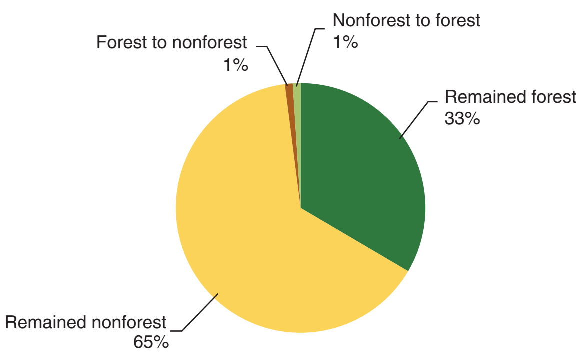


Figure 7.—Proportion of unchanged land area, forest loss, and forest gain, Missouri, 2008 to 2013.

According to the FIA remeasurement data, Missouri's gross forest loss was 450,000 acres and was offset by forest gains of the same magnitude, resulting in no net change in forest land area (Fig. 8). Sixty-seven percent of the gross forest loss was due to diversion to agricultural land uses including pasture (43 percent), cropland (14 percent), and agricultural land (10 percent). Forest was also lost to developed uses (16 percent), rights-of-way (8 percent), water (7 percent) and other uses (2 percent). There was more forest land gained from agricultural uses (77 percent) than was lost to agriculture (67 percent) (Fig. 9).

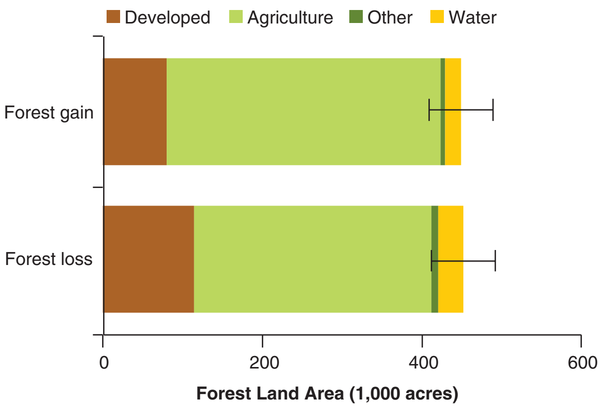


Figure 8.—Forest loss and forest gain by land-use category, Missouri, 2008 to 2013.

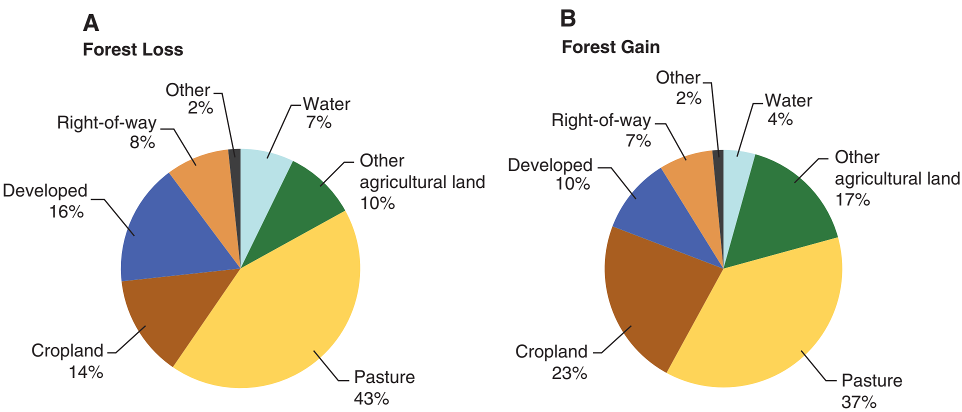


Figure 9.—Forest loss (A) by current land use and forest gain (B) by previous land use, Missouri, 2008 to 2013.

FIA data can be used to characterize the forest land that has been lost and gained to see if it differs from the characteristics of forest land in all of Missouri. The forests of Missouri are dominated by stands in the large diameter size classes with only 9 percent of forests in small diameter stands. However, the forest land that has been gained has a greater proportion of small diameter stands (38 percent). Similarly, the forest land that has been lost has a greater proportion of small diameter stands (38 percent) than in Missouri as a whole.

Figure 10 shows the distribution of remeasured plots across Missouri, highlighting plots on which 25 percent or more of the area has experienced a lost or gain in forest land. Forest change plots appear to be distributed throughout the State with no strong spatial pattern.

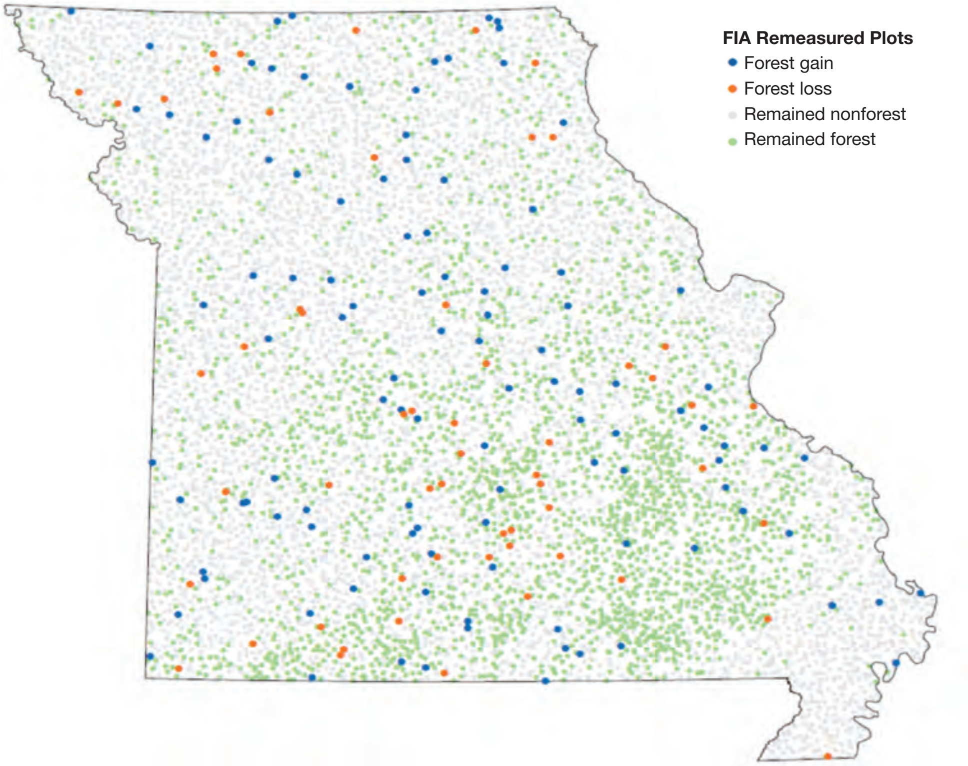


Figure 10.—Distribution of remeasured inventory plots showing forest gains and losses, Missouri, 2008 to 2013. Plot locations are approximate.

What this means

Agriculture is the dominant land use in Missouri and gains and losses in pasture, cropland, and other agricultural land appear to drive much of the land use change dynamics in the State. Forest losses to agricultural uses in Missouri may be a result of prices paid for agricultural crops. With increased interest in domestic fuel sources, there may be increased demand for suitable cropland for biofuel crops.

Gains in forest land may come from reverting agricultural land, usually land in close proximity to streams. There has been a concerted effort in the State's public and private sectors to prioritize the reforestation of these riparian areas. Agroforestry efforts promote the maintenance of tree cover in the form of windbreaks and forest buffers that help sustain a high agricultural output while conserving and protecting Missouri's soil and water resources. These forested areas are also important to Missouri's wildlife populations. Riparian forests often connect to form wildlife corridors which allow for greater species movement.

Some of the gains and losses of forest land in Missouri may be from marginal forest land moving into and out of the forest land base. 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. These fluctuations likely contribute to the losses from and gains in developed land and rights-of-way. Permanent forest loss to development may also be occurring, especially near Missouri's larger cities including St. Louis, Kansas City, and Springfield, where surrounding counties have experienced population growth rates higher than the state average. Overall, however, the pressure from population growth has been low in Missouri with the State's population growth (0.9 percent) from 2010 to 2013, well below the national average (2.5 percent; U.S. Census Bureau, N.d. b). The area of forest land lost to development is relatively small. Rather, the primary land source for new development in Missouri is agriculture. Seventy-eight percent of the gains in developed land come from converted agricultural land versus 18 percent from forest land.

For this most recent Missouri inventory, gains in forest land equaled forest loss; this is a change from the results of the last inventory cycle from 2004 to 2008 when gross gains in forest land were more than twice as large as gross forest loss (Raeker et al. 2011). The difference in net change between the two inventory periods can be attributed primary to a decrease in the amount of nonforest land that reverted to forest; the amount of gross forest loss remained relatively stable between the two inventory cycles. The extent of forest cover may be starting to stabilize in Missouri after a period of growth since the 1970s.

Ownership

Background

The fate of Missouri's forest lies in the hands of the people, organizations, and governing bodies that own it. The goods and services produced and provided by forests are a function of the forest land owners' objectives, opportunities, and constraints. Continued pressures from a changing society alter what landowners can and will provide. FIA conducts the National Woodland Owner Survey (NWOS) to better understand who owns the forest, why they own it, and how they use it (Butler et al. 2016a, b). Because NWOS is a separate and supplementary survey from traditional FIA plot measurement, estimates obtained from the two surveys may not be exactly the same. The most recent survey was conducted from 2011 to 2013.

What we found

Three-fourths of the forest land in Missouri is owned by private individuals, and another 6 percent is owned by private corporations, local associations or clubs, and nongovernmental conservation or natural resource organizations (Fig. 11). The Mark Twain National Forest is the largest public forest land owner with 10 percent of all of the forest land in the State, followed by State ownership at 5 percent. Only 2 percent of the forest land in Missouri is owned by other federal agencies, and 1 percent is owned by local county or municipal governments.

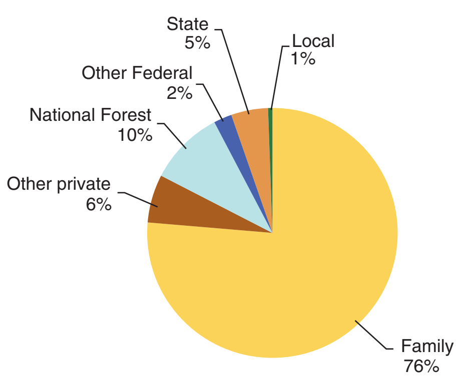


Figure 11.—Distribution of forest land by public and private ownership, Missouri, 2013.

According to the NWOS, there are an estimated 212,000 family forest ownerships across Missouri that each own at least 10 acres of forest land, a collective 11.0 million acres. The average forest holding size of this group is 51 acres; 69 percent of these family forest ownerships is less than 50 acres of forest land, but 73 percent of the family forest land is in holdings of at least 50 acres (Fig. 12). The primary reasons for owning forest land are related to aesthetics, wildlife, privacy, and nature protection (Fig. 13). 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. 14). Most family forest ownerships did not participate in traditional forestry management and assistance programs in between 2009 and 2013. The average age of family forest owners in Missouri is 61 years with 39 percent of the family forest land owned by people who are at least 65 years of age (Fig. 15).

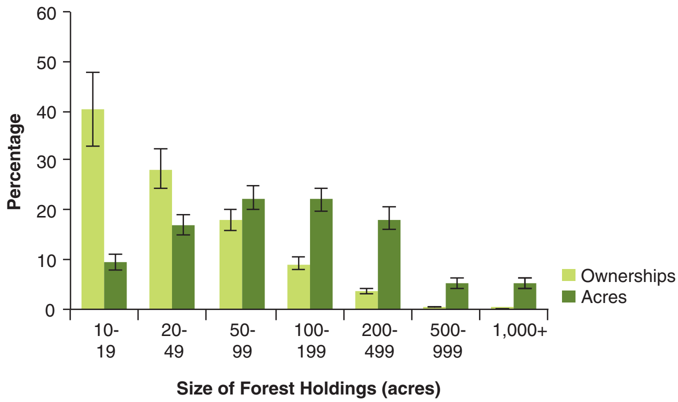


Figure 12.—Percentage of family forest ownerships and acres of forest land by size of forest land holdings, Missouri, 2013. Error bars represent a 68 percent confidence interval around the estimated mean.

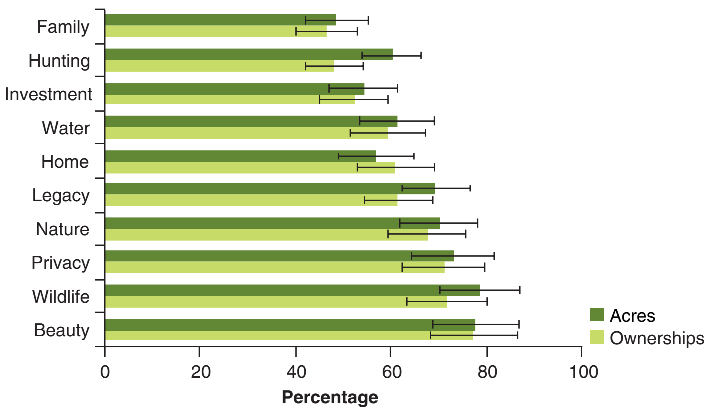


Figure 13.—Percentage of family forest ownerships and acres of forest land by reasons for owning forest land ranked as very important or important, Missouri, 2013. Categories are not exclusive. Error bars represent a 68 percent confidence interval around the estimated mean.

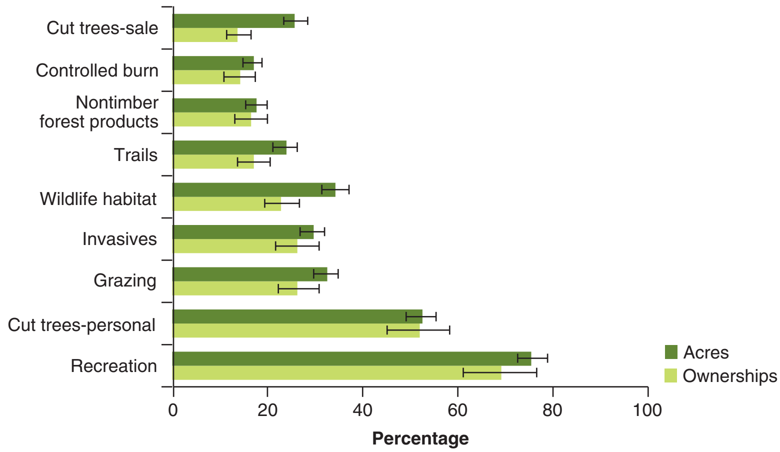


Figure 14.—Percentage of family forest ownerships and acres of forest land by forest activity in the past 5 years, Missouri, 2013. Categories are not exclusive. Error bars represent a 68 percent confidence interval around the estimated mean.

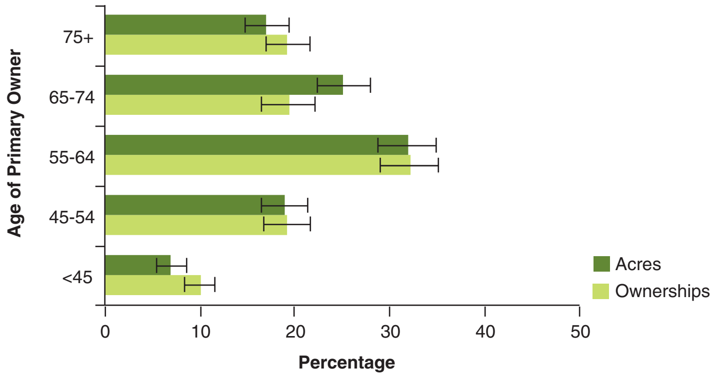


Figure 15.—Percentage of family forest ownerships and acres of forest land by age of primary owner, Missouri, 2013. Categories are not exclusive. Error bars represent a 68 percent confidence interval around the estimated mean.

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, an estimated 95 percent of them do not have a management plan nor have they participated in most other traditional forest management planning or assistance programs. There are significant opportunities to help these owners increase their engagement and stewardship of their lands. The Missouri Department of Conservation provides landowners information and links to resources for stewardship of their lands at http://mdc.mo.gov/your-property. The Missouri Consulting Foresters Association website allows users to find consulting foresters for hire based on location, desired services, and certifications. 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.

Species Composition

Background

The species composition of a forest drives the dynamics of its growth, development, and ecosystem function. Forest composition is constantly changing. Influenced by the presence or absence of disturbances such as timber management, recreation, wildfire, prescribed burning, extreme weather, and invasive species, the current state of species composition is a reflection of historical and environmental trends within a forest. As a result, the composition of species in a forest is an indicator of forest health, growth, succession, and the need for stand improvement, i.e., management. Knowledge of the distribution of species within a stand allows for the measurement and prediction of change.

What we found

Missouri's forest land contains 8.2 billion trees (greater than 1 inch d.b.h.) representing 93 different tree species (see appendix for common and scientific names of trees recorded in Missouri). Between 2008 and 2013, the number of live trees greater than 1 inch d.b.h. on forest land decreased by 4 percent. Eastern redcedar, which replaced white oak as the most numerous tree species in 2008, remains the most numerous tree species in 2013 (Fig. 16). The next four most numerous trees species have all decreased in number since 2003: white oak by 7 percent, flowering dogwood by 19 percent, black oak by 21 percent, and post oak by 16 percent. The number of hackberry trees increased by more than 40 percent from 2003 to 2013, moving it from the fourteenth most numerous tree in 2003, to the ninth in 2013.

In contrast to the number of trees, the volume of live trees increased by 4 percent between 2008 and 2013 (Fig. 17). The top four species by volume are oaks (white oak, black oak, post oak, and northern red oak), which when combined, account for nearly half of the total volume of all live trees at least 5 inches d.b.h. on forest land in Missouri.

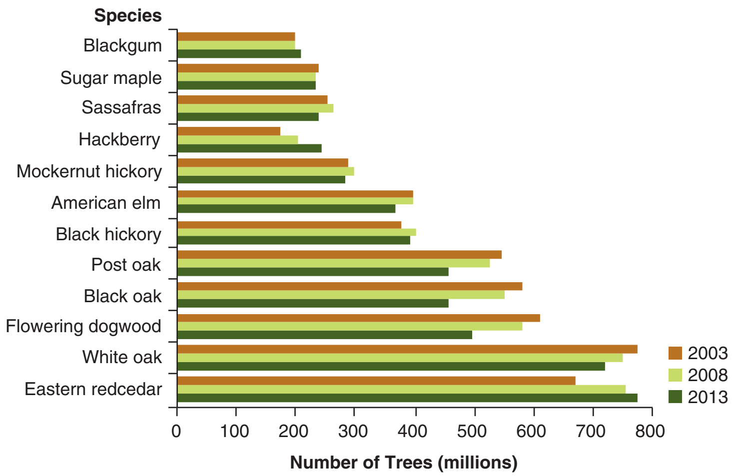


Figure 16.—Number of live trees on forest land for common species by inventory year, Missouri.

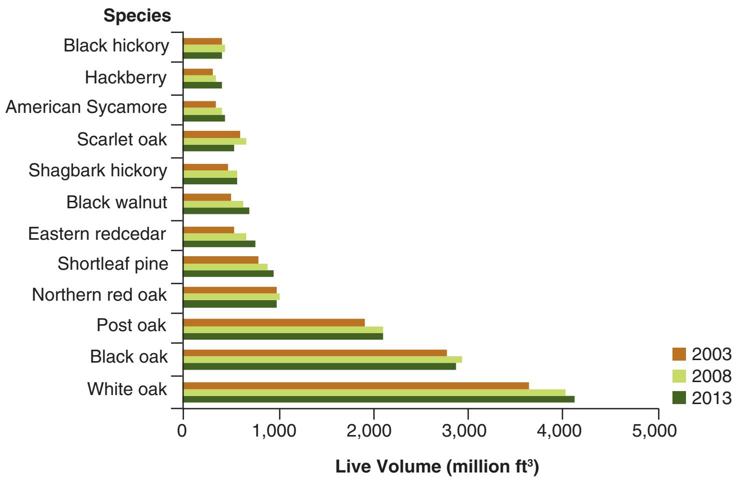


Figure 17.—Volume of live trees on forest land for common species by inventory year, Missouri.

In general, oaks are dominant throughout the State. Nineteen species of oak were recorded on forest land, accounting for 58 percent of the total live tree volume. Eastern redcedar fell to sixth in terms of volume, but it also had the largest increase in volume of the top 12 species between 2003 and 2013, with a 39 percent increase. Scarlet oak was the only “top 12” species to decrease in volume between 2003 and 2013.

What this means

The composition of Missouri’s forests and the dominance of individual tree species continue to evolve. With a 10 percent increase in volume between 2003 and 2013, oaks continue to dominate, but the increase is well below the State’s overall average volume increase of 16 percent for all species. Oak dominance in volume reflects large numbers of mature, overstory trees and little oak regeneration in the understory. The high mortality rate of these mature oaks has led to a decrease in the total volume between 2003 and 2013. Due to fire suppression over the last 50 years, the presence of fire-intolerant species has increased dramatically. The number of eastern redcedar trees has increased by 15 percent since 2003. Though eastern redcedar has beneficial characteristics, it can have negative impacts if it replaces other species. Dense stands of eastern redcedar can form monocultures, decreasing or eliminating plant and animal species diversity, and decrease understory vegetation and groundcover that can lead to soil erosion. In addition, eastern redcedar contains volatile oils that make it very flammable under the right conditions.

Forest Tree Diversity

Background

The diversity of a forest may be defined by a variety of factors, including differences in overstory tree species or size, diversity of understory species, and/or some variation in spacing. Each of these factors provide different types of habitat for wildlife. In addition, a diverse forest has the potential to be more resilient in the face of disturbances. The Shannon Diversity Index (SDI) for species measures a combination of the number of species and the relative distribution of those species (Magurran 1988). SDI by itself is not a measure of forest health, but it can be used, along with other factors, to evaluate a forest’s health. Depending on what the forest is being evaluated for (e.g., a specific wildlife species), a high SDI is not necessarily better than a low SDI. In this report, the SDI was applied to the tree species in individual forest types in each Forest Inventory unit.

What we found

There are pockets of high and low tree species diversity in Missouri forests (Fig. 18), with lower diversity plots more prominent in the northern and western part of the State, and higher diversity plots more prominent in the southeastern part of the State. Across the State, three of the five Forest Inventory units have had a steady increase in the calculated SDI for live trees on timberland since 1989, with the current inventory only indicating a loss in diversity in the Prairie Unit when compared to the 2003 inventory (Fig. 19). Looking at tree species diversity by forest type, the data suggest that the major oak forest types (post oak/blackjack oak, white oak/red oak/hickory, white oak, and northern red oak) have a relatively diverse tree species composition across the State for all the Forest Inventory units (Fig. 20). For other forest types, such as chestnut oak/black oak/scarlet oak and sycamore/pecan/American elm, the tree species diversity differs depending on where they are located in the State. The white oak/red oak/hickory forest type, which accounts for nearly 45 percent of the total timberland area in Missouri, has the highest average SDI at 3.2.

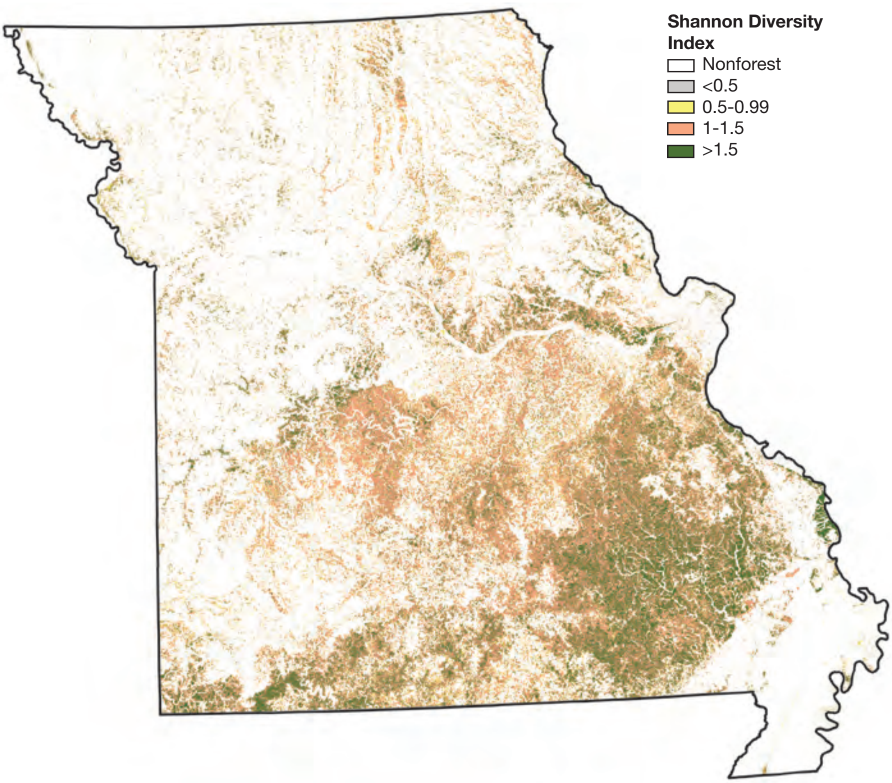


Figure 18.—Shannon Diversity Index (SDI) scores for live trees on timberland, Missouri, 2013.

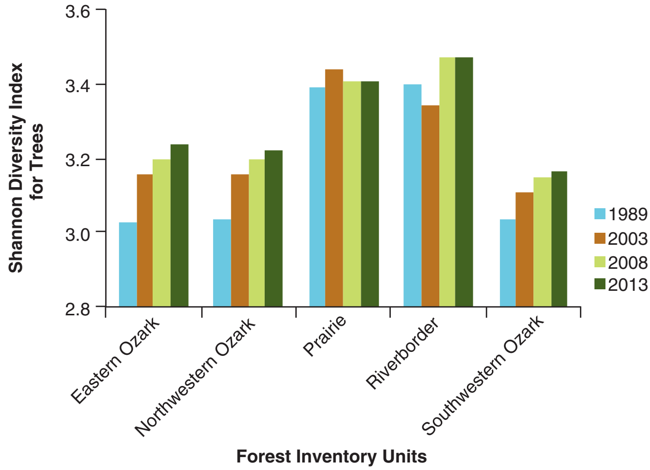


Figure 19.—SDI for live trees on timberland by Forest Inventory unit and inventory year, Missouri.

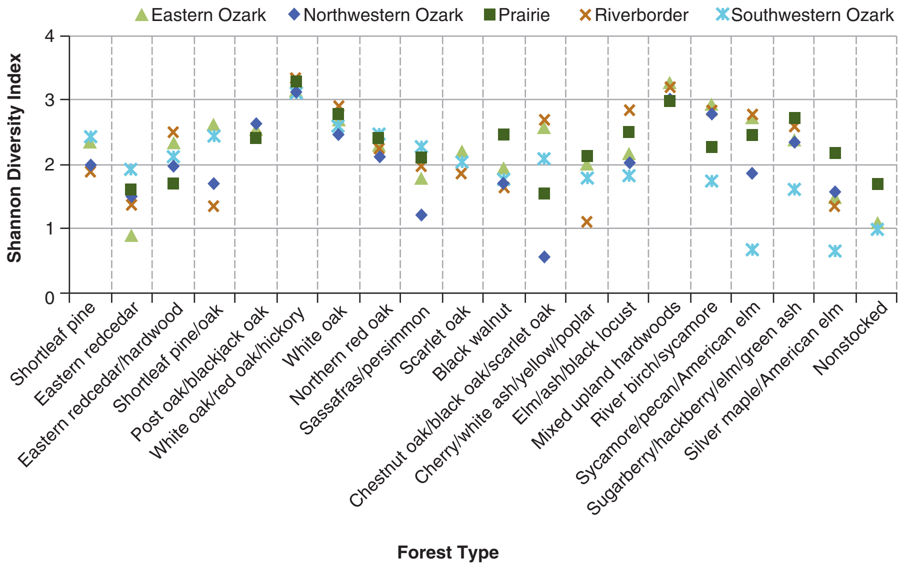


Figure 20.—SDI for live trees on timberland by forest type and Forest Inventory unit, Missouri, 2013.

What this means

Climatic and site-productivity factors and natural disturbances, such as storms, can influence the number of species on a particular site. Low or high soil moisture not only limits the potential for species to even exist on a site, but also impacts species that can tolerate such extremes by reducing their total potential productivity. Thus, we see less tree species diversity in the eastern redcedar forest type, which tends to be found on dry uplands, abandoned fields, limestone outcrops, and other shallow soils, and in the silver maple/American elm forest type, which tend to be found on wetter sites along river bottoms and floodplains.

Forest Density

Background

The density of a forest indicates the current phase of stand development and has implications for diameter growth, tree mortality, and yield. Density is typically measured in terms of number of trees or basal area per unit area. Stocking, a relative measure of density, represents the degree of tree occupancy required to fully utilize the growth potential of the land.

What we found

While the density of Missouri's timberland experienced a period of increase following the 1989 inventory, the number of live trees per acre has decreased since 2003 (Fig. 21). In contrast, the average volume of live trees per acre continues to increase; currently total live tree volume is an estimated 1,360 cubic feet per acre (Fig. 22). Forty-four percent of Missouri timberland is moderately stocked and 43 percent is fully stocked (Fig. 23). Poorly stocked stands represent 9 percent of timberland, and overstocked stands represent less than 4 percent. Nonstocked stands, which account for less than 1 percent of timberland, are stands that have been recently harvested and regeneration has yet to begin.

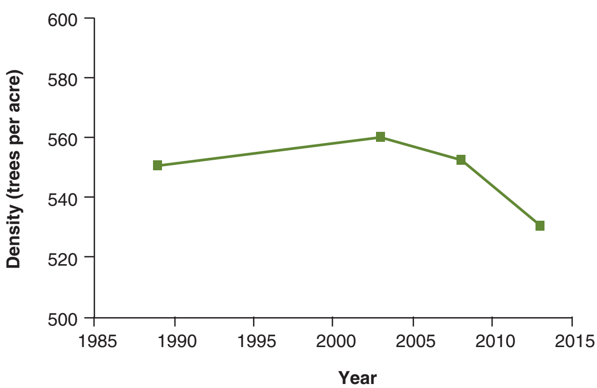


Figure 21.—Density of live trees on timberland by inventory year, Missouri.

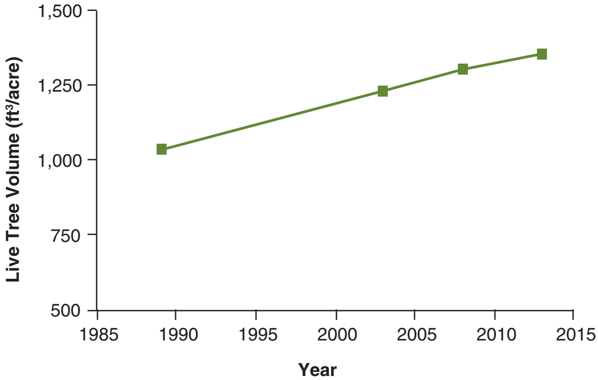


Figure 22.—Live tree volume per acre on timberland by inventory year, Missouri.

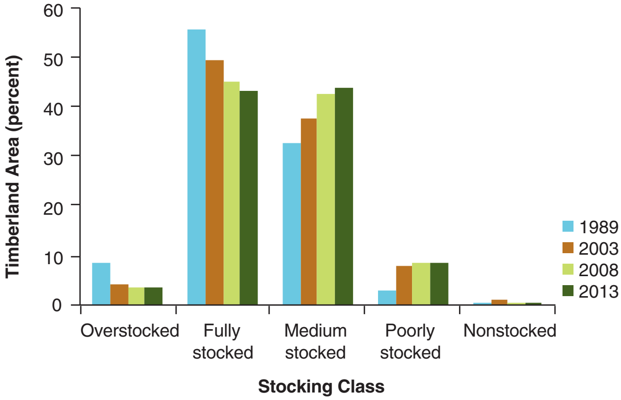


Figure 23.—Area of timberland by stocking class and inventory year, Missouri.

What this means

Decreasing numbers of trees and increasing volume are indicative of a maturing forest resource. In the absence of natural or human disturbance this trend can be expected to continue until stands reach a state of senescence. Current stocking levels indicate adequate growing conditions, but also show a trend towards fewer fully stocked stands. The area of fully stocked and overstocked stands has decreased while the area of medium stocked and poorly stocked stands has increased. As trees grow and put on additional volume, stands face an increased stagnation issues, including density-induced mortality.

Stand-size Class

Background

Forests usually contain trees of various sizes. Stand size is a measure of the average diameter of the dominant trees in a stand. There are three stand-size classes: large diameter—softwood trees at least 9 inches d.b.h. and hardwoods at least 11 inches d.b.h.; medium diameter—softwood trees from 5 to 9 inches d.b.h. and hardwood trees from 5 to 1 inches d.b.h.; and small diameter—trees less than 5 inches d.b.h. Nonstocked stands may have trees in any size class but do not have enough trees present to be classified as a stocked stand, so they are not grouped into a stand-size class. Changes in the distribution of stand-size class over time provide information about forest sustainability and succession, wood potentially available for products and wildlife habitat, and potential recreational opportunities.

What we found

Large-diameter stands continue to predominate in Missouri's forest land (Fig. 24). Since 2003, the area of large diameter stands has increased by 25 percent and now occupies 9.4 million acres, or 60 percent of the forest land area. At the same time, medium diameter stands declined by 14 percent and small diameter stands declined by 15 percent, falling to 4.7 million acres and 1.3 million acres, respectively. Less than 1 percent (76,000 acres) of the forest land is nonstocked. Nearly three-quarters of the forest land in the Riverborder Unit is in the large diameter size class, and only 7 percent is in the small diameter size class (Fig. 25). The other four Forest Inventory units have a better distribution of size classes between large diameter and medium diameter stands, but no unit has more than 10 percent of the forest land in small diameter stands.

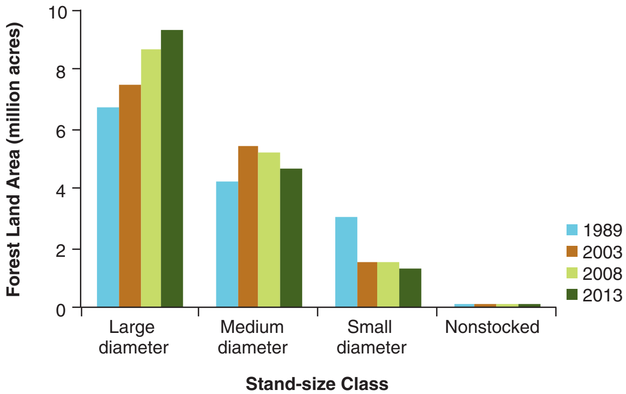


Figure 24.—Area of forest land by stand-size class and inventory year, Missouri.

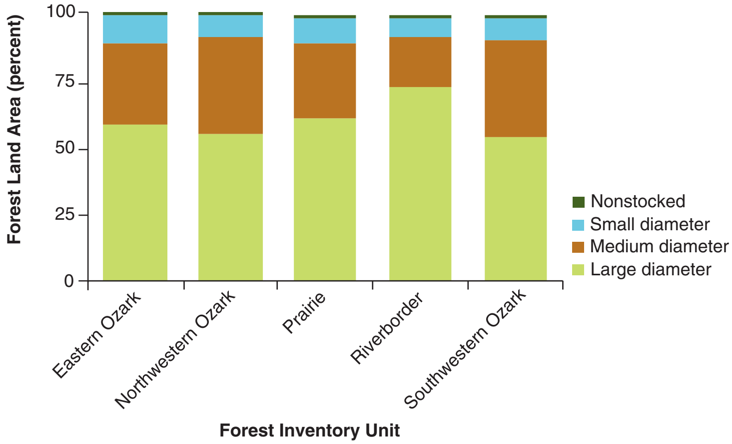


Figure 25.—Percentage forest land by Forest Inventory unit and stand-size class, Missouri, 2013.

What this means

Over the years, the distribution of forest tree diameters in Missouri has increased. The large proportion of total area in large diameter trees indicates a maturing forest. The expansion of large diameter stands suggests that harvesting, flooding, or other natural disturbances are reducing few stands to early successional stages. Four of the eight most common forest types in the State have less than 5 percent of their forest land area in small diameter stands: white oak (1 percent); post oak/blackjack oak (4 percent); shortleaf pine/oak (3 percent); shortleaf pine (1 percent) (Fig. 26). Oak species account for nearly 20 percent of the total number of seedlings on forest land, but with the exclusion of fire and decline in timber harvesting, more shade-tolerant species such as red maple are becoming more abundant in the understory. Shortleaf pine is a species that warrants continued monitoring because it accounts for less than 1 percent of the seedlings on forest land. Shortleaf pine is a shade-intolerant species and does not survive or grow well when suppressed.

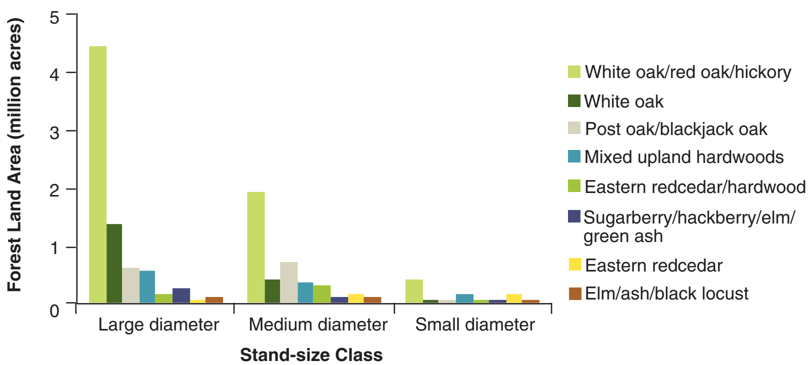


Figure 26.—Area of forest land by stand-size class and 8 most common forest types, Missouri, 2013.

Stand Age

Background

The age of a forest can determine its growth, suitability for a particular species of wildlife, or potential for economic use. Stand age is closely correlated to stand-size class; the smaller trees tend to be the younger trees and the larger trees tend to be the older trees. Forest age can help us figure out whether a past disturbance was caused by weather, insects, disease, or humans. It can also help us predict the forest's susceptibility and response to disturbance.

What we found

More than 70 percent of Missouri's forest land has a stand age over 50 years (Fig. 27). Between 2003 and 2013, forest land stands greater than 50 years old have increased by 31 percent, while the stands 50 years old or younger have decreased by 28 percent. Stands in the 75- to 100-year age class had the largest increase (59 percent), and stands in the 0- to 10-year age class had the largest decrease (54 percent). In 2013, there was almost 2½ times as much forest land dominated by trees greater than 100 years old as there were stands that were 1 to 10 years old. Only 8 percent of the forest land in the white oak forest type and 14 percent in the shortleaf pine/oak forest type have a stand age of 50 years or less (Fig. 28). The elm/ash/black locust and eastern redcedar forest types are the youngest of the common forest types, with 70 percent and 69 percent respectively, of the area 50 years or younger in age.

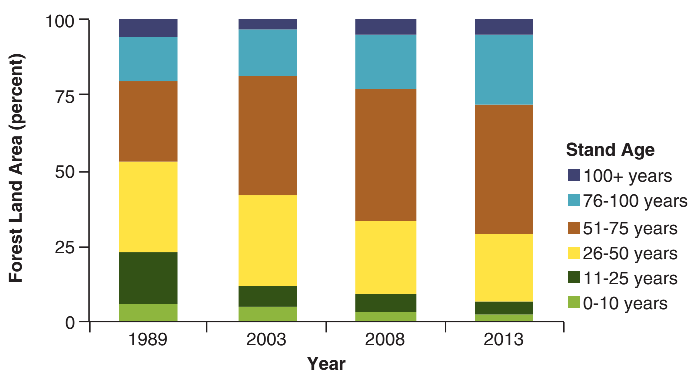


Figure 27.—Distribution of forest land by stand-age class and inventory year, Missouri.

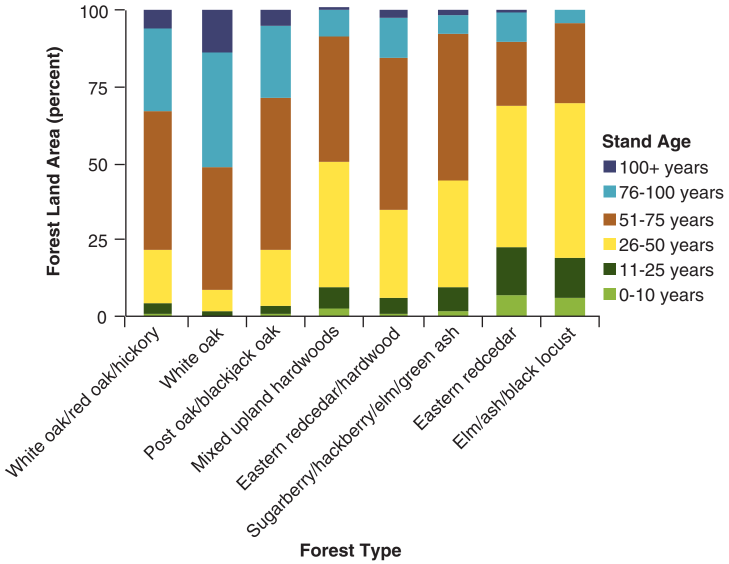


Figure 28.—Proportion of forest land area for selected forest types by stand-age class, Missouri, 2013.

What this means

Most of the stands in Missouri forests are more than 50 years old, and oak stands are generally older. Most oaks require disturbances such as fire and timber harvesting, which promote regeneration by allowing sunlight to reach oak seedlings on the forest floor. In the absence of stand disturbances, shade-tolerant hardwoods (e.g., maples) in the midstory are replacing oaks. Oaks are important for Missouri's timber products industry and provide woodlot owners income from harvesting. With few large, high quality oaks likely to come from Missouri's woodlots, income and value-added economic activity may decrease. Further, certain wildlife species would be adversely affected by fewer oaks. Generally, older oaks are prolific seed producers, benefiting mast-eating wildlife. However, with fewer young oaks available to eventually replace the older oaks as they die or are harvested, these wildlife species could be negatively impacted.

Biomass

Background

Tree biomass is the total dry weight of all live aboveground components of forest trees including boles, stumps, tops, and limbs. In commercial timber harvesting, the bole usually is the primary product because it contains wood used as lumber or veneer. Biomass estimates are increasingly important for carbon sequestration, fiber availability for fuel, and fuel load analyses.

What we found

The amount of live tree and sapling biomass on Missouri forest land and timberland has steadily increased since 2003, and currently is estimated at 641.4 million dry tons and 619.8 million dry tons, respectively (Fig. 29). Statewide, 72 percent of total biomass is contained in growing-stock trees; 19 percent is in non-growing-stock trees; and 9 percent is in saplings (Fig. 30). There is an average of 42 dry tons of biomass per acre of forest land, but 7 of the 10 counties on the eastern edge of the Riverborder Unit have an average of more than 50 dry tons per acre (Fig. 31). In general, these counties contain little forest land area, but 90 percent of this small forest land area is in the large diameter stand-size class. Biomass on private forest land is more than four times greater than biomass on public forest land; however, public forest land contains more biomass per acre (44 tons per acre on public forest land versus 41 tons per acre on private forest land).

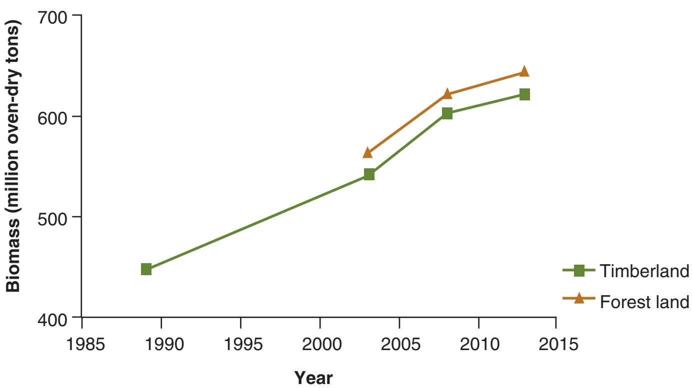


Figure 29.—Live tree and sapling biomass on forest land and timberland by inventory year, Missouri.

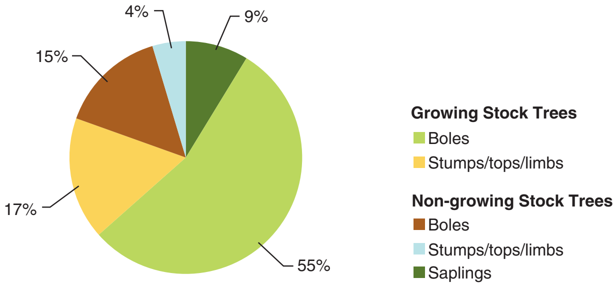


Figure 30.—Forest biomass on forest land by tree component, Missouri, 2013.

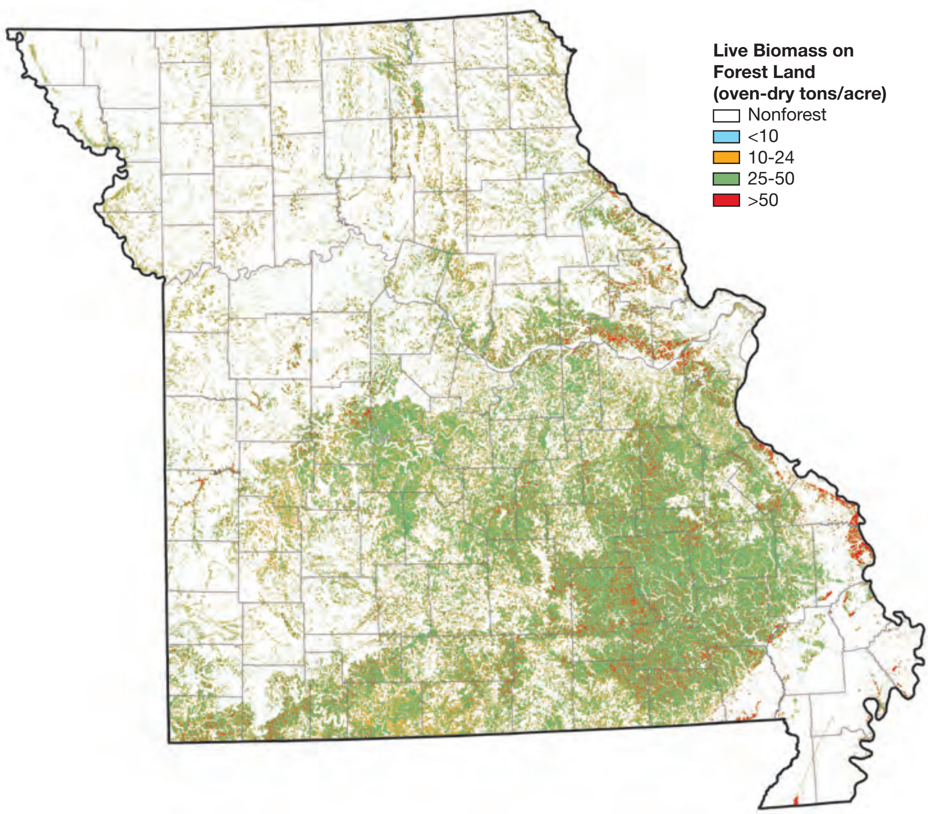


Figure 31.—Distribution of live-tree and sapling biomass on forest land, Missouri, 2013.

What this means

The increase in live tree biomass on forest land in Missouri is driven by the increase in large diameter trees. As holders of the majority of forest land, and thus most of the biomass, private forest landowners play an important role in sustaining this resource.

Because most of the forest biomass is found in the boles of growing-stock trees, the management of forests is closely tied to the dynamics of carbon storage and future wood availability. Given the increasing demand to manage biomass components for bioenergy and carbon, monitoring forest biomass will become more critical.

Carbon Stocks

Background

Carbon has become a part of forest resource reporting in recent years because forests sequester carbon from the atmospheric greenhouse gas carbon dioxide, which is linked to global 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 greenhouse gas emissions. For example, carbon sequestration by U.S. forests represented an offset of over 11 percent of total U.S. greenhouse gas emissions in 2013 (US EPA 2015); the continuing increase in Missouri forest carbon stocks contributes to this effect.

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. Over time, this stored carbon also accumulates in dead trees, woody debris, litter, and forest soils. In most forests, the understory grasses, forbs, and nonvascular plants, as well as wildlife, represent minor pools of carbon stocks. 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, for example. From a greenhouse gas reporting perspective, it is important to note that not all losses result in release of carbon dioxide to the atmosphere; some wood products represent continued long-term carbon sequestration.

The carbon pools discussed in this report include live tree and sapling components (saplings, merchantable boles, stumps, tops and limbs, and live tree roots), standing dead trees, down dead wood, forest floor litter (other nonliving plant material), understory vegetation, 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 (2014a,b), 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 aims to improve the estimates (US EPA 2015). The carbon estimates for Missouri forests are consistent with the data and 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 (US EPA 2015).

What we found

Total forest ecosystem carbon stocks in Missouri are estimated to be 830 million tons carbon, a 3 percent increase compared to 5 years ago. Live trees and soil organic carbon account for 87 percent of forest carbon stocks, and 27 percent of carbon is in the wood and bark of the bole of trees at least 5 inches d.b.h (Fig. 32). Average aboveground carbon per acre increases with stand age, and greater net accumulation is within biomass (Fig. 33). The other softwood forest-type group has the greatest average total ecosystem carbon per acre in the State, at 77 short tons per acre (Fig. 34). The elm/ash/cottonwood forest-type group contains the second most total ecosystem carbon per acre at 71 short tons per acre.

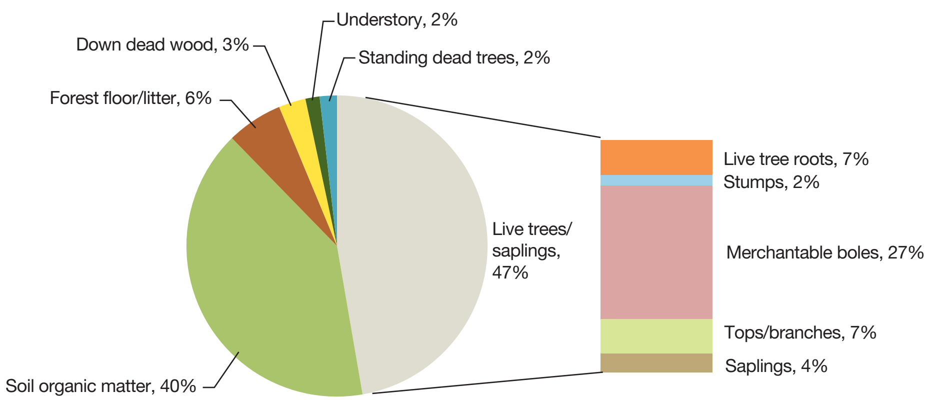


Figure 32.—Percentage of total Missouri forest carbon stocks by forest carbon component, Missouri, 2013. Note that live tree carbon is subdivided into live tree components.

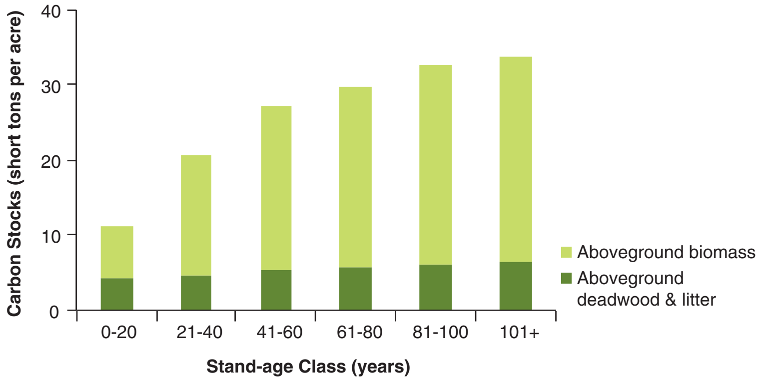


Figure 33.—Carbon stocks for aboveground biomass by stand-age class, Missouri, 2013.

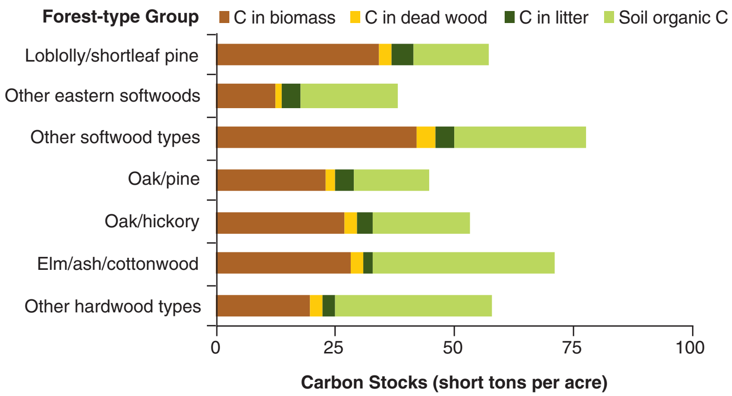


Figure 34.—Average ton per acre of carbon by forest-type group and biomass component, Missouri, 2013.

Sixty-four percent of total aboveground carbon stocks are found in stands 41 to 80 years of age; in contrast, 25 percent of the forest carbon stocks are in stands greater than 80 years of age, and only 11 percent is found in stands less 40 years of age, or younger. The oak/hickory forest-type group, which accounts for the majority of the forest land area in the State, accounts for 80 percent of the total carbon stocks. The largest single pool of forest carbon stocks is the biomass component within the oak/hickory forest-type group, which accounts for 40 percent of all of Missouri's forest carbon stocks.

What this means

The largest pool, aboveground carbon in live trees and saplings, is influenced by timber harvesting and other disturbances. It is this pool that can be most affected by forest management. Thinning stands can keep them growing at optimal rates, while the removed wood is stored in products or is used as fuel, potentially offsetting the burning of fossil fuels. Soil carbon, the second largest pool, is important to long-term carbon sequestration, but because changes to it are slow, there are few opportunities to manage for it in the near term. Managing forests for carbon in combination with other land management objectives will require careful planning and creative silviculture beyond simply managing to maximize growth and timber yield.

In general, forest carbon stocks or differences in stock broadly reflect other measures of forest resources such as stand age, volume, or stocking. However, these summaries offer a reference measure of carbon stocks for the State relative to published regional or national forest carbon reports, thereby providing a ready estimate of the role of Missouri's forests.

Timberland Growth, Mortality, and Removals

Background

The capacity of forests to grow wood is an indicator of health, vigor, and development stage of trees in stands. Forest growth is expressed as average annual net growth, which is gross growth minus mortality; growth is typically measured in terms of increasing wood volume. Mortality volume is the volume of wood in trees that have died from natural causes. Tree mortality is caused by factors such as disease, insect attack, physical damage, weather, and old age; these factors often occur in combination with one another. Removals volume is the volume of wood removed from stands through timber harvesting, cultural operations (e.g., timber stand improvement), land clearing, and changes in land use. Forest growth, tree mortality, and tree removals are computed by measuring the volume of trees at two points in time and determining the average annual change in volume over the period. One measure of sustainability is the ratio of average annual net growth to average annual removals (G/R). A number greater than 1.0 indicates the volume of the species is increasing. A number less than 1.0 indicates the volume is decreasing.

What we found

Since the sharp rise in the rate of growing-stock growth on Missouri timberland between 1989 and 2003, the rate has decreased, falling to 328.3 million cubic feet per year in 2013 (Fig. 35). More than 90 percent of net growth resulted from growth in hardwoods. Nearly 70 percent of the net growth occurred in the select white oaks, other red oaks, hickory, and other eastern soft hardwoods species groups (Fig. 36). Collectively, white oak, black oak, post oak, northern red oak, and pin oak account for 47 percent of total growth.

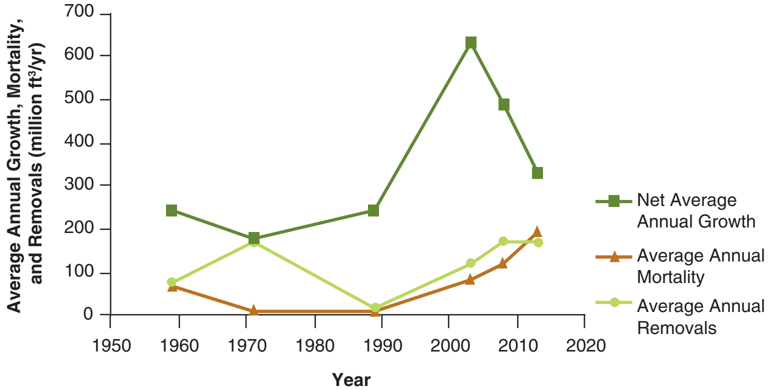


Figure 35.—Average annual net growth, mortality, and removals of growing-stock trees on timberland by inventory year, Missouri.

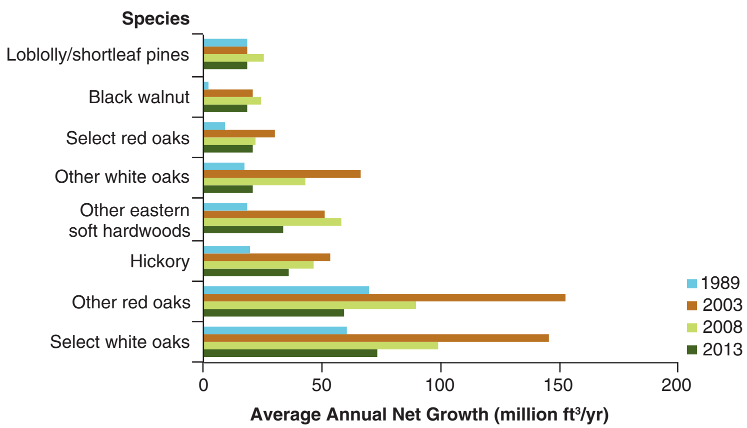


Figure 36.—Average annual net growth of growing-stock trees on timberland by species group and inventory year, Missouri.

An average of 189.8 million cubic feet of growing stock on timberland died each year (average annual mortality) between 2008 and 2013, an increase of 54 percent from the mortality rate of the 2003 to 2008 inventory period. Greater than one-third of the total mortality was from the other red oak species group (Fig. 37). Black oak, white oak, scarlet oak, post oak, and northern red oak collectively accounted for 55 percent of the total mortality in 2013.

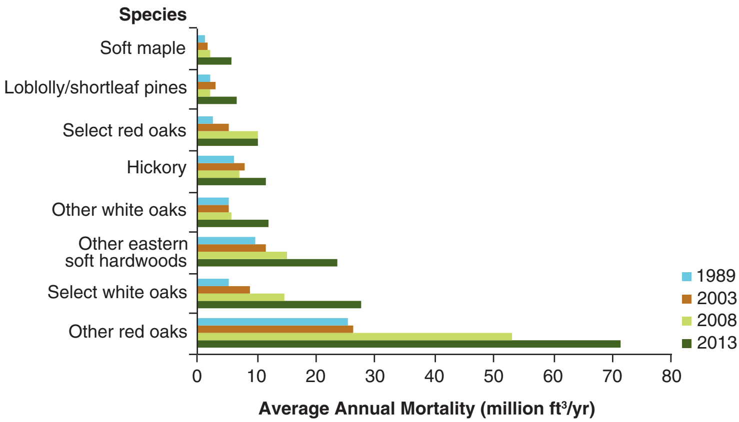


Figure 37.—Average annual mortality of growing-stock trees on timberland by species group and inventory year, Missouri.

Between 2008 and 2013, there was an average of 171.8 million cubic feet of growing stock on timberland that was removed by timber harvests, precommercial thinning, land clearing, or land use change each year (average annual removals). The other red oak species group accounted for one-third of the total average annual removals during the same period (Fig. 38). Fifty-eight percent of all removals were made up of black oak, white oak, post oak, and scarlet oak.

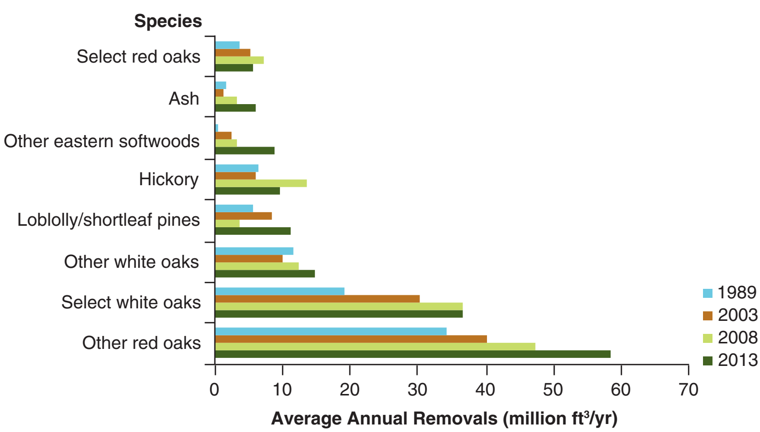


Figure 38.—Average annual removals of growing-stock trees on timberland by species group and inventory year, Missouri.

What this means

The G/R for growing stock on timberland in Missouri is 1.9, indicating that between 2008 and 2013, the volume of growing stock is increasing nearly twice as fast as it is being removed (Table 1). American sycamore, which is fast-growing and had a low mortality and removal rate, had a G/R of 47.7; only 8 percent of the total growth was lost to mortality and another 2 percent was removed through harvesting, cultural operation, or land use conversion. Of the top 20 species by volume, only two had a G/R ratio less than 1: scarlet oak (G/R=0.2) and chinkapin oak (G/R=0.5). These two species had high mortality rates compared to total growth, and removals greater than net growth.

Table 1.—Net volume, average annual net growth, and average annual removals of growing-stock trees (at least 5 inches d.b.h.) on timberland, and growth-to-removals ratio (G/R) for select species, Missouri, 2009-2013

Species	Net volume	Average annual net growth[a]	Average annual removals	G/R ratio
	- - - - - - - - - - - - - - -	*million cubic feet*	*- - - - - - - - - - - - - -*	
White oak	3,614	68.5	33.5	2.0
Black oak	2,465	40.3	37.7	1.1
Post oak	1,554	21.0	14.9	1.4
Shortleaf pine	902	17.9	11.2	1.6
Northern red oak	838	15.2	8.6	1.8
Black walnut	516	18.8	5.3	3.5
Shagbark hickory	509	9.9	2.8	3.5
Scarlet oak	486	3.1	13.6	0.2
American sycamore	427	14.3	0.3	47.7
Black hickory	340	6.2	2.5	2.5
Mockernut hickory	330	5.1	1.4	3.6
Hackberry	305	12.0	1.4	8.6
Eastern redcedar	278	10.2	8.8	1.2
Silver maple	277	6.6	3.2	2.1
Bitternut hickory	242	7.4	0.8	9.3
Eastern cottonwood	238	6.0	0.7	8.6
Sugar maple	233	4.8	1.7	2.8
Pin oak	225	9.2	2.9	3.2
Pignut hickory	222	5.2	1.7	3.1
Chinkapin oak	217	1.4	2.9	0.5
State total	16,364	328.0	171.8	1.9

[a] Average annual net growth = average annual gross growth – average annual mortality.

The G/R calculation for this report includes both harvest and nonharvest related removals. Harvest removals account for nearly 75 percent of the total removals from Missouri's forest land. The growth to harvest removal ratio is 1 of 64 indicators of forest sustainability cited in the report "National Report on Sustainable Forests—2010" (U.S. Forest Service 2011). These 64 indicators reflect many of the environmental, social, and economic concerns of the American public regarding forests to help forest managers establish a quantitative baseline for measuring progress toward sustainability. Criterion 2 cited in U.S. Forest Service 2011 focuses on maintaining the productive capacity of forest ecosystems. Indicator 2.13 focuses specifically on the G/R (see also Montreal Process Working Group 2009). Of the three components of change (growth, mortality, and removals), removals is the one most directly tied to human activity and is thus the most influenced by changing economic conditions.

Forest Indicators

White oak decline pocket at Pea Ridge Conservation Area. Photo by Missouri Department of Conservation, used with permission.

Urbanization and Fragmentation of Forest Land

Background

The expansion of urban lands that accompanies human population growth often results in the fragmentation and urbanization of remaining natural habitat (Wilcox and Murphy 1985). Forest fragmentation and habitat loss diminish biodiversity and are recognized as a major threat to animal populations worldwide (Honnay et al. 2005, Rosenberg et al. 1999), particularly for species that require interior forest conditions for all or part of their life cycle (Donovan and Lamberson 2001), are wide-ranging, slow-moving, and/or slow reproducing (Forman et al. 2003, Maine Audubon 2007). Forest fragmentation can also affect forest ecosystem processes through changes in microclimate conditions, and it affects the ability of tree species to move in response to climate change (Iverson and Prasad 1998). Changes in the size of remaining forest patches, in their level of connectivity to other large patches, in the amount of general forest cover surrounding each patch, and in the amount of forest-nonforest edge, all directly affect the amount and quality of interior forest and consequently the species and ecosystem functions that depend on these interior conditions. The same factors also affect the ease with which exotic, invasive, or generalist species can gain a foothold, the ability of wildlife species to move across the landscape, and the ability of the forest to protect the quality and quantity of surface and ground water supplies.

Spatial landscape pattern metrics (SLPM) help quantify these different characteristics of fragmentation. In the 2008 Missouri inventory report (Raeker et al. 2011), we examined urban encroachment into forested areas and the amount of forest in edge versus core situations with respect to the most widely used thresholds for interpreting likely impact. The results highlighted the considerable range of interior versus edge conditions between Missouri's heavily forested Eastern Ozark Unit and the agricultural area (Prairie Unit), and the current and potential residential housing pressure present in Missouri's Riverborder and Northwestern Ozarks Units.

SLPM values are sensitive to the resolution of the land cover data source used (Moody and Woodcock 1995), similar to the way that animal species see the landscape very differently depending on the scale at which they operate—e.g., the same patch that supplies interior forest conditions for one species is viewed as an unsuitable fragment by another species with higher quality or larger area requirements. Since important forest ecosystem processes operate at different scales, in this report we examine current levels of fragmentation at two scales. We adapted a spatial integrity index (SII) developed by Kapos et al. (2000) for the Global Forest Resources Assessment

(FRA) that integrates three of these important facets of fragmentation affecting some aspect of forest ecosystem functioning—patch size, local forest density, and patch connectivity to core forest areas—to create a single resulting metric for comparison. Since even acceptably low misclassification rates in the source land cover data can be magnified into substantial errors in SLPM values (Langford et al. 2006, Shao and Wu 2008), we have calculated spatial integrity at the two scales corresponding to two reliable and widely available source datasets—the 30 m scale of the 2011 National Land Cover Dataset (Jin et al. 2013), and the 250 m scale of the 2009 FIA forest cover dataset (Wilson et al. 2012). Both scales fall within the 10 to 1,000 km^2 scale at which pattern process linkages are often of greatest management interest (Forman and Godron 1986).

In the SII calculation, core forest is defined by patch size and local forest density within a defined local neighborhood area. An unconnected forest fragment is defined by its patch size, local forest density, and distance to a core forest area. The spatial integrity of all other forest land is scaled between these two ends. Table 2 identifies the thresholds used to define both core forest and unconnected fragments, at the 250 m and 30 m scales, respectively.[1] These two scales capture a relatively broad range of definitions for core forest and spatial integrity that should encompass the scales appropriate for understanding impacts on a wide range of wildlife species and ecosystem processes affected by forest fragmentation.

Table 2.—Spatial integrity index (SII) parameters used in calculations at each scale

	Scale	
Definition of Core	**250 m**	**30 m**
Patch size	>1,544 acres	>22 acres
Local forest density	90% +	90%
Neighborhood radius	0.78 miles	0.09 miles
Definition of Unconnected Fragment	**250 m**	**30 m**
Patch size	<30 acres	<2.5 acres
Local forest density	≤10%	≤10%
Neighborhood radius	0.78 miles	0.09 miles
Distance to core	>4.2 miles	>0.5 miles

The population of Missouri increased by 7.0 percent between 2000 and 2010, to 6.0 million. During that same period the number of housing units increased by 11.1 percent (U.S. Census Bureau 2010). Stated another way, between 2000 and 2010 housing units increased at a pace 1.6 times the rate of increase in population, a trend not unique to Missouri. In recent decades this housing growth has occurred not only

[1] Riemann, R. 2014. Adaptation of a spatial integrity index to 30 m and 250 m scales, and its application across the northeastern United States. Unpublished data on file with Rachel Riemann, Troy, NY.

in increasing suburban rings around urban areas but also in rural areas. Lepczyk et al. (2007), Theobald (2005), and Hammer et al. (2004) observed that among the areas facing particularly rapid increases in housing density currently and into the future are amenity-rich rural areas around lakes and other forest recreation areas. The 22 percent increase in the number of reported second homes from 2000 to 2010 could be a partial reflection of this trend in Missouri (U.S. Census Bureau 2010). This can put additional pressure on forested areas even above the general increases in population density and housing density.

What SII identifies as core does not represent completely intact forest conditions because it is calculated from forest canopy and does not consider underlying house densities or proximity to roads. Using the definition of wildland-urban interface (WUI) intermix from Radeloff et al. (2005) (more than 15.5 houses per square mile [6 per square km]), we identified how much forest, and particularly core or intact forest land, coincided with these areas. The WUI is described as the zone where human development meets or intermingles with undeveloped wildland vegetation. It is associated with a variety of human-environment conflicts. Radeloff et al. (2005) have defined this area in terms of the density of houses (WUI "intermix" areas), the proximity to developed areas (WUI "interface" areas), and percentage of vegetation coverage. We used WUI intermix areas intersected with forest land in the 2011 NLCD (Jin et al. 2013) to examine changes in the amount of forest land co-occurring with WUI house densities.

Roads represent an additional important urbanization impact affecting forest lands that is not completely captured by either of the previous two indices. In Missouri as a whole, 36 percent of the forest land was within 650 feet of a road of some sort, and 65 percent was within 1,310 feet (calculated from NLCD 2006 forest [Fry et al. 2011] and U.S. Census Bureau 2000). Roads have a variety of effects: direct hydrological, chemical, and sediment effects; serving as vectors for invasive species; facilitating human access and use; increasing habitat fragmentation; and wildlife mortality. Actual impacts will vary depending on road width, use, construction, level of maintenance, and hydrologic and wildlife accommodations (Forman et al. 2003, Maine Audubon 2007), but in general, when more than 60 percent of the total land area in a region is within 1,310 feet of a road, cumulative ecological impacts from roads should be an important consideration (Riitters and Wickham 2003).

What we found

Considering SII classes at the 250 m scale, 40 percent of the forest land in Missouri is core forest, 25 percent has high integrity, 10 percent has medium integrity, 1 percent has low spatial integrity, and 23 percent of the forest is in unconnected fragments. At the 30 m scale, with 22 acres or greater considered core forest, 54 percent of the forest land in Missouri is core forest, 21 percent has high spatial integrity, 9 percent has medium or low integrity, and 16 percent of the forest is in unconnected fragments. Table 3 contains a breakdown of SII values by FIA unit for both scales. Forest connectivity is highest in the Eastern Ozarks Unit and lowest in the Riverborder Unit. The spatial distribution of forest land by SII classes at the 250 m scale is depicted in Figure 39. Remaining large areas of relatively continuous forest clearly stand out. At the 30 m scale, the lower threshold of 22 acres for defining core forest means that more forest patches are considered core. Figure 40 compares the SII classes between the two scales for an area around St. Louis. It is important to note that the forest landscape data used here are depicting tree cover only and may not incorporate the presence of local development associated with or underlying this tree cover.

Table 3.—Forest land by spatial integrity index (SII), by FIA unit, at two scales, and before and after incorporating WUI areas into the SII calculation at the State level

	Percent of forest by 30 m spatial integrity class				
FIA Unit	Forest fragment	Low SII	Medium SII	High SII	Core forest
Eastern Ozarks	2	0	3	15	79
Southwestern Ozarks	9	1	8	24	58
Northwestern Ozarks	8	1	8	25	57
Riverborder	4	2	12	20	22
Prairie	14	1	12	25	48
Missouri	16	1	8	21	54
Missouri with WUI	16	1	9	28	47

	Percent of forest by 250 m spatial integrity class				
FIA Unit	Forest fragment	Low SII	Medium SII	High SII	Core forest
Eastern Ozarks	2	0	4	21	72
Southwestern Ozarks	15	2	12	34	38
Northwestern Ozarks	14	2	18	33	34
Riverborder	83	1	6	8	2
Prairie	25	2	17	34	22
Missouri	23	1	10	25	40
Missouri with WUI	23	2	11	28	35

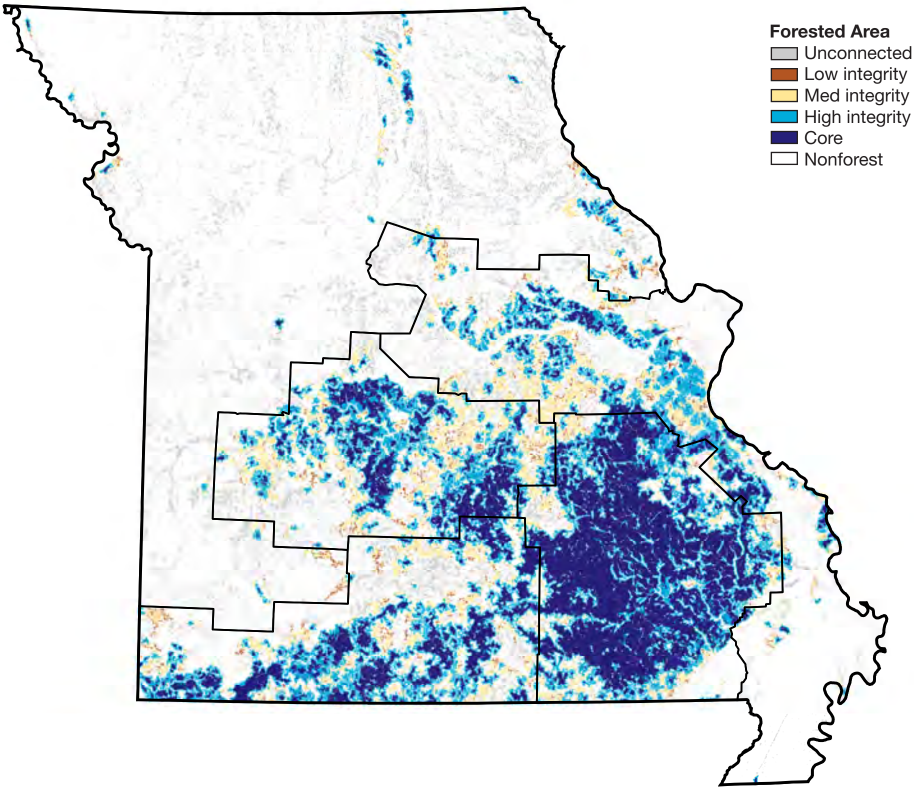


Figure 39.—Forest land by Spatial Integrity Index (SII), at the 250 m scale, Missouri, 2009.

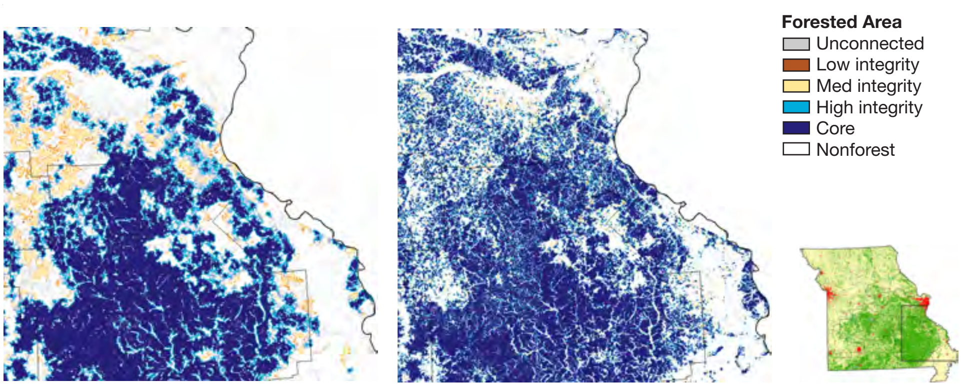


Figure 40.—Forest land by Spatial Integrity Index (SII) at the 250 m scale (A) (2009 dataset), and 30 m scale (B) (2006 NLCD dataset) in the area around St. Louis, MO.

Forest land with sufficient underlying housing density to qualify as WUI areas has been steadily increasing. In 1990, 9.6 percent of the forest land was in low and medium density WUI. In 2000 this increased to 12.8 percent of the forest land, and in 2010 it was 14.3 percent of the forest land in Missouri. The distribution of forested WUI in Missouri is depicted in Figure 41 and Table 4. Substantial impact to forest land is visible around St. Louis, along the shores of the Missouri River near Columbia, along Interstate 44, and around the lakes in the center and southwestern border of the State. These underlying house densities are poorly captured by the tree canopy cover data used in the calculation of spatial integrity above. When we integrate SII results at the 250 m scale with the WUI classes, 5 percent of Missouri's forest land moves from being core to lower spatial integrity classes, decreasing the proportion of forest land in the core class from 40 percent to 35 percent of forest land. At the 30 m scale, 7 percent of Missouri's forest land moves from being core to a lower spatial integrity class—from 54 percent to 47 percent. In addition, WUI areas tend to concentrate in amenity-rich areas and the outskirts of major cities. Changes in SII that occur when WUI status is incorporated, in the region around St. Louis, is illustrated in Figure 42.

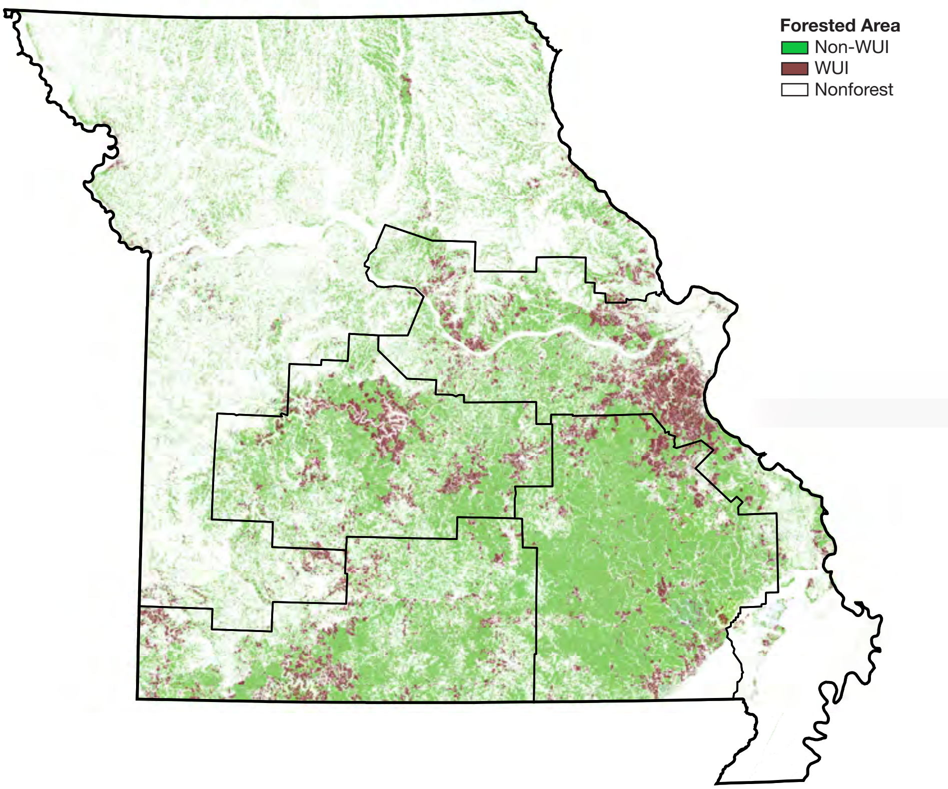


Figure 41.—Forest land by wildland urban interface (WUI) status, Missouri, 2010 census (restricted to 2011 NLCD forest).

Table 4.—The distribution of forest land with respect to several urbanization and fragmentation factors, expressed as a percent of the forest land in each FIA unit, Missouri

FIA Unit	% forest of total land in unit[a]	% of forest land in wildland urban intermix[b]	% of forest land <650 feet from road[c]
Eastern Ozarks	73	9	33
Southwestern Ozarks	55	13	37
Northwestern Ozarks	57	14	40
Riverborder	20	6	32
Prairie	36	26	43
State total	39	13	36

[a] Percent of forest estimate based on NLCD 2011 (Jin et al. 2013). Values are generally higher than estimates from FIA plot data.

[b] Approximating the forest land potentially affected by underlying or nearby development. 2010 Census data.

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

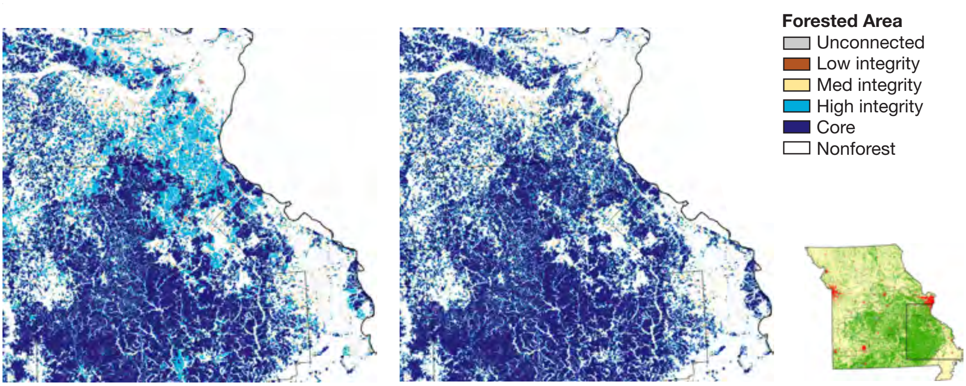


Figure 42.—Forest land by Spatial Integrity Index (SII) at the 30 m scale, with (A) and without (B) incorporating WUI status into SII, in the area around St. Louis, MO (data sources: 2006 NLCD [Fry et al. 2011] and 2010 Census [U.S. Census Bureau 2010).

Roads remain pervasive in the landscape, existing even in areas that appear to be continuous forest land from the air. In 2000, 32 percent of the forest area in the Riverborder Unit was within 650 feet of a road, and 33, 37, 40, and 43 percent of the forest land in the Eastern Ozarks, Southwestern Ozarks, Northwestern Ozarks, and Prairie Units, respectively, was within 650 feet of a road (U.S. Census Bureau 2000) (Table 4 and Fig. 43). Much of this area coincides with WUI areas of housing development. However, it is worth noting that the roads included in the U.S. Census Bureau data (U.S. Census Bureau 2010) do not include many minor roads not associated with housing development, and that including these minor roads actually doubles road densities in areas like northern Wisconsin (Hawbaker and Radeloff 2004).

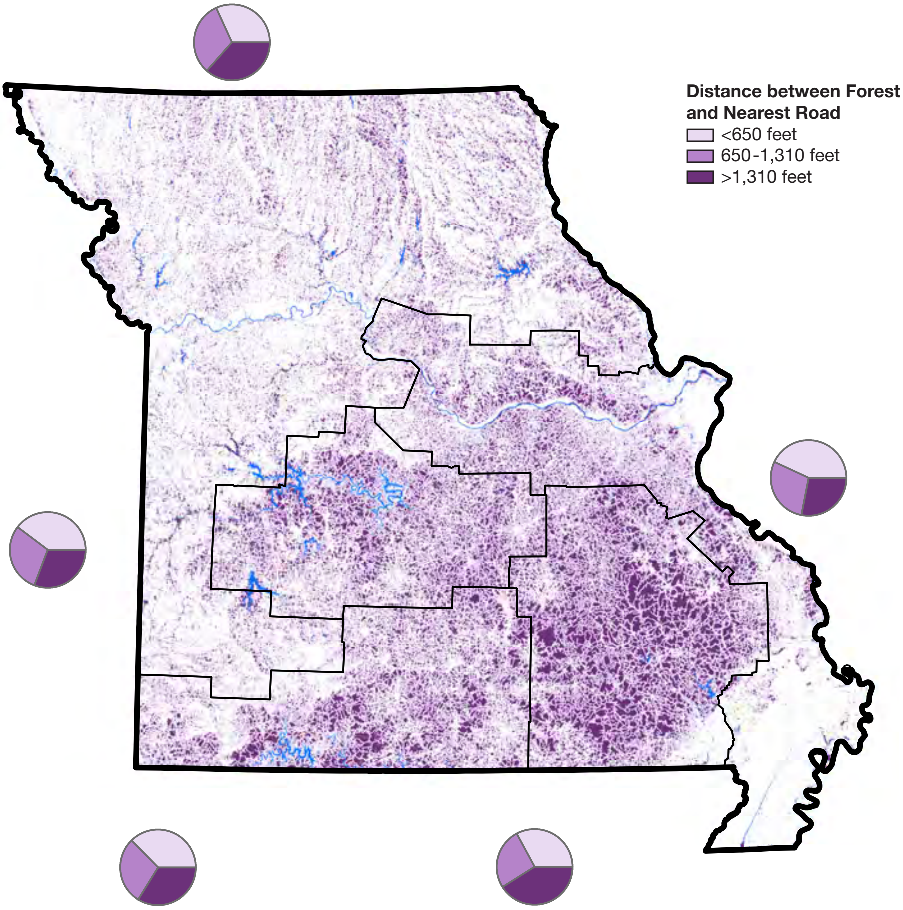


Figure 43.—Forest land by distance from the nearest road, Missouri, 2000 roads (restricted to 2001 NLCD forest).

What it means

Between 40 and 54 percent of the forest land in Missouri meets the definition of core forest statewide, using the 250 m and 30 m scales; between 17 and 24 percent of the forest land is in unconnected fragments or has low spatial integrity. Bringing WUI areas into the calculation has a considerable effect on the amount of forest land remaining in core forest conditions, particularly in several local areas, most noticeably around St. Louis and the Lake of the Ozarks, and other similar areas. Bringing roads into the calculation, even at the levels available in the 2000 Census TIGER dataset (U.S. Census Bureau 2010), reduces the integrity of some areas still further.

Forest fragmentation is recognized as a major threat to wildlife populations, particularly for species that require interior forest conditions for all or part of their life cycle or are wide-ranging or slow-moving. Forest fragmentation also increases edge conditions that can change micro-climate conditions and ecosystem processes, and limits the ability of plants and animals to move in response to climate change (Forman et al. 2003, Honnay et al. 2005, Iverson and Prasad 1998).

Urbanization increases the proximity of people, development, and other anthropogenic pressures to natural habitats. Both urbanization and forest fragmentation change the way in which humans use forest land, frequently decreasing the likelihood that it will be managed for forest products and potentially increasing its use for outdoor recreation, although urbanization has also been observed to increase the incidence of "posting" forested land, which decreases outdoor recreation opportunities and alters local cultural use of forest land (Butler 2016b, Kline et al. 2004, Wear et al. 1999). Continuing fragmentation, parcelization, and urbanization can be barriers to stewardship if they result in forest tracts that are too small or too isolated for effective management (Shifley and Moser 2016).

Invasive species and introduced pests are also a concern, as is the ability of forest systems to adapt to changes in season, temperatures, rainfall patterns, and relative phenological shifts associated with climate change. An intact functioning forest also is critical in protecting both the quantity and quality of surface and groundwater resources (McMahon and Cuffney 2000, Riva-Murray et al. 2010).

Fragmentation and urbanization are changing how Missouri's forests function and affect forest sustainability. Fragmentation diminishes the benefits and services forests provide and makes forest management more difficult. As Missouri's population continues to move into rural areas, fragmentation of forest land is a growing concern to land managers. Factors that increase fragmentation, such as development incursions into core and high integrity forest areas, should become the focus of conservation and planning activities. In addition, the characteristics and maintenance of roads and development can also play a role in their actual impact on the resilience of forest land and its ability to continue to supply the forest products and ecosystem services we expect and need.

Tree Crown Health and Damage

Background

The crown condition of trees is influenced by various biotic and abiotic stressors. Abiotic stressors include drought, flooding, cold temperatures or freeze injury, nutrient deficiencies, soil physical properties affecting soil moisture and aeration, or toxic pollutants. Biotic stressors include native or introduced insects, diseases, invasive plant species, and animals. Invasions by exotic diseases and insects are one of the most important threats to the productivity and stability of forest ecosystems around the world (Liebhold et al. 1995, Pimentel et al. 2000, Vitousek et al. 1996).

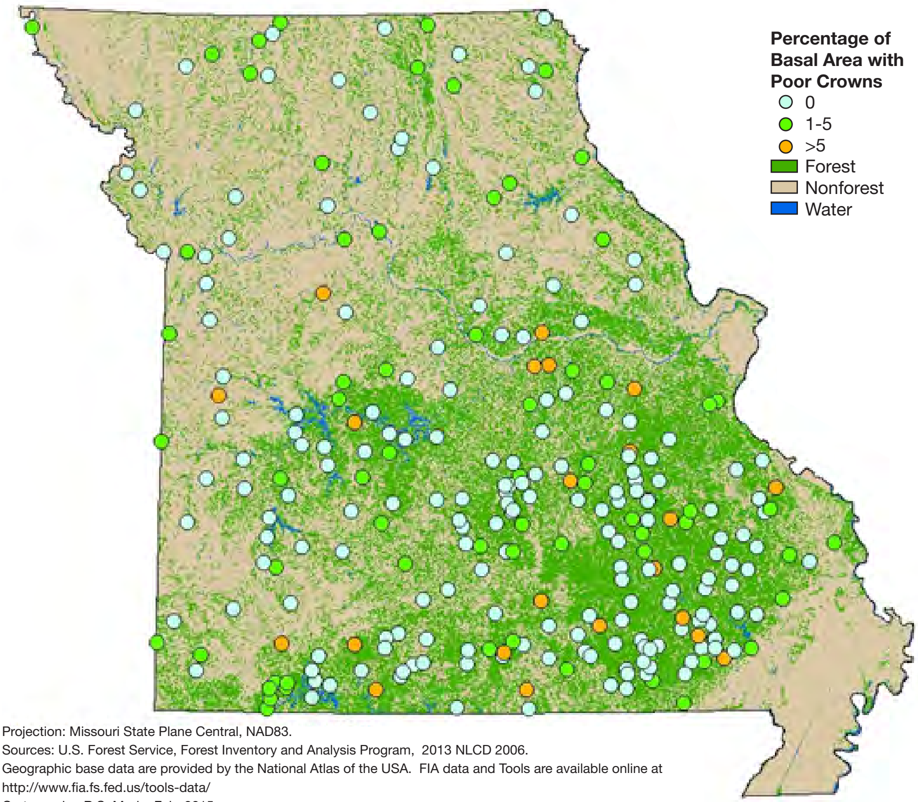
Over the last century, Missouri's forests have suffered the effects of oak decline, which is often related to stress caused by the native insect, two-lined chestnut borer (*Agrilus bilineatus* Weber), and the root disease, armillaria root rot (*Armillaria mellea* Vahl:Fr.). More recently, invasions by the emerald ash borer (*Agrilus planipennis*) and European gypsy moth (*Lymantria dispar*) are threatening the health of trees. Additionally, although Asian longhorned beetle (*Anoplophora glabripennis*) and thousand cankers disease have not yet been discovered in Missouri, they are emerging threats that have been confirmed in nearby states. Another relatively new threat is rapid white oak mortality, which has been reported in isolated areas of southern and central Missouri.

Tree-level crown dieback is collected on P2+ plots (a subset of FIA P2 plots on which additional measurements are taken). 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 5.0 inches or greater d.b.h. Up to three of the following types of damage can be recorded: insect damage, cankers, decay, fire, animal damage, weather, and logging damage. If more than three types of damage are observed, decisions about which three are recorded are based on the relative abundance of the damaging agents (U.S. Forest Service 2010).

What we found

The incidence of poor crown condition is low across Missouri with no discernable spatial pattern (Fig. 44). The only species with more than 4 percent of live basal area containing poor crowns are black walnut and scarlet oak (Table 5). Mean dieback ranged less than 1 percent for shortleaf pine and eastern redcedar to 7 percent for black oak (Table 6).



Projection: Missouri State Plane Central, NAD83.
Sources: U.S. Forest Service, Forest Inventory and Analysis Program, 2013 NLCD 2006.
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. Feb. 2015

Figure 44.—Percent of live basal area with poor crowns, Missouri, 2013.

Table 5.—Percent of live basal area with poor crowns, Missouri, 2008 and 2013

Species	2008	2013
Black walnut	1.8	4.1
Scarlet oak	0.0	4.0
Black oak	3.6	3.1
Northern red oak	0.1	1.6
White oak	0.9	1.4
American sycamore	0.0	1.2
Post oak	2.1	0.9
Shagbark hickory	1.3	0.6
Shortleaf pine	0.2	0.4
Eastern redcedar	0.4	0.3

Table 6.—Mean crown dieback and other statistics for live trees (>5 inches d.b.h.) on forest land by species, Missouri, 2013

Species	Trees	Mean	SE	Minimum	Median	Maximum
	number	-----------------------------	*percent*	-----------------------------		
Black oak	566	6.8	0.57	0	5	99
Scarlet oak	155	5.3	0.80	0	5	90
Black walnut	145	5.2	0.92	0	5	99
Northern red oak	119	4.8	0.70	0	5	75
Post oak	586	4.2	0.31	0	5	99
Shagbark hickory	119	3.6	0.32	0	5	30
White oak	1,005	3.4	0.27	0	0	99
American sycamore	28	3.2	1.00	0	0	25
Eastern redcedar	404	1.9	0.16	0	0	30
Shortleaf pine	462	1.7	0.33	0	0	99

The proportion of trees that die increases with increasing crown dieback (Fig 45). Seventy-five percent of trees with crown dieback greater than 20 percent during the 2008 inventory were dead when visited again during the 2013 inventory.

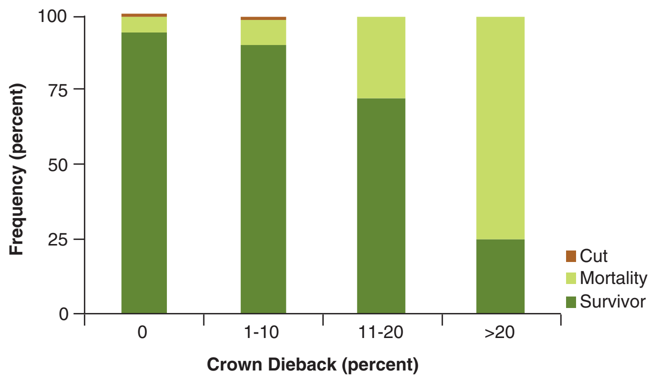


Figure 45.—Percentage distribution of crown dieback (2008) by tree survivorship (2013) for remeasured trees, Missouri.

Damage was recorded on about 21 percent of the trees in Missouri, but there is considerable variation between species. The most frequent damage on all species was decay (12 percent of trees), but it ranged from 2 percent or less on softwood species to 12 percent or greater on red oak species (northern red oak, scarlet oak, and black oak). Decay was 10 percent or greater on black walnut and American sycamore. Notably, insect damage was present on 20 and 16 percent of scarlet and black oak, respectively, and weather damage was observed on 8 percent of American sycamore trees. The occurrence of all other injury types was very low (Table 7).

Table 7.—Percent of trees with damage by species, Missouri, 2013

	None	Animal	Cankers	Decay	Insect damage	Logging/ human	Other	Weather
American sycamore	80.2	0.5	0.0	11.5	0.0	0.7	2.3	8.0
Black oak	70.2	0.9	0.7	12.4	15.5	1.2	2.9	4.7
Black walnut	76.7	3.0	0.8	13.8	0.1	2.0	3.4	5.2
Eastern redcedar	90.0	1.9	0.1	4.1	0.0	1.4	1.2	2.6
Northern red oak	76.2	0.9	0.2	17.2	5.7	1.0	1.6	3.8
Post oak	84.1	0.6	1.4	10.3	0.5	1.6	2.1	3.0
Scarlet oak	67.6	1.9	0.6	16.1	19.7	0.8	3.9	2.7
Shagbark hickory	85.1	2.6	0.2	8.1	0.1	1.8	1.1	2.8

What this means

The trees in the forests of Missouri are generally in good health. However, the health of tree crowns in oak species, ash species, maple species, black walnut, and butternut should be monitored closely due to recent, and likely future outbreaks of emerald ash borer, gypsy moth, Asian longhorned beetle, and thousand cankers disease, as well as the potential impacts of oak decline and rapid white oak mortality.

Decay is the most commonly observed type damage, not unusual given that most of Missouri's forests are composed of mature trees. The incidence of insect damage on the red oak species is likely caused by the native pest red oak borer (*Enapholodes rufulus* Haldeman) (Donley and Acciavatti 1980), which has been causing extensive mortality and crown dieback in Missouri since 1999 (Starkey et al. 2004).

Down Woody Materials

Background

Down woody materials, in the various forms of fallen trees and shed branches, fulfill a critical ecological niche in forests of Missouri. Down woody materials provide valuable wildlife habitat, stand structural diversity, a store of carbon/biomass, and contribute toward forest fire hazards via surface woody fuels. Down woody materials can be subdivided into fine and coarse woody debris and piles of residue from harvest operations.

What we found

The total carbon stored in down woody materials (fine and coarse woody debris and residue piles) on Missouri's forest land exceeded 37 million tons (Fig. 46). Downed woody debris carbon is normally distributed by stand-age class with moderately aged stands having the highest total carbon (~13 million tons). The downed dead wood biomass within Missouri's forests is dominated by coarse woody debris (Fig. 47)—about 47 million tons; fine woody debris comprises over a third of statewide total. Coarse woody debris volume was highest in the private ownership category—about 3.4 billion cubic feet in Missouri's forests (Fig. 48). State and local forests had the second largest, albeit substantially lower totals of coarse woody debris volume (319 million cubic feet) compared to private ownerships. State and locally owned forest lands had the highest volumes of dead wood in piles at over 67 million cubic feet. Compared to southeastern states where there is more pervasive industrial management of forests (Woodall et al. 2013), there were relatively few residue piles sampled in this first down woody materials inventory of Missouri's forests.

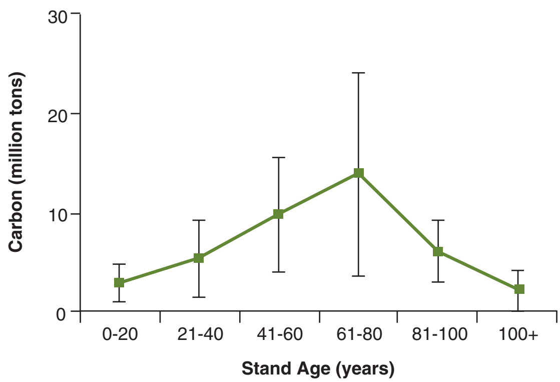


Figure 46.—Down woody material carbon by stand-age class on forest land, Missouri, 2010. Error bars represent a 68 percent confidence interval around the estimated mean.

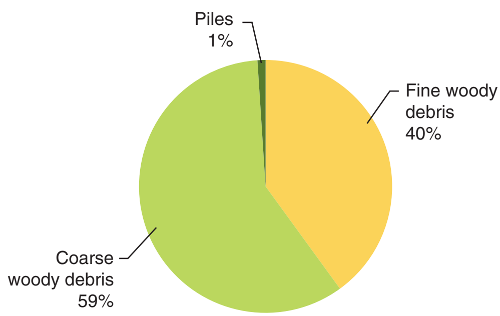


Figure 47.—Proportion of biomass on forest land by down woody material component, Missouri, 2010.

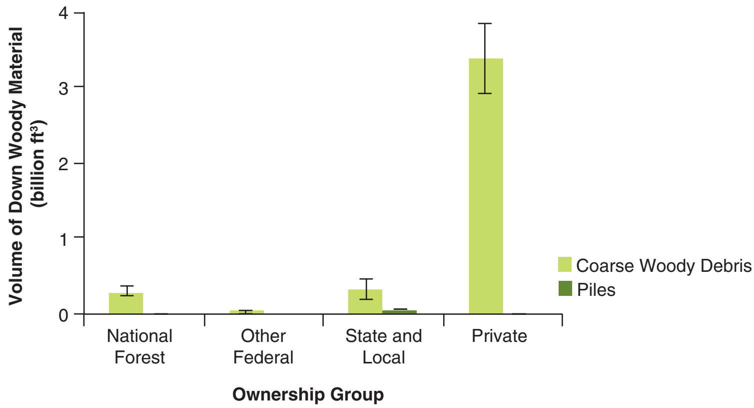


Figure 48.—Volume of coarse woody debris and deadwood piles on forest land by ownership group, Missouri, 2010. Error bars represent a 68 percent confidence interval around the estimated mean.

What this means

Only in times of drought would the biomass with down woody materials be considered a fire hazard in Missouri due to the relatively moist temperate forests across the State. Although the carbon stocks of down woody materials are relatively small compared to those of soils and standing live biomass across Missouri, it is still a critical component of the carbon cycle as a transitory stage between live biomass and other detrital pools such as the litter. Beyond transition of dead wood carbon to other pools, if future temperature and precipitation patterns change, there is a potential for a reduction in these stocks due to increased rates of decay (Russell et al. 2014 a, b). The loss of dead wood carbon stocks could indicate the reduction of other pools in the future. Given that most coarse woody debris volume is estimated to be in private ownership, it is the management of Missouri's private forests that may affect the future of down woody material contributions to statewide forest carbon stocks and wildlife habitat (i.e., stand structure). Because fuel loadings are estimated to not be exceedingly high across Missouri, potential fire dangers may be outweighed by the numerous ecosystem services provided by down woody materials. Down woody materials, in the form of fallen trees and branches, fill a critical ecological niche in Missouri's forests. Down woody materials provide valuable wildlife habitat in the form of coarse woody debris and contribute toward forest fire hazards via surface woody fuels.

Forest Insects and Diseases

Background

Emerald ash borer—Emerald ash borer (EAB), an exotic wood-boring beetle, was detected in the United States in 2002 near Detroit, Michigan. A pest of all North American ash (*Fraxinus* spp.) and white fringetree (*Chionanthus virginicus*), EAB has been present in Missouri since 2008 (Cipollini 2015).

Gypsy moth—European gypsy moth continues to spread west across the United States. Tree species were split into preferred and nonpreferred suitability classes based on field and laboratory tests by Liebhold et al. (1995). Species in the highest suitability class were considered preferred and all others were considered nonpreferred.

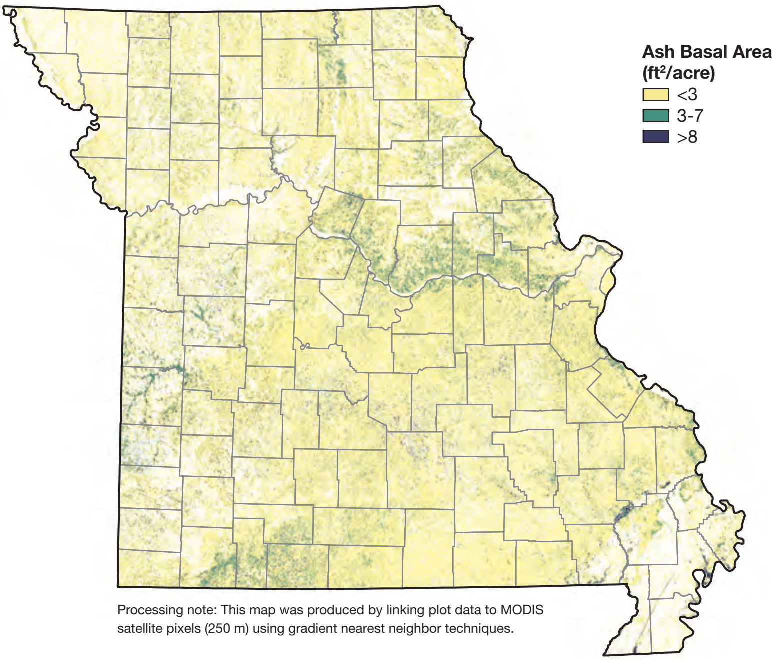
Thousand cankers disease—Thousand cankers disease (TCD) is a disease complex that primarily affects black walnut and results from the interaction between the *Geosmithia morbida* fungus and the walnut twig beetle (*Pityophthorus juglandis*). TCD occurs throughout the western United States and has been introduced to several eastern states including Tennessee, Indiana, and Ohio. While not found in Missouri during the 2013 inventory, a statewide quarantine, which restricts the movement of untreated walnut material, is in effect.

What we found

Emerald ash borer—Missouri's forest land contains an estimated 289.9 million ash trees greater than 1 inch diameter d.b.h., which is approximately 3.5 percent of all trees. Ash is widely distributed across the State, though it is concentrated along rivers and streams with 21 percent of ash occurring on wet sites (Fig. 49). The net volume of live ash trees (greater than 5 inches d.b.h.) is 495.9 million cubic feet.

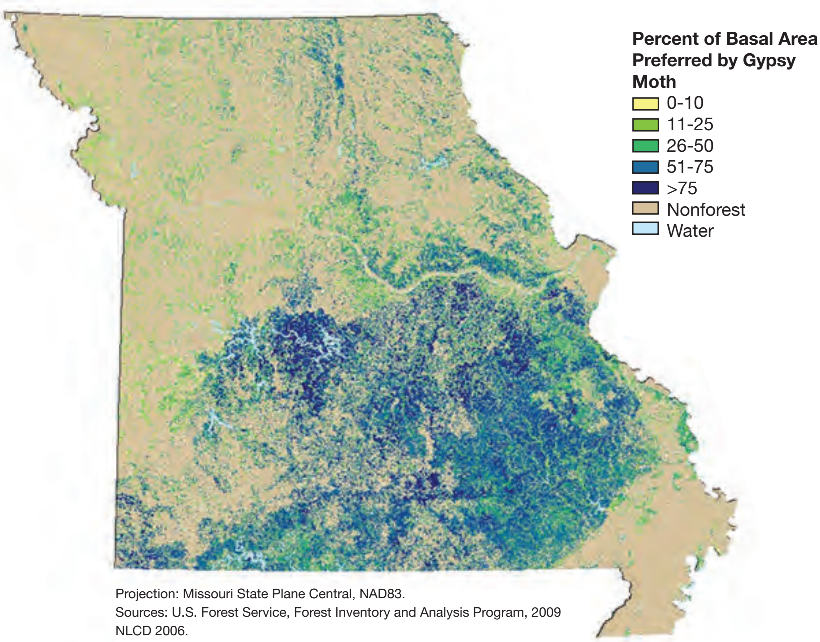
Gypsy moth—About 66 percent of the live tree volume in Missouri is preferred by gypsy moth. The most abundant preferred species in Missouri are the oaks. The density of preferred gypsy moth host species is high across most of the forests in the State but the central part of Missouri has the highest proportional densities (Fig. 50).

Thousand cankers disease—There are an estimated 114.9 million black walnut trees (greater than 1 inch d.b.h.) on forest land. Black walnut is distributed throughout Missouri, although it is concentrated in the western, central, and northern portions of the State (Fig. 51). Average annual harvest removals of black walnut sawtimber from forest land is about 18.4 million board feet, or about 3 percent of the total State harvest removals.



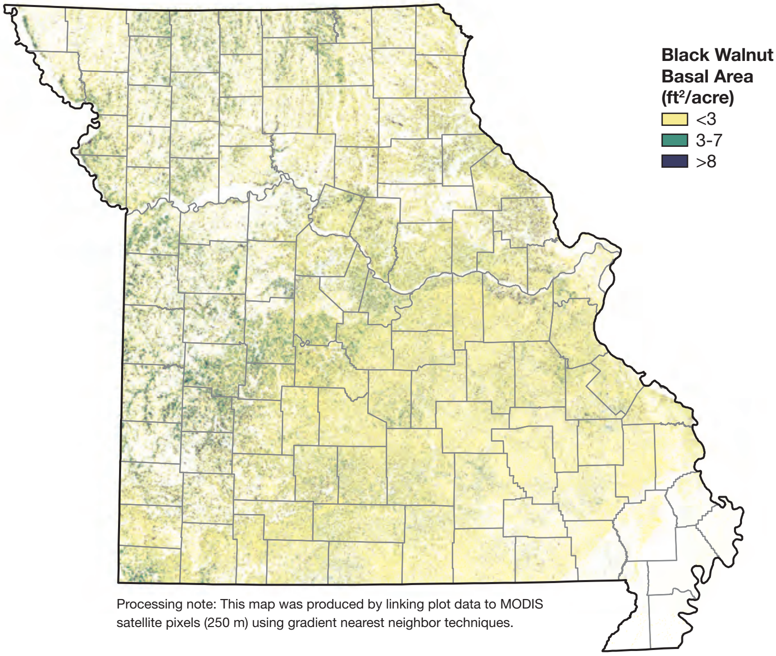
Processing note: This map was produced by linking plot data to MODIS satellite pixels (250 m) using gradient nearest neighbor techniques.

Figure 49.—Ash density on forest land, Missouri, 2006.



Projection: Missouri State Plane Central, NAD83.
Sources: U.S. Forest Service, Forest Inventory and Analysis Program, 2009
NLCD 2006.
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. Feb. 2015

Figure 50.—Density of gypsy moth preferred host trees, Missouri, 2013.



Processing note: This map was produced by linking plot data to MODIS satellite pixels (250 m) using gradient nearest neighbor techniques.

Figure 51.—Black walnut density on forest land, Missouri, 2009.

What this means

Emerald ash borer—Ash is an abundant component of Missouri's woodlands, including riparian and urban forests. Therefore, continued spread of EAB could have a considerable impact on ash health and the future composition of Missouri's forests.

Gypsy moth—Gypsy moth has not impacted the forests of Missouri as of yet, but moths have been captured in the State as part of the Gypsy Moth Slow the Spread program (Slow the Spread Foundation, n.d.). Quantification of the amount of the forest resource that is preferred by the gypsy moth can help land managers prepare for future outbreaks.

Thousand cankers disease—Since walnut is an ecologically and economically important species, the introduction TCD has the potential to cause extensive walnut mortality and dramatically impact Missouri's forest ecosystem and timber industry.

During the past decades, native and nonnative insects and diseases have had a large impact on the structure, diversity, and health of Missouri's forests. Insects and diseases often cause damage when forests are affected by abiotic stressors such as drought and storm damage. Monitoring insects and diseases in the context of abiotic agents is crucial to predicting and managing Missouri's future forest resources.

Oak Threats

Background

Missouri's oak resource is under threat from a number of insects and disease pathogens. One of the greatest threats being faced is oak decline, which is the term used to describe a complex of factors that together cause injury and mortality to oak trees. Oak decline develops when oak trees are under stress because of drought, physiological maturity, high stem density, or injuries caused by weather (frost, ice, wind, etc.), then are subsequently attacked by pathogens such as Armillaria root disease or insects such as the red oak borer (Kabrick et al. 2008). Species in the red oak group are particularly susceptible to oak decline. Missouri contains 926.8 million trees in the red oak group, the majority of which are in the Ozark Highlands Unit, making forests there at an increased risk of oak decline.

Rapid white oak mortality (RWOM) has been a threat in Missouri since 2011. The Missouri Department of Conservation (MDC) has received numerous reports of mortality in white oak trees, mainly in the southeast and east portions of the State. Unlike oak decline, RWOM tends to be rapid and affect white oaks on high quality sites. Similar to oak decline, RWOM hits after trees have been stressed by drought or other stressors.

Another emerging threat to bur oak trees is bur oak blight (BOB), a late-season leaf disease that is mostly found in Iowa but has been found in surrounding states, including northern Missouri. Caused by the newly described pathogen *Tubakia iowensis,* symptoms of BOB include necrosis of leaf tissue along the veins eventually leading to death of the entire leaf starting around late July (Harrington et al. 2012). Mature bur oaks in upland forests appear to be most at risk of severe symptoms.

What we found

The volume of red oaks declined between the 2008 and 2013 inventories after a period of increasing volume that began before the 1989 inventory. Scarlet oak, blackjack oak, black oak, and northern red oak all saw volume decreases (Fig. 52). The average annual mortality of red oaks in 2013 increased by nearly 20 percent over 2008 inventory estimates (Fig. 53). Scarlet oak saw the greatest increase in annual mortality, from 7.3 million cubic feet per year in 2008 to 22.3 million cubic feet per year in 2013.

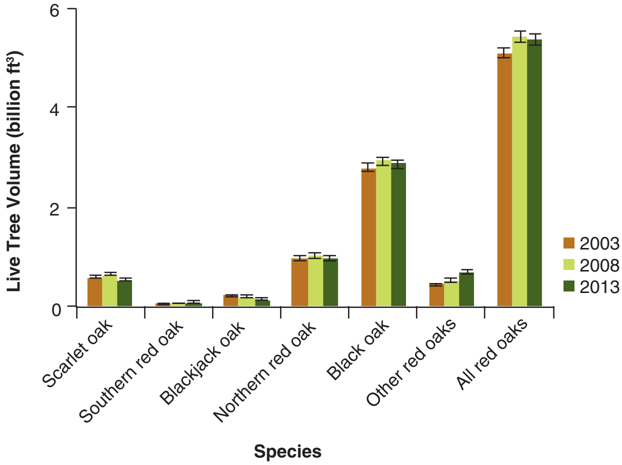


Figure 52.—Volume of red oaks on forest land by species and inventory year, Missouri. Error bars show the 68 percent confidence interval around the mean.

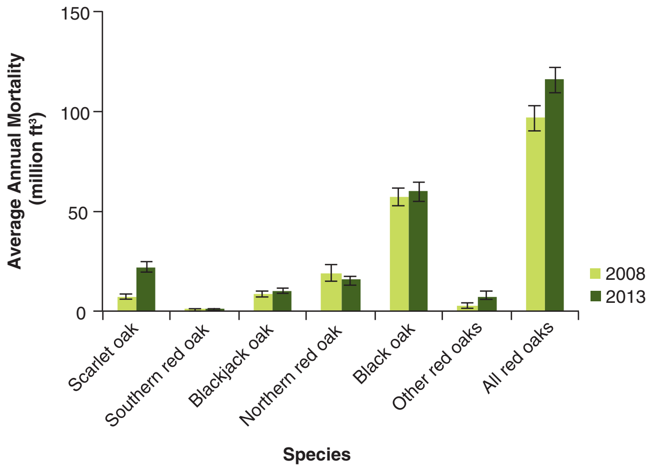


Figure 53.—Average annual mortality of red oaks on forest land by species and inventory year, Missouri. Error bars show the 68 percent confidence interval around the mean.

The white oak species group has increased in volume over the past three inventories, however the increase was much smaller from 2008 to 2013 than from 2003 to 2008 (Fig. 54). The average annual mortality of the white oak species group increased 49 percent in 2013 over the 2008 inventory (Fig. 55). The increase was the greatest among the white oak species, going from 19.6 million cubic feet per year in 2008 to 32.2 million cubic feet per year in 2013. Bur oak also had a large jump in mortality, increasing from slightly less than 100,000 cubic feet per year to 1.4 million cubic feet per year.

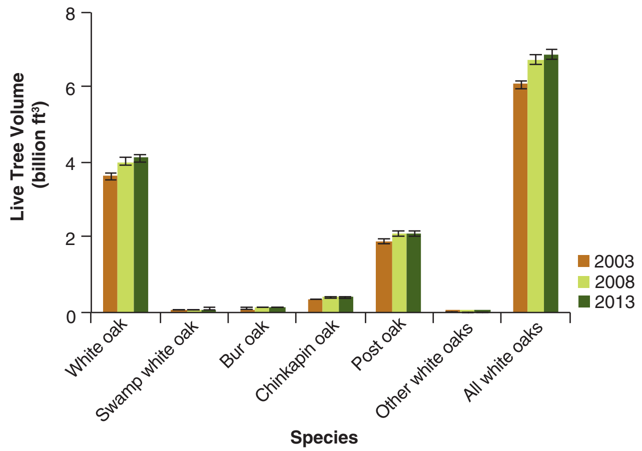


Figure 54.—Volume of white oaks on forest land by species and inventory year, Missouri. Error bars show the 68 percent confidence interval around the mean.

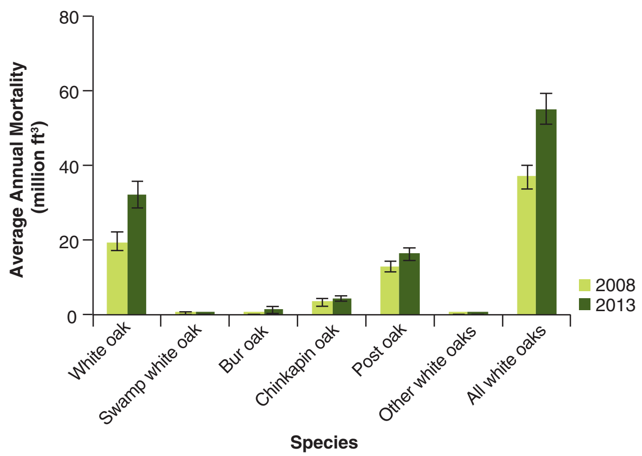


Figure 55.—Average annual mortality of white oaks on forest land by species and inventory year, Missouri. Error bars show the 68 percent confidence interval.

What this means

Whether it's the increasing rates of mortality and decreasing volume, in the case of red oaks, or slowing of volume increase in the case of the white oak species group, land managers have reason to be concerned about the oak resource in Missouri. While mortality is a natural process in the forest, monitoring of oaks by the MDC, forest industry, researchers, landowners, and others indicate that the mortality oaks are experiencing now is higher than what may be considered normal. Research and continued monitoring of threats that oaks face, whether ongoing such as oak decline, or emerging, such as RWOM or BOB, will help land managers make decisions on how best to manage Missouri's oaks and mitigate or reduce threats.

Invasive Plants

Background

Invasive plant species (IPS) are both native and nonnative species that can cause negative ecological effects. These species can quickly invade forests, changing light, nutrient, and water availability for trees. IPS can form dense monocultures which not only reduce regeneration but also impact wildlife quality through altering forest structure and forage availability. Aside from the invasive species' effects on forested environments, they can also impact agricultural systems. An example is common barberry, an alternate host for wheat stem rust, which can cause the compete loss of grain fields. Common buckthorn is another troublesome IPS as it is an alternate host for the soybean aphid (*Aphis glycines*). While there are some beneficial uses for these invaders (e.g., reed canarygrass has culinary, medicinal, and soil contaminant extraction uses [Kurtz 2013]), the negative effects are worrisome. Each year the inspection, management, and mitigation of IPS costs billions of dollars.

What we found

To aid in monitoring these species, FIA assesses the presence of 40 IPS (39 species and one undifferentiated genus) on 530 P2 invasive plots in Missouri from 2009 through 2013. Of the 40 invasives monitored, 20 were observed (Table 8). Multiflora rose was the most commonly observed species (275 plots; 51.9 percent of P2 invasive plots) (Fig. 56) and was found throughout the State. This aggressive shrub was introduced to the United States in 1866 and has become the most common invasive of the 40 monitored by the Northern Research Station (Kurtz and Hansen 2013). Japanese honeysuckle (46 plots) and nonnative bush honeysuckles (33 plots) were the next most commonly observed species and occurred on less than 10.0 percent of plots. Four of the 20 IPS observed were found on 5.0 percent or more of the plots with 58.3 percent of the plots having one or more of the monitored IPS. The number of IPS per plot ranged from 0 to 5 (Fig. 57). The location of plots with invasives present is fairly homogeneous throughout the State (Fig. 58). There is a slightly greater number of IPS per plot in the region covered by Buchanan, Platte, Clay, and Ray Counties (counties around Kansas City, MO). Plots in Jefferson County also had a high number of invasives per plot. When reviewing these figures it is important to remember that the inventory is of forested areas, so areas with less forest land have fewer plots. Aside from the distribution of the monitored invasives, it is important to note that there is a significant difference in the distance to the nearest road for plots with and without invasive plants ($p<0.05$). On average, plots with IPS were closer to roads (1,318 feet versus 1,840 feet for plots without invasive species).

Table 8.—Invasive plant species monitored and observed on P2 invasive plots, Missouri, 2013

Common name	Scientific name	Observances	Percentage of plots
Tree Species			
Norway maple	*Acer platanoides*	--	--
Tree of heaven	*Ailanthus altissima*	4	0.8
Silktree	*Albizia julibrissin*	1	0.2
Russian olive	*Elaeagnus angustifolia*	2	0.4
Punktree	*Melaleuca quinquenervia*	--	--
Chinaberry	*Melia azedarach*	--	--
Princesstree	*Paulownia tomentosa*	--	--
Black locust	*Robinia pseudoacacia*	20	3.8
Saltcedar	*Tamarix ramosissima*	--	--
Tallow tree	*Triadica sebifera*	--	--
Siberian elm	*Ulmus pumila*	1	0.2
Woody Species			
Japanese barberry	*Berberis thunbergii*	1	0.2
Common barberry	*Berberis vulgaris*	--	--
Autumn olive	*Elaeagnus umbellata*	27	5.1
Glossy buckthorn	*Frangula alnus*	--	--
European privet	*Ligustrum vulgare*	2	0.4
Nonnative bush honeysuckles	*Lonicera* spp.	33	6.2
Common buckthorn	*Rhamnus cathartica*	--	--
Multiflora rose	*Rosa multiflora*	275	51.9
Japanese meadowsweet	*Spiraea japonica*	--	--
European cranberrybush	*Viburnum opulus*	--	--
Vine Species			
Oriental bittersweet	*Celastrus orbiculatus*	--	--
English ivy	*Hedera helix*	--	--
Japanese honeysuckle	*Lonicera japonica*	46	8.7
Herbaceous Species			
Garlic mustard	*Alliaria petiolata*	13	2.5
Spotted knapweed	*Centaurea stoebe* ssp. *micranthos*	--	--
Canada thistle	*Cirsium arvense*	1	0.2
Bull thistle	*Cirsium vulgare*	5	0.9
Black swallow-wort	*Cynanchum louiseae*	--	--
European swallow-wort	*Cynanchum rossicum*	--	--
Leafy spurge	*Euphorbia esula*	1	0.2
Dames rocket	*Hesperis matronalis*	--	--
Creeping jenny	*Lysimachia nummularia*	2	0.4
Purple loosestrife	*Lythrum salicaria*	--	--
Japanese knotweed	*Polygonum cuspidatum*	1	0.2
Giant knotweed	*Polygonum sachalinense*	--	--
Bohemian knotweed	*Polygonum xbohemicum*	--	--
Grass Species			
Nepalese browntop	*Microstegium vimineum*	2	0.4
Reed canarygrass	*Phalaris arundinacea*	2	0.4
Common reed	*Phragmites australis*	1	0.2

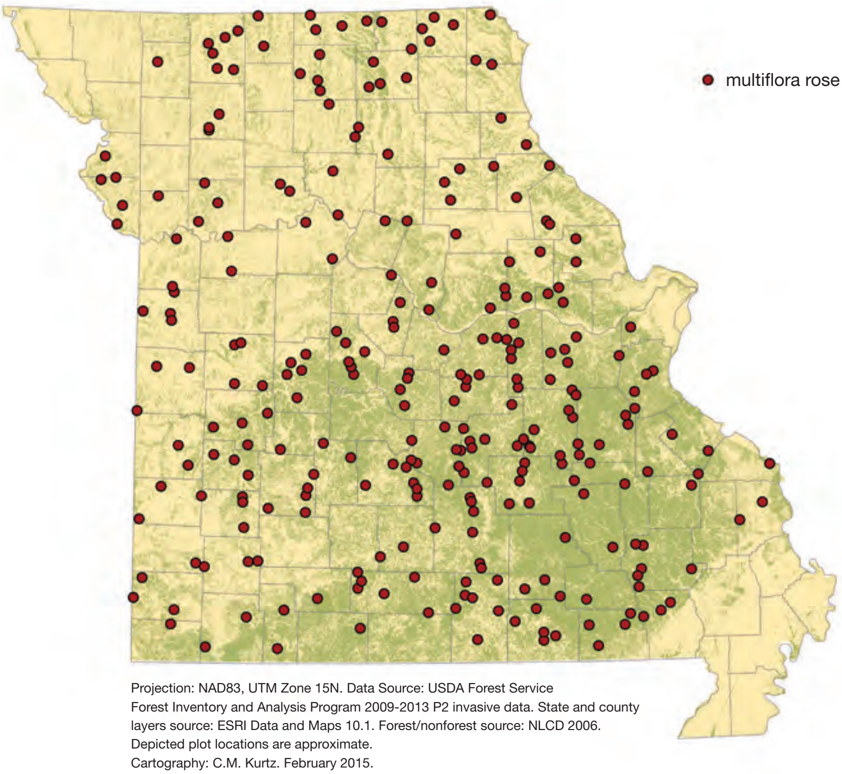


Figure 56.—Distribution of multiflora rose on P2 invasive plots, Missouri, 2013.

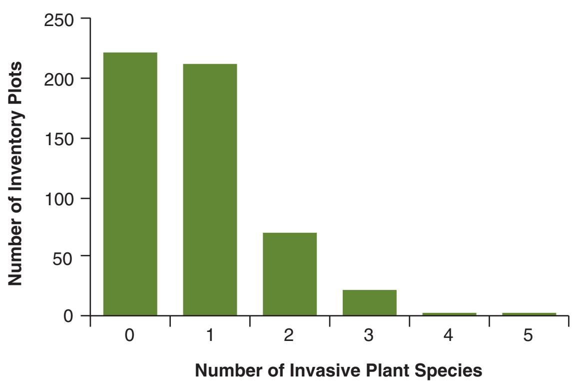


Figure 57.—Number of invasive plant species per P2 invasive plot, Missouri, 2013.

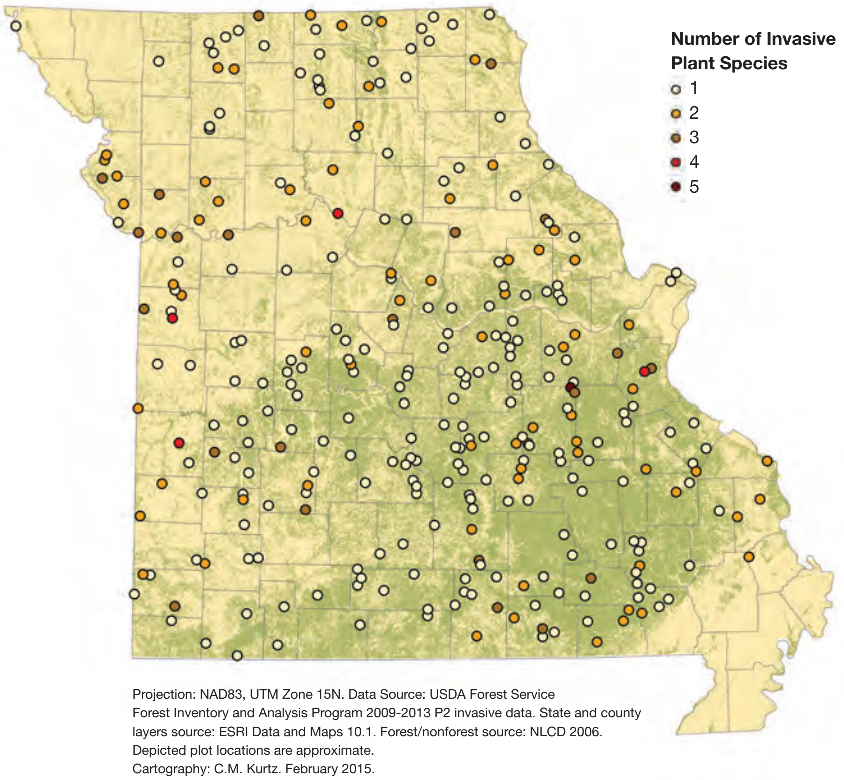


Figure 58.—Number of invasive plant species per P2 invasive plot, Missouri, 2013.

In 2008, only 2 years of invasive plant data were reported and multiflora rose was the most commonly observed invasive plant species (Raeker et al. 2011). Since then, multiflora rose remained the most commonly observed IPS in 2013 and the percentage of plots on which it was recorded increased from 36.5 to 51.9 percent of P2 invasive plots. However, it is important to note that according to the 2008 Phase 3 data, multiflora rose was present on 62.5 percent of plots. Furthermore, in 2008 Japanese honeysuckle was recorded on 13.6 percent of P3 plots but only 3.2 percent of P2 invasive plots, the exact same percentages of plots on which it was observed in 2013. Over time it will be important to monitor the percentage of plots where these species are observed as well as to watch for the presence of new invasive species.

What this means

Missouri forests had fewer plots invaded (58.3 percent) than neighboring Iowa, where 94.4 percent of plots had one or more of the monitored invasive plant species (Nelson et al. 2016). A potential reason there are fewer plots with invasives may be because Missouri has more interior, intact forests than neighboring Iowa. However, the presence of IPS within Missouri's forests is still troublesome and it is important to monitor these species over time to ensure that managers and the general public are aware of their occurrence and spread.

Invasive plants are effective competitors and are able to alter forested ecosystems by displacing native species and impacting the fauna that depend upon them. Several factors contribute to their success such as prolific seed production, rapid growth rate, ability to propagate vegetatively, and survival in harsh conditions. Many factors contribute to forest invasion such as ungulates, development, fragmentation, and timber harvesting. When IPS invade forests, they negatively affect the carbon budget by reducing future tree cover. Furthermore, these species can cause negative economic implications by reducing timber yield and aesthetic beauty. Further investigation of the inventory data may help to reveal influential site and regional trends.

Forest Soils

Background

Well-managed forest cover provides ideal natural vegetation for healthy streams and rivers; it is widely known to be superior to agricultural and urban land uses in this regard. Trees and forests, when managed properly, are highly effective at conserving soil and water resources. Forest vegetation and leaf litter help protect soil from forces that cause erosion. Through filtration, interception, and evapotranspiration, trees and forests reduce storm water runoff problems and moderate stream-flow rates and volumes. In these and other ways, forested landscapes produce much of our cleanest and most cost-effective and reliable drinking water. Missouri's previous forest inventory report (Raeker et al. 2011) used Barnes et al. (2009) to highlight the importance of several watersheds for surface drinking water supplies in Missouri. For this report, the underlying research was updated by Weidner and Todd (2011) and mapped across smaller watersheds. Data from the Forest Service's Forests to Faucets project (U.S. Forest Service, n.d.) were used to evaluate the importance of Missouri's forests for contributions to water quality. Importance values are reported in a nationwide relative index ranging from 0 (no importance) to 100 (most important).

What we found

The Meramec basin still includes forests that are important for drinking water, but the Clear Creek-Mineral Fork and Mineral Fork watersheds within the adjacent Big

River basin are now identified as particularly significant (Fig. 59A). Private forests are especially important to drinking water in Lower Missouri, Meramec, and Big basins (Fig. 59B). Developments within in the Lost Creek and Schluersburg Creek-Femme Osage Creek watersheds of the Lower Missouri basin, and the Hamilton Creek watershed of the Meramec basin pose the most significant threats to forests critical to surface water supply. (Fig. 59D).

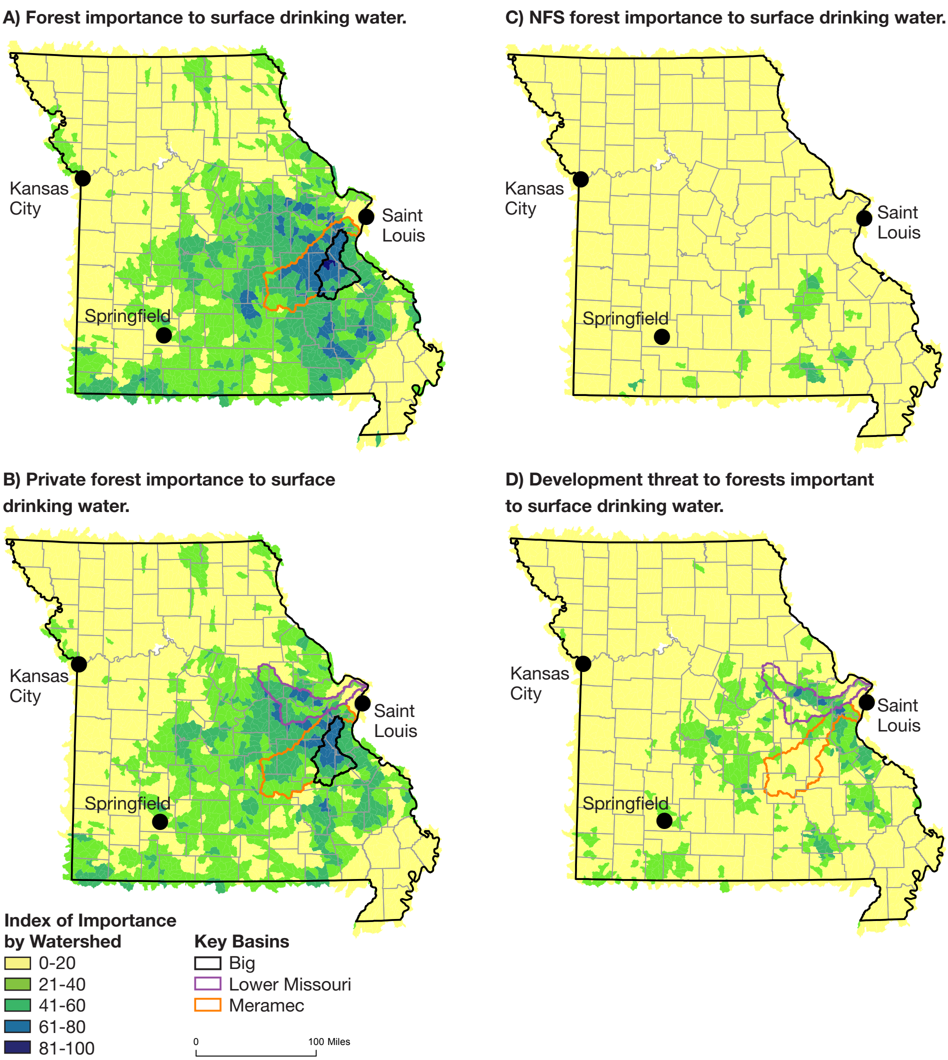


Figure 59.—Relative importance of Missouri's public and private forests to surface drinking water as modeled by the Forests to Faucets project. Development threats are also predicted. (NFS is the Mark Twain National Forest.)

What this means

The U.S. Forest Service and its partners continue to improve watershed-scale assessments of forests important to surface drinking water. New information since Raeker et al. (2011) facilitates assessments of importance and threat at finer scales. The watersheds west and southwest of St. Louis contain large areas of forest land very important to surface drinking water supplies, and these same basins are under the greatest threat to development. Forested watersheds not only provide clean water for homes and businesses, but fill rivers, streams, lakes, and wetlands, and sustain fisheries and wildlife. Water may be the most valuable product produced by public and private forest lands. For natural resource agencies, a renewed focus on forests and their connection to clean and abundant water will be critical.

Forest Products

Lumber from the mill. Photo used with permission of Missouri Department of Conservation.

Growing-stock Volume

Background

Growing-stock volume is a measure that can be used to estimate the volume of wood material that is available for the manufacturing of timber products. Growing-stock volume is the volume of merchantable wood from the 1 foot stump to a 4 inch top diameter inside bark, in standing live trees that are sound, reasonably straight, and more than 5 inches d.b.h. Knowing the growing-stock volume that is available for producing wood products is important in economic planning and development and is an essential consideration in evaluating sustainable forest management.

What we found

Following a 15 percent increase in total growing-stock volume between 2003 and 2008, growing-stock volume has leveled off at 16.4 billion cubic feet (Fig. 60). Between the two inventories, the growing-stock volume of sawtimber-size trees increased by 2 percent while the growing-stock volume of pole-size trees decreased by 9 percent. The volume of growing stock on timberland decreased by 4 percent in the Southwest Ozark Unit between 2008 and 2013; decreased by 2 percent in the Eastern Ozark and Northeastern Ozark Units; and remained the same in the Prairie and Riverborder Units (Fig. 61). Of the 10 most voluminous species in 2008, half had decreases in growing-stock volume between 2008 and 2013. Scarlet oak had a 14 percent decrease, the largest of the group, followed by black hickory with an 11 percent decrease (Fig. 62).

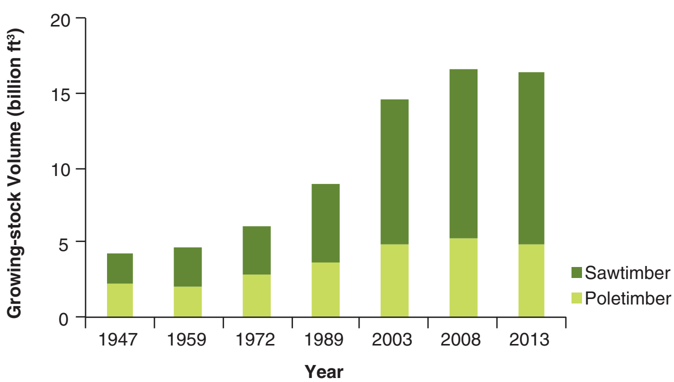


Figure 60.—Growing-stock volume on timberland by tree size and inventory year, Missouri.

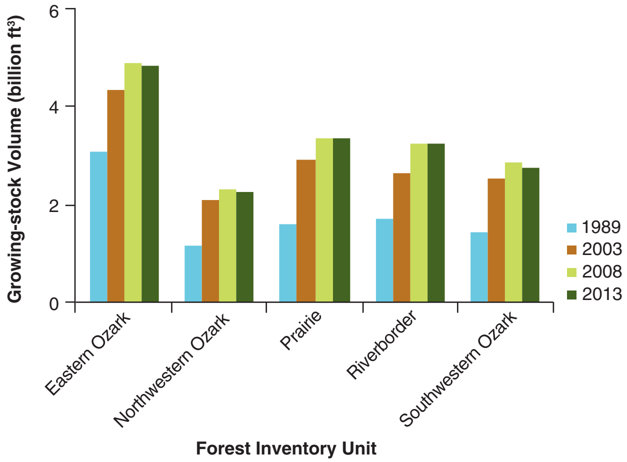


Figure 61.—Growing-stock volume on timberland by Forest Inventory unit and inventory year, Missouri.

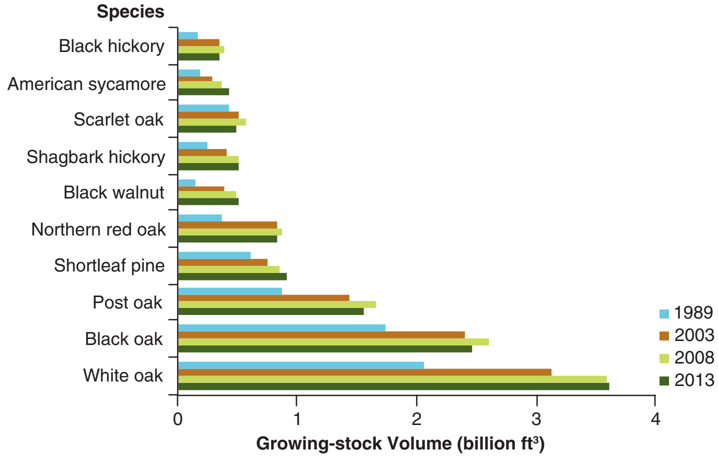


Figure 62.—Growing-stock volume on timberland by species and inventory year, Missouri.

What this means

The slight decrease in growing-stock volume can be attributed to the leveling off of forest land and timberland area, as well as an increase in mortality. Although oak species still maintain significant growing-stock volumes, they had a 3 percent decrease in volume between 2008 and 2013. The growing-stock volume of eastern redcedar, which is the most numerous tree species in the State, decreased by nearly 40 percent. Meanwhile, the growing-stock volume for less common species such as American beech, yellow-poplar, blackgum, and silver maple, has been increasing rapidly. Missouri's forests supply much of the wood for the State's timber products industry; however, as stands mature, sustainability issues (e.g., oak mortality and oak regeneration) should be monitored.

Sawtimber Volume and Quality

Background

Sawtimber trees are live trees of commercial species that contain either one 12-foot or two noncontiguous 8-foot logs that are free of defect. To qualify as sawtimber, hardwoods must be at least 11 inches d.b.h. and softwoods must be 9 inches d.b.h. Sawtimber volume is defined as the net volume of the saw-log portion of live sawtimber, measured in board feet, from a 1 foot stump to minimum top diameter (9 inches for hardwoods and 7 inches for softwoods). Estimates of sawtimber volume are used to determine the monetary value of wood volume and to identify the quantity of merchantable wood availability. The quality of live sawtimber volume is rated using tree grades 1 to 4 (depending on species), where grade 1 is the highest quality and grade 4 the lowest. Tree grades are based on diameter and the presence or absence of defects such as knots, decay, and curvature of the bole. Hardwood sawtimber is valued for wood products like flooring and furniture, while softwood sawtimber is valued primarily for lumber.

What we found

Since 1947, the sawtimber volume on Missouri timberland has more than quadrupled, reaching an estimated 55.5 billion board feet in 2013 (Fig. 63). More than 60 percent the volume of sawtimber is in five species: white oak, black oak, post oak, shortleaf pine, and northern red oak. Collectively, 64 percent of sawtimber volume is made up of mature oaks. Most species groups have had gains in sawtimber volume since 2008, however, increases were not uniform across all species groups (Fig. 64). Oaks continued to show the least growth in sawtimber, with decreasing volumes for the other white oaks and other red oaks species groups. The other eastern softwoods species group, which only contains eastern redcedar in Missouri, had the greatest decrease in sawtimber volume, 56 percent. Since 2003, the quality of Missouri sawtimber has remained fairly consistent, with grade 1 and 2 trees combined accounting for about one-third of the total sawtimber volume, and grade 3 and 4 trees each accounting for one-third of the total volume (Fig. 65). In 1989, grade 4 trees accounted for half of the total sawtimber volume, and grade 1 and 2 trees combined for only 15 percent of the total.

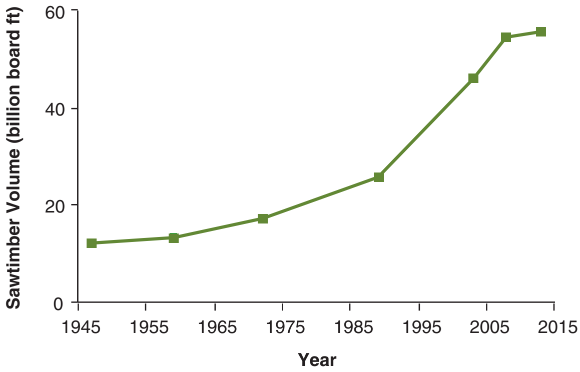


Figure 63.—Sawtimber volume on timberland by inventory year, Missouri.

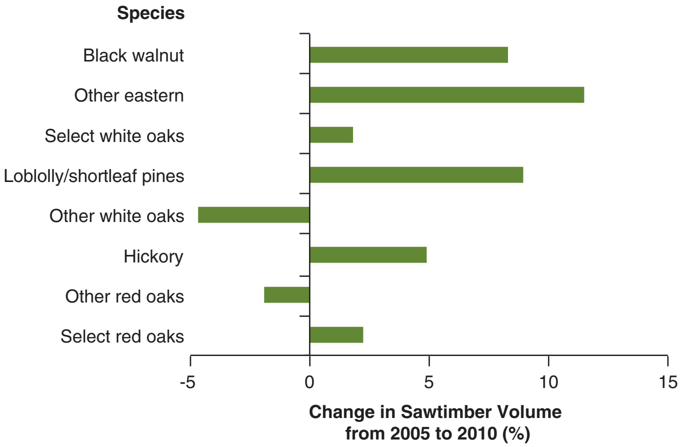


Figure 64.—Percentage change in sawtimber volume on timberland for selected species groups, Missouri, 2008 to 2013.

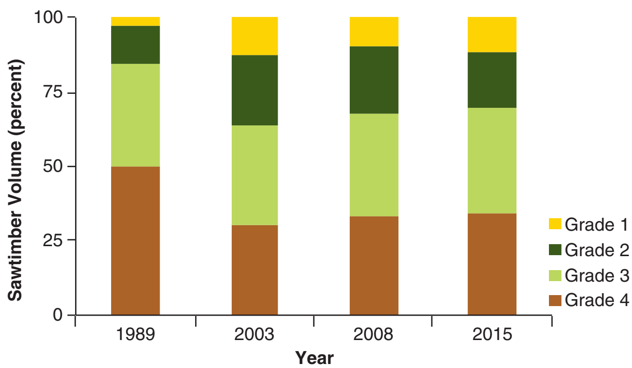


Figure 65.—Sawtimber volume on timberland by tree grade and inventory year, Missouri.

What this means

As Missouri's forests mature, there is the potential for small diameter, sawtimber-size trees to move into better grades as their diameter increases. But, in overmature stands, defects such as cracks and rot become more common in the older trees, resulting in lower tree grades. In addition, losses of sawtimber volume due to damage or mortality increase due to weather, insect, or disease problems.

Timber Products

Background

The harvesting and processing of timber products produces a stream of income shared by timber owners, managers, marketers, loggers, truckers, and processors. A 2011 economic impact analysis for Missouri's forest products industry (a broad definition including logging and sawmill operations, secondary wood products, wood products, furniture and cabinet makers, log cabins, paperboard manufacturing, etc.) found that each year forest products contribute $7.3 billion to the Missouri economy, support over 41,200 jobs at a payroll of about $1.9 billion, and are responsible for almost $610 million in taxes, including $77 million in State sales tax (Treiman 2012). To better manage the State's forests, the primary wood-using industries of Missouri are surveyed periodically to determine the species, amounts, and locations of timber being harvested.[2]

What we found

Between 2008 and 2010, the number of employees working in the forest products industry in Missouri decreased more than 25 percent, but since 2010, the number of employees has increased by 14 percent (U.S. Census Bureau, n.d.a). The total value of shipments decreased by 11 percent from 2007 to 2010, but since 2010 have increased by 15 percent. The 397 primary wood-using industries of Missouri received and processed 127.8 million cubic feet of industrial roundwood in 2012, 23 percent more than was processed in 2009 in the midst of the recent recession (Fig. 66). More than 90 percent of the industrial roundwood processed came from the forest land of Missouri. Arkansas supplied 4 percent of the wood that was processed, and Illinois supplied another 3 percent, with the remainder coming from many different states. Saw logs processed into grade lumber, pallet lumber, railroad ties, or blocking accounted for 88 percent of the volume processed. Cooperage logs, at 4 percent, were the second most processed product.

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[2] Piva, R.J.; Treiman, T.B. Manuscript in preparation. Missouri timber industry: an assessment of timber product output and use, 2012.

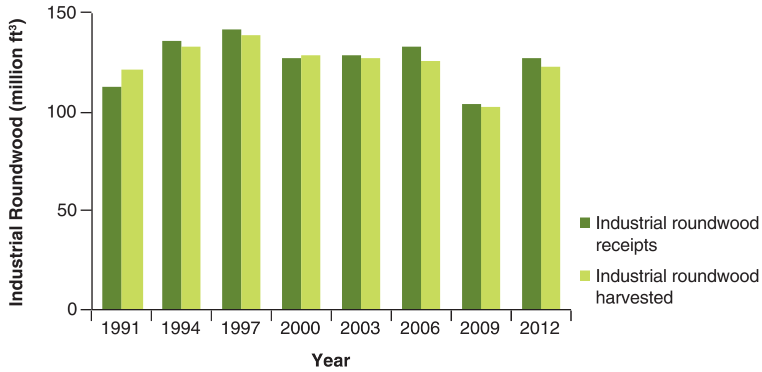

Figure 66.—Industrial roundwood receipts and industrial roundwood harvested by survey year, Missouri.

There were 122.6 million cubic feet of industrial roundwood harvested from Missouri in 2012, an increase of 19 percent from 2009. Saw logs account for 87 percent of the products harvested, and cooperage and pulpwood each account for 3 percent of the total harvest (Fig. 67). Most of the pulpwood harvested is sent to mills in other states. The red oak group is the most harvested species group, accounting for 47 percent of the total harvest, followed by the white oak group at 28 percent (Fig. 68). In the process of harvesting industrial roundwood, 84.2 million cubic feet of harvest residue is left on the ground, with growing-stock material making up 28 percent of the residues.

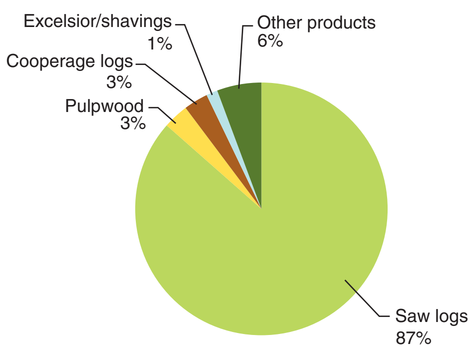

Figure 67.—Industrial roundwood harvested by product, Missouri, 2012.

The processing of industrial roundwood in the State's primary wood-using mills generates about 181,000 green tons of wood and bark residues. A third of the mill residues is used for the production of charcoal (Fig. 69). Other important uses of the mill residues are fiber products, industrial fuelwood, and other miscellaneous uses such as animal bedding and small dimension products. Only 2 percent of the mill residues go unused.

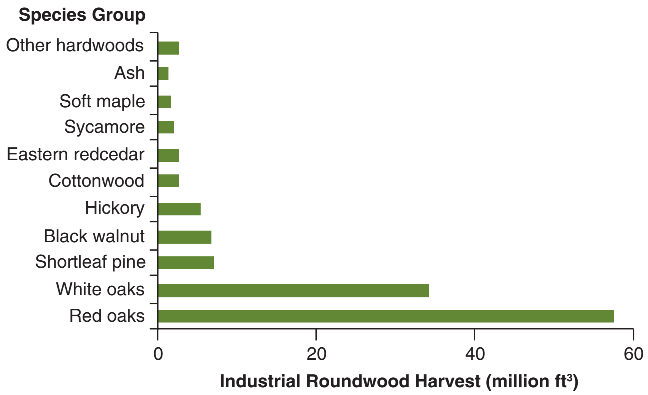

Figure 68.—Industrial roundwood harvested by species group, Missouri, 2012.

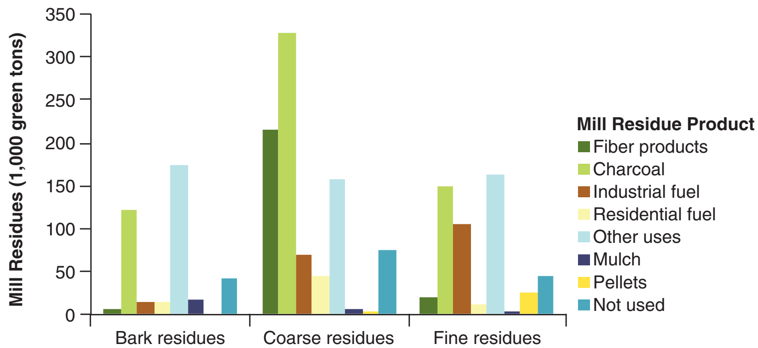

Figure 69.—End use of mill residues generated by primary wood-using mills, Missouri, 2012.

What this means

The increase in shipment value is due to the increase in demand for higher value forest products such as white oak cooperage and black walnut veneer, much of which is being exported out of the United States. As the economy improves and the demand for wood products increases, the forest product mills that were able to withstand the recession are beginning to increase their production, resulting in an increase in the number of employees in the forest products industry.

Another important issue is the volume of unused harvest residues that are generated in the State. Twenty-eight percent of the harvest residues are from growing-stock sources (wood material that could be used to produce products). Missouri's primary forest products industry processes mostly saw logs. This leaves a large volume of usable, small dimension wood material above the saw log top. Markets that could utilize this smaller dimension material would lead to better use of the forest resource. Small, localized, industrial fuelwood or wood pellet manufacturers could lead to better utilization of the lower quality forest resources that are also left as residues.

Forest Habitats

Deer at Ruby Clark Willingham Memorial Wildlife Area. Photo by Missouri Department of Conservation, used with permission.

Background

Forests, woodlands, and savannas provide habitats for 125 species of Missouri birds, 49 species of mammals, and 66 species of amphibians and reptiles (NatureServe 2011). Different forest types at different structural stages provide natural communities (habitats) at a “coarse filter” scale of conservation. Rare, imperiled, or wide-ranging wildlife species may not be fully served at this scale, so a “fine filter” approach is used to identify species-specific conservation needs. Representing an intermediate or “meso-filter” scale of conservation are specific habitat features (e.g., snags, riparian forest strips), which may serve particular habitat requirements for multiple species. This report characterizes habitats at the coarse-filter scale (forest age/size) and meso-filter scale (standing dead trees).

Like all states, Missouri has developed a comprehensive wildlife conservation strategy, also known as a State Wildlife Action Plan (SWAP). Missouri’s first Wildlife Action Plan was completed in 2005; a revised version is now available (Missouri Department of Conservation 2015). Bird, mammal, reptile, and amphibian species of greatest conservation need (SGCN) are included in the plan, including forest-associated species and their forest habitats. For example, prothonotary warbler is a migratory songbird that nests in tree cavities and often forages in downed logs and standing dead trees. Indiana bat is a federally listed endangered species that raises young under bark of certain trees and hibernates through the winter in caves and abandoned mines. Fallen logs in densely forested areas provide habitat features for several salamander SGCN. Young forest provides early successional habitat for several game species. We report on the condition and trends in forest attributes of forest age and size. One of the fine scale conservation issues associated with forest habitats is the presence and abundance of snags and nest cavities. We report on the quantity and distribution of standing dead trees.

Forest Age and Size

Background

Some species of wildlife depend on early successional forests comprised of smaller, younger trees, while others require older, interior forests containing large trees with complex canopy structure. Yet other species inhabit the ecotone (edge) between different forest stages, and many require multiple structural stages of forests to meet different phases of their life cycle needs. Abundance and trends in structural and successional stages serve as indicators of population carrying capacity for wildlife species (Hunter et al. 2001). Historical trends in Missouri’s forest habitats are reported for timberland, which comprises over 96 percent of all forest land in the State. For current habitat conditions, estimates are reported for all forest land.

What we found

Abundance of small diameter stand-size class on Missouri timberland decreased substantially between 1989 and 2003, and has decreased slightly more in the past decade. In contrast, large diameter stand-size class has increased substantially while medium diameter stand-size class has increased moderately during recent decades (Fig. 70). Between 1989 and 2003, area of timberland under 20 years of age has decreased by more than half, and nearly by half again in the past decade. Timberland older than 100 years represents the smallest area of any age class, and has fluctuated slightly up and down since 1989. The age class with greatest increase in timberland area was 61 to 80 years, which nearly doubled since 1989 (Fig. 71). In Missouri, all three stand-size classes contain forests from at least five age classes. Medium stand-size class is predominated by forests of 41 to 60 years of age, with lower abundance of both younger and older forest. Large stand-size class has a similar age distribution, but skewed slightly to the right, predominated by 61-80 year age class. Young forest (0 to 20 years) comprises the greatest area in small diameter stand-size class, but only slightly exceeding 21 to 40 year age class (Fig. 72).

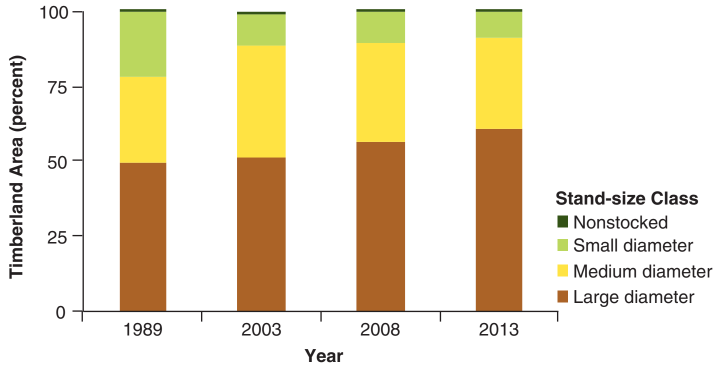

Figure 70.—Percentage of timberland by stand-size class and inventory year, Missouri.

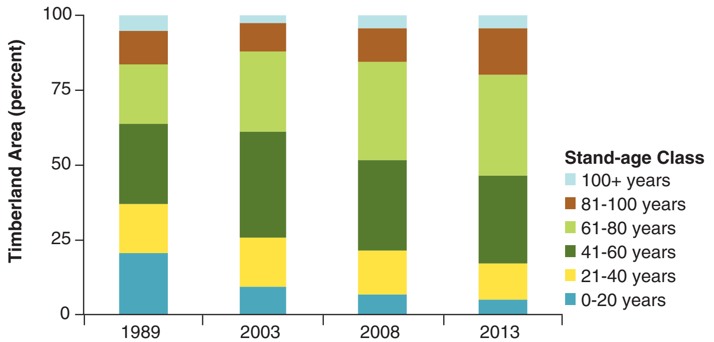

Figure 71.—Percentage of timberland by stand-age class and inventory year, Missouri.

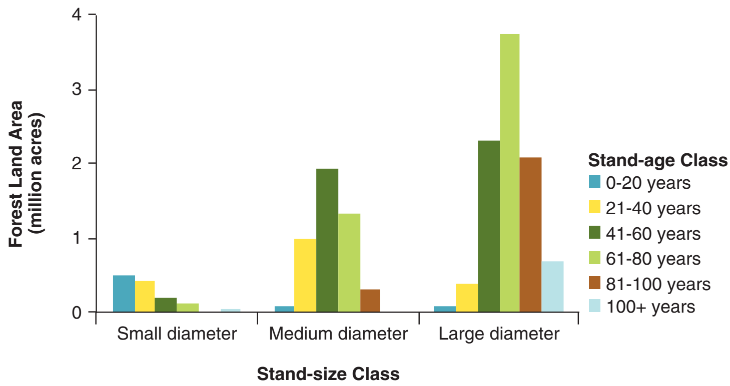

Figure 72.—Area of forest land by age class and stand-size class, Missouri, 2013.

What this means

Increasing area in timberland of large diameter stand-size class comes at the expense of small diameter stand-size class. Similarly, timberland of at least 60 years of age increased by 66 percent between 1989 and 2013 while timberland less than 40 years of age decreased by 48 percent. Both stand-size class and stand-age class are indicators of forest structural/successional stage. Over 73 percent of 0 to 20 year old forest is in small diameter-size class, but only 39 percent of small diameter forest is 0 to 20 years of age. There is no small diameter forest in stand ages over 80 years, and very little in forest older than 60 years. The 41 to 60 year old age class contains nearly as much medium as large stand-size class. The 21 to 40 year old class, although predominated by medium diameter forest, also contains nearly equal amounts of both small and large diameter class. Such mixtures of different aged or sized trees provide a vertical diversity of vegetation structure that can enhance habitat conditions for some species. Managing forest conditions in both younger and older age classes (and smaller and larger structural stages) to maintain both early and late successional habitats for a diversity of forest-associated species may conserve habitat and viable populations of many forest-associated wildlife species.

Standing Dead Trees

Background

Specific habitat features like nesting cavities and standing dead trees provide critical habitat components for many forest-associated wildlife species. Standing dead trees that are large enough to meet habitat requirements for wildlife are referred to as snags. According to one definition, "for wildlife habitat purposes, a snag is sometimes regarded as being at least 10 inches (25.4 cm) in diameter at breast height and at least 6 feet (1.8 m) tall" (Society of American Foresters 1998). Standing dead trees serve as important indicators not only of wildlife habitat, but also for past mortality events and carbon storage. And, they serve as sources of down woody material (discussed elsewhere in this report), which also provides habitat features for wildlife. The number and density of standing dead trees, together with decay classes, species, and sizes, define an important wildlife habitat feature across Missouri's forests.

What we found

FIA collects data on standing dead trees (at least 5 inches d.b.h.) of numerous species and sizes in varying stages of decay. According to current inventory data, more than 170 million standing dead trees are present on Missouri forest land. This equates to an overall density of 11.0 standing dead trees per acre of forest land, with slightly higher densities on public (12.5) than on private (10.7) ownership classes. Five species groups each contributed more than 10 million standing dead trees, with the top group, "other red oaks," contributing over 49 million (Fig. 73), 32.7 million of which are in black oak alone. Six species groups exceeded 10 standing dead trees per 100 live trees (of at least 5 inch d.b.h.) of the same species group, with "other yellow pines" species group topping the list at 73 standing dead trees per 100 live trees (of at least 5 inch d.b.h.) (Fig. 74). (However, records for 'other yellow pine species group' are based on only four trees, observed on only two plots, meaning that this observation is unreliable.) Over 76 percent of standing dead trees were smaller than 11 inches d.b.h., with 41 percent between 5 and 6.9 inches d.b.h.; only 5 percent are over 17 inches (Fig. 75), the same percentage of live trees (of at least 5 inch d.b.h.) that are over 17 inches. With the exception of the class for most decay (no evidence of branches remain), the numbers of standing dead trees are relatively evenly distributed among four classes of least decay, ranging from 22 to 26 percent of trees; the remaining 3 percent of trees are in the class of most decay. This pattern of distribution is similar for all diameter classes except for the 5.0-6.9 inch class (Fig. 75).

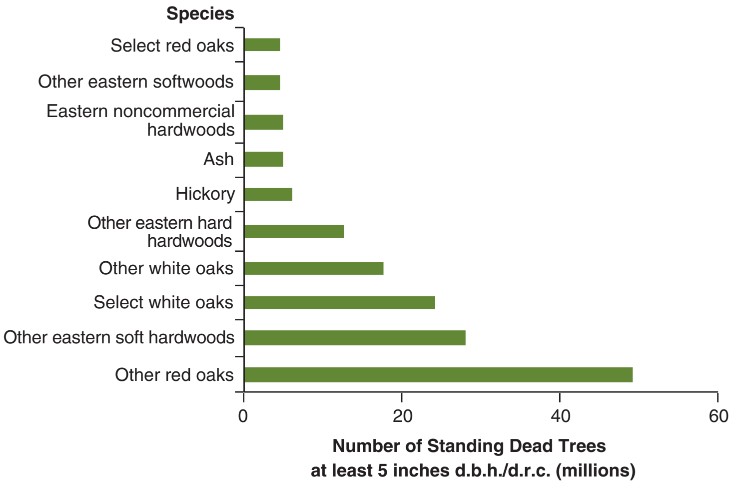

Figure 73.—Number of standing dead trees by the top 10 species groups, Missouri, 2013.

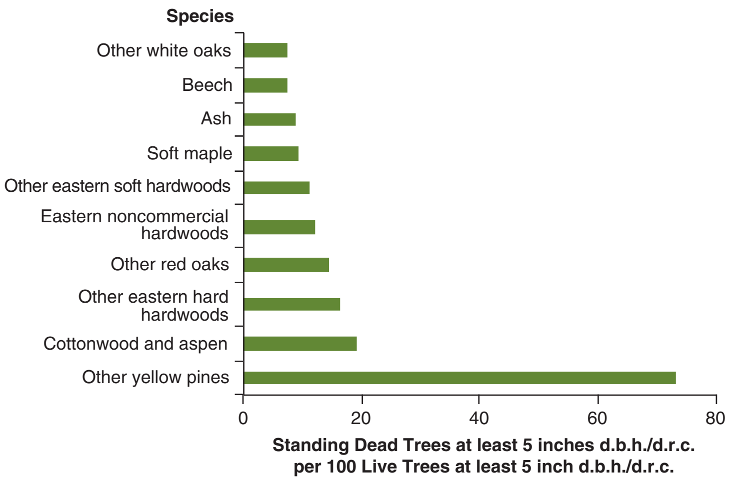

Figure 74.—Number of standing dead trees per 100 live trees (of at least 5 in. d.b.h.) by the top 10 species groups, Missouri, 2013.

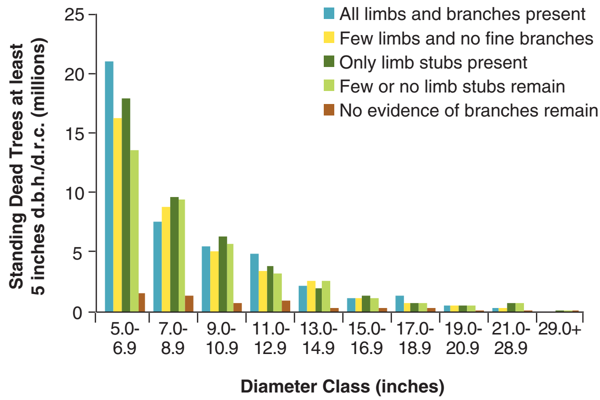

Figure 75.—Distribution of standing dead trees by decay and diameter classes for all dead trees, Missouri, 2013.

What this means

Snags and smaller standing dead trees result from a variety of potential causes, including diseases and insects, weather damage, fire, flooding, drought, and competition, and other factors. Other red oaks species group contained the largest number of standing dead trees. Excluding other yellow pines (due to insufficient sample size), cottonwood and aspen species group had the highest density of standing dead trees per 100 live trees. About 12.5 standing dead trees are present for every acre of forest land; about 8 are present for every 100 live trees (of at least 5 inch d.b.h.). Dead trees may contain significantly more cavities per tree than occur in live trees (Fan et al. 2003), thereby providing habitat features for foraging, nesting, roosting, hunting perches, and cavity excavation for wildlife, from primary colonizers such as insects, bacteria, and fungi to birds, mammals, and reptiles. Most cavity nesting birds are insectivores which help to control insect populations. The availability of very large standing dead trees (snags) may be a limiting meso-scale habitat feature for some species of wildlife. Providing a variety of forest structural stages and retaining specific features like snags on both private and public lands are ways that forest managers maintain the abundance and quality of habitat for forest-associated wildlife species in Missouri.

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. Forests of Missouri face numerous regeneration stressors such as invasive plants, insects, diseases, herbivory, and climate change. As forests mature and undergo stand replacement disturbances, it is imperative to know the condition of the regeneration component. Although planting and seeding are options in some stands, Missouri is dominated by forest systems that typically regenerate naturally. In most situations, establishing desirable reproduction is the key to replacing stands in need with high-canopy species that meet managers' objectives. Managing young stands to control composition and stocking levels is also an important consideration (Johnson et al. 2009, Smith 1997). Information about regeneration is critically important to understand and project future forests and ultimately determines sustainability of the full suite of forest values available from Missouri's forests.

FIA added protocols on a subset of plots to collect detailed information on regeneration; this is known as the regeneration indicator sample (McWilliams et al. 2015). Field crews measured all established tree seedlings less than 1 inch d.b.h. and assessed white-tailed deer (*Odocoileus virginianus*) browse impact for the area surrounding the sample location. Results presented here are for regeneration data collected in 2012 and 2013.

What we found

There are an estimated 106.2 billion seedlings on forest land in Missouri, or an average of 6,300 seedlings per acre. Fifty-two percent of the seedlings are less than 1 foot tall, 40 percent are 1.0 to 4.9 feet, and 8 percent are 5.0 feet and taller (Fig. 76). Overall seedling abundance exhibits no apparent pattern across Missouri (Fig. 77).

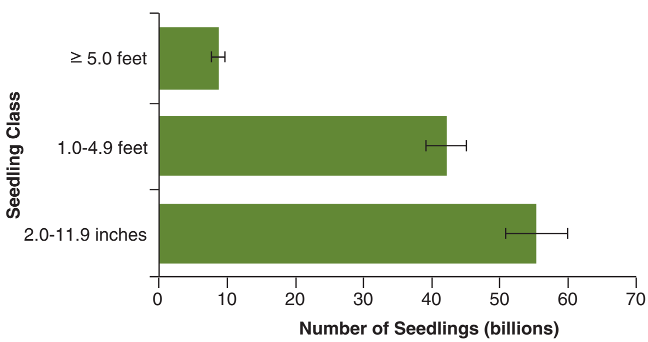

Figure 76.—Number of seedlings on forest land by height class, Missouri, 2012-2013. Error bars represent 68-percent confidence interval around the estimate.

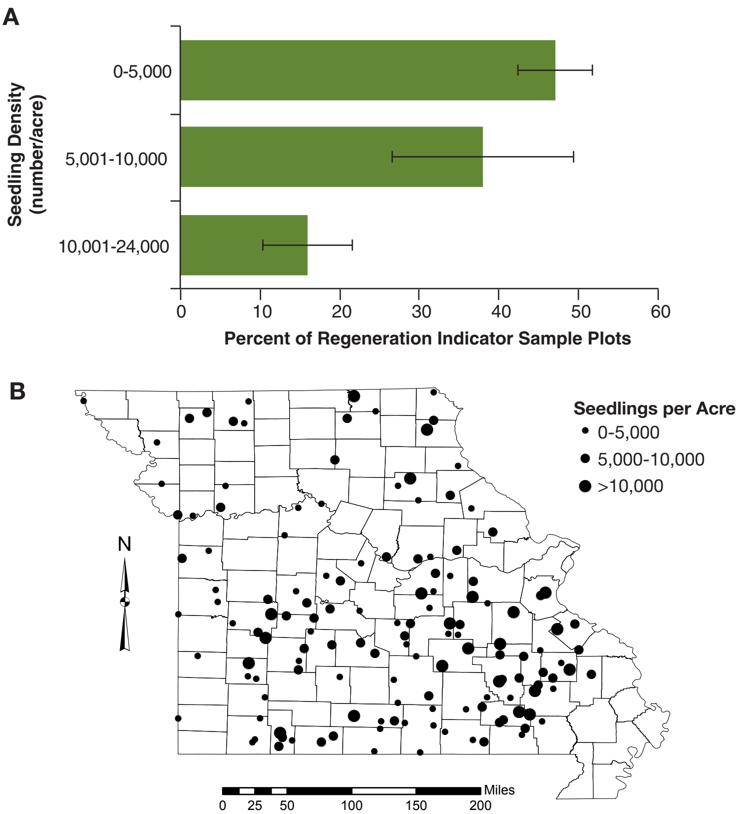

Figure 77.—Seedling density distribution (A) and approximate locations of sample plots (B) on forest land, Missouri, 2012-2013. Error bars represent a 68 percent confidence interval around the estimate. Plot locations are approximate.

Field crews observed 57 species/species groups, with oak being the most abundant genera (20 percent of total number of seedlings). White oaks were the most prominent oak species, with 13 percent of the seedlings. Ash was the second most important genera with 16 percent, followed by elm (13 percent), maple (8 percent), and hickory/black walnut (7 percent). Even though the oak genera is the most abundant, white ash, with 11.9 billion seedlings, and hackberry, with 9.1 billion seedlings, are the most numerous (Fig. 78). Many of the other taxa with at least 1 percent of the seedling pool are species that typically develop as understory or midstory components, e.g., eastern redbud and flowering dogwood.

Fifty-five percent of sample plots had low (55 percent) or medium (36 percent) levels of browse of understory plants (Fig. 79). Only 8 percent were found to have high or very high browse levels. Examination of browse impact across the State reveals that most of the samples with medium or higher levels of browse impact were in the north and west areas of the State, which are less forested then the southern part (Fig. 80).

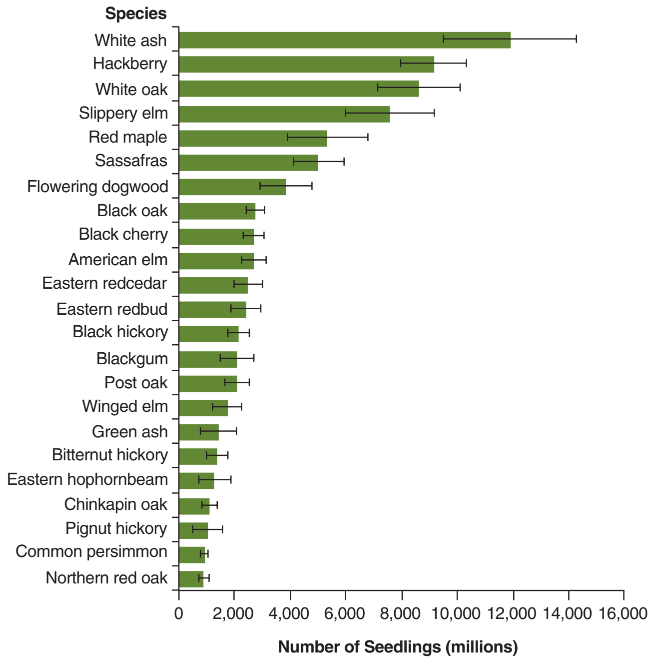

Figure 78.—Number of seedlings by species on forest land, Missouri, 2012-2013. Error bars represent 1 standard error or a 68-percent confidence interval.

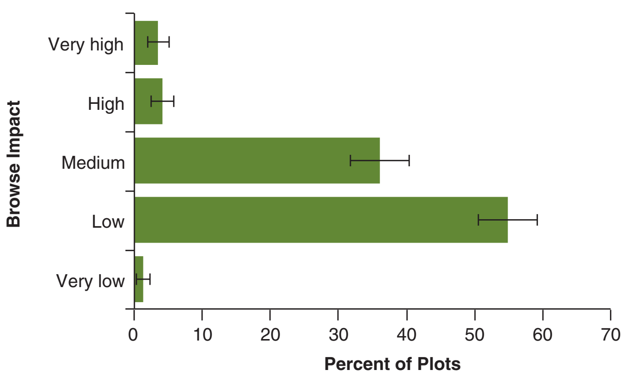

Figure 79.—Proportion of plots by browse impact level, Missouri. Seedling estimates are for 2012-2013. Sapling and tree estimates are for 2009-2013.

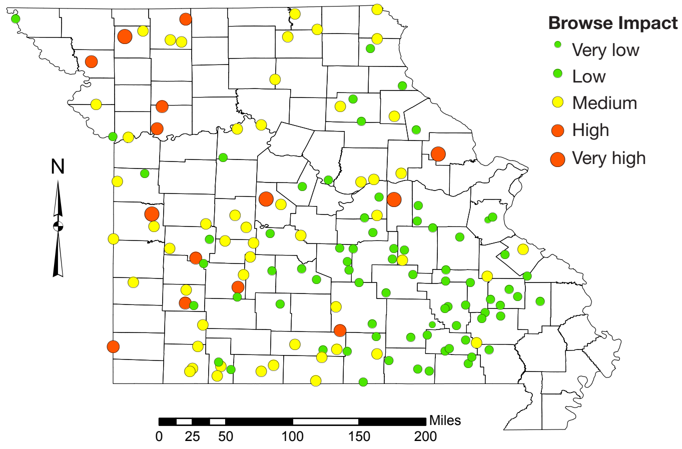

Figure 80.—Browse impact by sample plot. Plot locations are approximate.

What this means

Early successional young forest habitat provides unique plant biota and landscape heterogeneity (Greenberg et al. 2011). Missouri's forests supports 470 species of birds and mammals, many of which depend on young forest habitat (Missouri Department of Conservation 2010). Some prime examples include golden-winged warbler (*Vermivora chrysoptera*), American woodcock (*Scolopax minor*), and cottontail rabbit (*Sylvilagus floridanus*) (Gilbart 2012). The quality and health of Missouri's young forest depends directly on the condition of the regeneration component. Since 1989, the area of young forest (0 to 20 years old) decreased form 19 percent of the total forest area to only 5 percent. Young oak/hickory stands now comprise 4 percent of the oak/hickory forest. This is important because oak/hickory forests provide valuable timber and are a critical source of wildlife food and habitat. The State's oak/hickory forest ranks second in size in the nation (behind Texas) and accounts for 8 out of 10 acres of the State's forest land (12.4 million acres).

Comparing species abundance relative to the number of trees, by height and diameter class, highlights potential pathways for future canopy dominants. Figure 81 depicts results for select species/species groups for seedlings and dominant/co-dominant saplings and adults based on the percentage each contribute to the total for each size class. Prospective "gainers" are those species with relatively high percentages of stems in the regeneration pool of seedlings and saplings compared to larger trees. Ash, maple, and the "other" species are the most apparent gainers. Ash as a potential "gainer" should be tempered with information on its prospective demise due to emerald ash borer. Prospective "losers" in the development of future canopy dominants are species with lower percentages in the regeneration pool than the adult pool. Potential losers are white oak, red oak, shortleaf pine, and eastern redcedar. Hickory/black walnut falls between the gainer and loser categories and bears watching in the future.

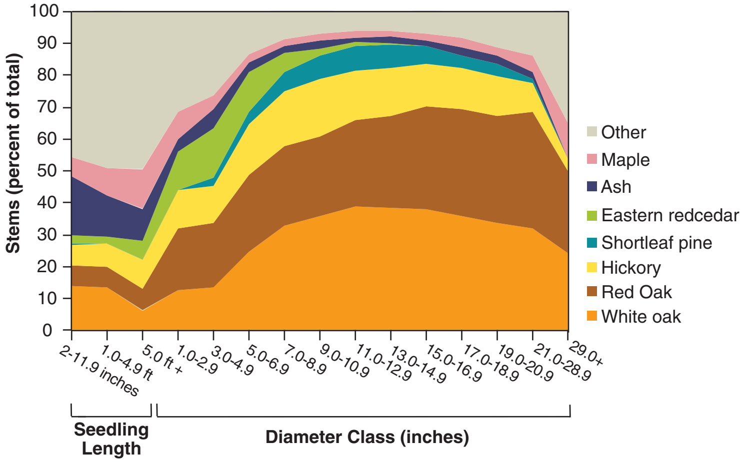

Figure 81.—Percent of total number of seedlings, saplings, and dominate/co-dominate growing-stock trees on forest land for select species by species group and size, Missouri. Seedling estimates are for 2012-2013; sapling and tree estimates are for 2009-2013.

Missouri forests face a variety of forest health risks. Forest regeneration is an integral factor in ameliorating most of these risks during the regeneration phase of development. The most important risk factors are described by Raeker et al. (2010) as follows:

- Forest fragmentation complicates forest regeneration management activity.
- Exotic invasive plants impede tree regeneration and reduce forest management options.
- Native species, such as red maple, invade sites previously supporting oaks.
- High deer populations can eliminate palatable tree seedlings.
- Lack of fire and other disturbances limits oak regeneration.
- Oak decline and gypsy moth degrade oak forest health.
- Ash is threatened by the emerald ash borer.
- Black walnut is threatened by the thousand cankers disease.
- Changing climate may cause species dislocation and competition from invasive plants.

Oak regeneration difficulties are a well-known issue in the Midwest (Holt and Fischer 1979). Existing management guides for oak provide the basis for mitigating regeneration stress factors. Nearly all oak regeneration in Missouri is a result of natural advance regeneration (Larsen and Johnson 1998). Xerophytic oaks depend on drought tolerance and the ability to resprout and require stand replacement disturbances, such as fire, to provide adequate light (Larsen et al. 1997, Steen et al. 2011). It was found that red and white oaks have lower percentages of seedling and sapling-size stems than larger trees. In dense forests, oaks are often replaced by more shade tolerant species (Abrams 1992). This is particularly true in mesophytic conditions, where maple seedlings and saplings are more abundant then other size-classes with the exception of the 29 inch diameter class. The finding that maples, particularly red maple, are poised to expand in the future as stands undergo stand replacement disturbance suggests that silvicultural intervention may be required for establishing young oak regeneration.

Very few shortleaf pine seedlings were observed, making this a species deserving of close monitoring. Shortleaf pine management includes a combination of thinning, planting, and burning to create young shortleaf forests that provide unique plant diversity and wildlife habitat (Raeker 2010).

The results presented here reflect only 28 percent of the measurements from 141 sample plots that will eventually comprise the first full baseline dataset for the regeneration indicator and will allow more detailed analyses by improving the level of statistical confidence in the estimates (i.e., narrower confidence intervals) and will facilitate research to evaluate plot-level regeneration adequacy for the major forest-type groups and future trends in composition, structure, and health of Missouri forests.

Future Forests of Missouri

Cypress swamp at Allred Lake Natural Area. Photo by Missouri Department of Conservation, used with permission.

What will Missouri forests look like in 2060? The Northern Forest Futures study examined several alternative future scenarios that cover a range of different assumptions about the economy, population, climate, and other driving forces that will affect the future conditions of forests (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 550,000 acres of forest land to be converted to urban land (Nowak 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 a storyline and storyline variation. They are identified by their storyline identifier (A1B, A2, or B2) followed by a hyphen and then their storyline variation (C, BIO, or EAB).

Two climate models, three storylines, and three variations were used to produce the seven scenarios listed in Table 9.

Table 9.—Scenarios used to project future forest conditions for Missouri as part of the Northern Forest Futures Project

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

[a] IPCC is the Intergovernmental Panel on Climate Change.

The two general circulation climate models are:

1) CGCM3.1—Canadian Centre for Climate Modeling and Analysis (CCCMA 2012b).

2) CGCM2—Coupled Global Climate Model (CCCMA 2012a).

The three storylines are:

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.

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.

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.

The three storyline variations (known as scenarios) are:

1) C—Standard scenario available for all three storylines.

2) BIO—Variations of the A1B, A2, and B2 storylines look at impact of increased harvest and utilization of woody biomass for energy. They are referred to as scenarios A1B-BIO, A2-BIO, and B2-BIO.

3) EAB—Variation of the A2 storyline examines the potential impact of continued spread of the emerald ash borer with associated mortality of all ash trees in the affected areas. This is referred to as scenario A2-EAB.

The anticipated declines in forest land, which total in the hundreds of thousands of acres, reverse the long-term trend of increasing forest area in Missouri since the 1972 inventory (Fig. 76). Specifically, over the next 50 years, forest land area is projected to decline from an estimated 15.4 million acres in 2010 to 14.6 million acres (-5 percent) in 2060 under scenario A1B-C; to 14.8 million acres (-4 percent) under scenario A2-C; and to 15.0 million acres (-3 percent) under scenario B2-C. The anticipated losses of forest land are still relatively small compared to the cumulative increase in forest area since the 1972 inventory of Missouri's forests. Only three scenarios are represented in Figure 82 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.

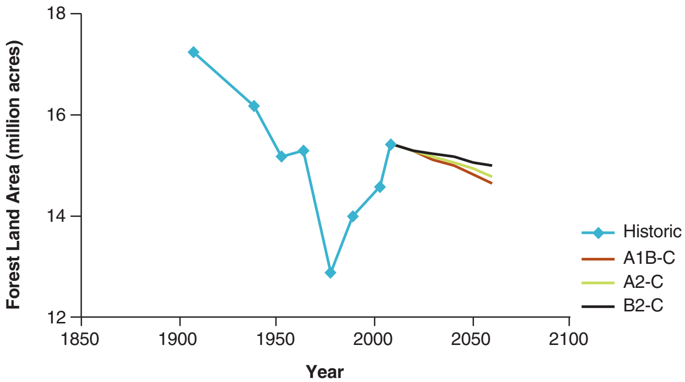

Figure 82.—Projected forest land area for Missouri by scenario, 2010-2060.

Emerald ash borer (EAB) was detected at Wappapello Lake in southeastern Missouri on July 23, 2008. Ash species comprise only 2 percent of the total live tree volume on forest land in Missouri and only 6 percent of the volume in the elm/ash/cottonwood forest-type group. Under scenario A2-C-EAB, ash species volume is projected to decline from 463 million cubic feet in 2010 to zero cubic feet by 2050. Under scenario A2-C, ash volume is expected to decline from 463 million cubic feet in 2010 to 353 million cubic feet by 2060. There is a slight decline if the area in the elm/ash/cottonwood forest-type group from 2010 to 2060 under both scenario A2-C (-12 percent) and A2-C-EAB (-28 percent) (Fig. 83). Surprisingly the decline is larger for the A2-C scenario than the A2-C-EAB scenario where ash species volume is nonexistent in 2060. The loss of the ash component in the elm/ash/cottonwood forest-type group in scenario A2-C-EAB is partially offset by increases in other associated species in the elm/ash/cottonwood forest-type group.

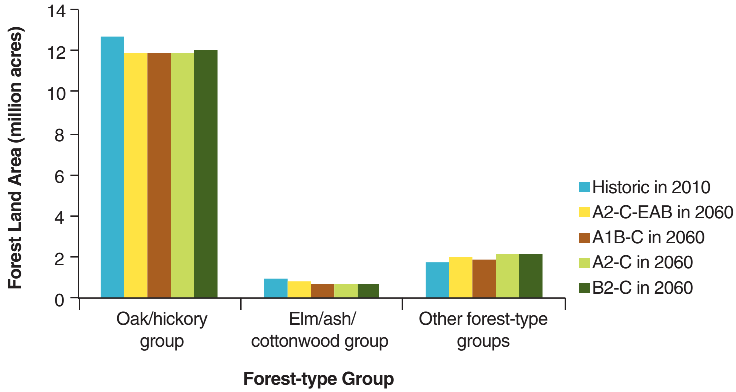

Figure 83.—Forest land area by forest-type group, 2010 and by scenario in 2060.

Projections show the negative impacts of EAB; ash volume under scenario A2-C-EAB is projected to be 0.4 percent less than the volume under scenario A2-C in 2060 (Fig. 84). This is still a rather small impact on overall volume; the impacts of EAB will be greater on Missouri forest diversity.

The three scenarios that project high biomass utilization (A1B-C-BIO, B2-C-BIO, and A2-C-BIO) show lower levels of live tree volume in 2060 than do their corresponding standard biomass utilization scenarios (A1B-C, B2-C, and A2-C), but surprisingly live tree volume on forest land in 2060 is projected to be less than the 2010 volume under only the A1B-C-BIO scenario. The area of forest land is expected to decrease but the volume per acre for all but the A1B-C-BIO scenario is expected to increase as forests continue to mature.

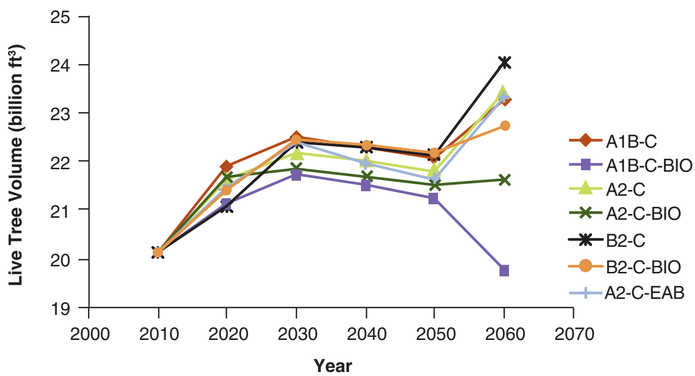

Figure 84.—Live tree volume on forest land in Missouri by scenario, 2010-2060.

Data Sources and Techniques

Forest Inventory

Information on the condition and status of forests in Missouri was obtained from the Northern Research Station's Forest Inventory and Analysis program. Previous inventories of Missouri's forest resources were completed in 1947 (U.S. Forest Service 1948), 1959 (Gansner 1965), 1972 (Spencer and Essex 1976), 1989 (Spencer et al. 1992), 2003 (Moser et al. 2007), and 2008 (Raeker et al. 2011). Detailed information on inventory methods and data from Missouri's forest inventories can be found in the companion report to this document, "Missouri Forests 2013: Statistics, Methods, and Quality Assurance," available as a supplementary file at https://doi.org/10.2737/NRS-RB-108.

National Woodland Owner Survey

Information about family forest owners is collected annually through the U.S. Forest Service's National Woodland Owner Survey (NWOS). The most recent survey methods and results can be found at Butler et al. 2016a and 2016b.

The NWOS was designed to increase our understanding of owner demographics and motivation. Individuals and private groups identified as woodland owners by FIA are invited to participate in the NWOS. Each year, questionnaires are mailed to 20 percent of private owners, with more detailed questionnaires sent out in years that end in 2 or 7 to coincide with national census, inventory, and assessment programs. Data presented here are based on survey responses from randomly selected families and individuals who own forest land in Missouri. For additional information about the NWOS, visit: www.fia.fs.fed.us/nwos.

Timber Products Output Survey

The Timber Products Output survey is a cooperative effort of Missouri Department of Conservation and the U.S. Forest Service's Northern Research Station. Using a questionnaire designed to determine the size and composition of Missouri's forest products industry, its use of roundwood (round sections cut from trees), and its generation and disposition of wood residues, MDC personnel visited all "known" primary wood-using mills within the state. Completed questionnaires were sent to NRS for processing and analyses. As part of data processing and analyses, all industrial roundwood volumes reported on the questionnaires were converted to standard units of measure using regional conversion factors. Timber removals by source of material and harvest residues generated during logging were estimated from standard product volumes using factors developed from logging utilization studies previously conducted by NRS.

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Appendix

Appendix—List of tree species, greater than or equal to 5 inches in diameter, found on FIA inventory plots, Missouri, 2008 to 2013

Common name	Genus	Species
Eastern redcedar	*Juniperus*	*virginiana*
Shortleaf pine	*Pinus*	*echinata*
Eastern white pine	*Pinus*	*strobus*
Scotch pine	*Pinus*	*sylvestris*
Virginia pine	*Pinus*	*virginiana*
Boxelder	*Acer*	*negundo*
Black maple	*Acer*	*nigrum*
red maple	*Acer*	*rubrum*
Silver maple	*Acer*	*saccharinum*
Sugar maple	*Acer*	*saccharum*
Ohio buckeye	*Aesculus*	*glabra*
Ailanthus	*Ailanthus*	*altissima*
Mimosa, silktree	*Albizia*	*julibrissin*
Serviceberry spp.	*Amelanchier*	spp.
Common serviceberry	*Amelanchier*	*arborea*
Pawpaw	*Asimina*	*triloba*
River birch	*Betula*	*nigra*
Chittamwood, gum bumelia	*Sideroxylon*	*lanuginosum*
American hornbeam, musclewood	*Carpinus*	*caroliniana*
Bitternut hickory	*Carya*	*cordiformis*
Pignut hickory	*Carya*	*glabra*
Pecan	*Carya*	*illinoinensis*
Shellbark hickory	*Carya*	*laciniosa*
Shagbark hickory	*Carya*	*ovata*
Black hickory	*Carya*	*texana*
Mockernut hickory	*Carya*	*alba*
Red hickory	*Carya*	*ovalis*
Chestnut spp.	*Castanea*	spp.
Northern catalpa	*Catalpa*	speciosa
Sugarberry	*Celtis*	*laevigata*
Hackberry	*Celtis*	*occidentalis*
Eastern redbud	*Cercis*	*canadensis*
Flowering dogwood	*Cornus*	*florida*
Smoketree	*Cotinus*	*obovatus*
Hawthorn spp.	*Crataegus*	spp.
Cockspur hawthorn	*Crataegus*	*crus-galli*

(Appendix continued on next page.)

(Appendix continued)

Common name	**Genus**	**Species**
Downy hawthorn	*Crataegus*	*mollis*
Persimmon spp.	*Diospyros*	spp.
Common persimmon	*Diospyros*	*virginiana*
American beech	*Fagus*	*grandifolia*
White ash	*Fraxinus*	*americana*
Black ash	*Fraxinus*	*nigra*
Green ash	*Fraxinus*	*pennsylvanica*
Pumpkin ash	*Fraxinus*	*profunda*
Blue ash	*Fraxinus*	*quadrangulata*
Waterlocust	*Gleditsia*	*aquatica*
Honeylocust	*Gleditsia*	*triacanthos*
Kentucky coffeetree	*Gymnocladus*	*dioicus*
Butternut	*Juglans*	*cinerea*
Black walnut	*Juglans*	*nigra*
Sweetgum	*Liquidambar*	*styraciflua*
Yellow-poplar	*Liriodendron*	*tulipifera*
Osage-orange	*Maclura*	*pomifera*
Cucumbertree	*Magnolia*	*acuminata*
Apple spp.	*Malus*	spp.
Mulberry spp.	*Morus*	spp.
White mulberry	*Morus*	*alba*
Red mulberry	*Morus*	*rubra*
Water tupelo	*Nyssa*	*aquatica*
Blackgum	*Nyssa*	*sylvatica*
Swamp tupelo	*Nyssa*	*biflora*
Eastern hophornbeam	*Ostrya*	*virginiana*
American sycamore	*Platanus*	*occidentalis*
Eastern cottonwood	*Populus*	*deltoides*
Cherry and plum spp.	*Prunus*	spp.
Black cherry	*Prunus*	*serotina*
Chokecherry	*Prunus*	*virginiana*
American plum	*Prunus*	*americana*
White oak	*Quercus*	*alba*
Swamp white oak	*Quercus*	*bicolor*
Scarlet oak	*Quercus*	*coccinea*
Northern pin oak	*Quercus*	*ellipsoidalis*
Southern red oak	*Quercus*	*falcata*

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(Appendix continued)

Common name	**Genus**	**Species**
Cherrybark oak	*Quercus*	*pagoda*
Shingle oak	*Quercus*	*imbricaria*
Overcup oak	*Quercus*	*lyrata*
Bur oak	*Quercus*	*macrocarpa*
Blackjack oak	*Quercus*	*marilandica*
Swamp chestnut oak	*Quercus*	*michauxii*
Chinkapin oak	*Quercus*	*muehlenbergii*
Water oak	*Quercus*	*nigra*
Nuttall oak	*Quercus*	*texana*
Pin oak	*Quercus*	*palustris*
Willow oak	*Quercus*	*phellos*
Chestnut oak	*Quercus*	*prinus*
Northern red oak	*Quercus*	*rubra*
Shumard oak	*Quercus*	*shumardii*
Post oak	*Quercus*	*stellata*
Black oak	*Quercus*	*velutina*
Black locust	*Robinia*	*pseudoacacia*
Peachleaf willow	*Salix*	*amygdaloides*
Black willow	*Salix*	*nigra*
Coastal plain willow	*Salix*	*caroliniana*
Sassafras	*Sassafras*	*albidum*
American basswood	*Tilia*	*americana*
Winged elm	*Ulmus*	*alata*
American elm	*Ulmus*	*americana*
Siberian elm	*Ulmus*	*pumila*
Slippery elm	*Ulmus*	*rubra*
Rock elm	*Ulmus*	*thomasii*

Piva, Ronald J.; Treiman, Thomas B.; Butler, Brett J.; Crocker, Susan J.; Gormanson, Dale D.; Griffith, Douglas M.; Kurtz, Cassandra M.; Lister, Tonya W.; Luppold, William G.; McWilliams, William H.; Miles, Patrick D.; Morin, Randall S.; Nelson, Mark D.; Perry, Charles H.; Riemann, Rachel; Smith, James E.; Walters, Brian F.; Woodall, Christopher W. 2016. **Missouri Forests 2013.** Resour. Bull. NRS-108. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 116 p.

The third full cycle of annual inventories (2009-2013) of Missouri's forests, completed in 2013, reports that there are an estimated 15.5 million acres of forest land in the State. An estimated 60 percent of the forest land area is in sawtimber size stands, 30 percent are pole timber size, and 10 percent are seedling/sapling size or nontstocked. The net volume of live trees on forest land increased by 4 percent, from 20.1 million cubic feet in 2008, to 21.0 million cubic feet in 2013. Average annual net growth of live trees on forest land decreased by more than 25 percent, from an average of 36 cubic feet per acre in 2008, to an average of 26 cubic feet per acre in 2013. This report includes additional information on forest attributes, land-use change, carbon, and forest health. In addition to this document, Missouri Forests 2013: Statistics, Methods, and Quality Assurance is online at https://doi.org/10.2737/NRS-RB-108. It contains 1) descriptive information on methods, statistics, and quality assurance of data collection, 2) a glossary of terms, 3) tables that summarize quality assurance, 4) a core set of tabular estimates for a variety of forest resources, 5) a set of user and database guides for P2, P3, and P2+, and 6) a Microsoft Access database that represents an archive of data used in this report, with tools that allow users to produce customized estimates.

KEY WORDS: biomass, carbon, growth, inventory, forest land, forest health, forest statistics, mortality, removals, volume

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