Missouri's Forests 2008

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Abstract

The second full annual inventory of Missouri's forests (2004-2008) reports more than 15 million acres of forest land, almost all of which is timberland (98 percent), with an average volume of more than 1,117 cubic feet of growing stock per acre. White oak and black oak are the most abundant in terms of live tree volume. Eighty-three percent of the State's forest land is owned by private landowners. This report includes additional information on forest attributes, land use change, carbon, timber products,climate change, forest health, and the role of fire. A DVD included in this report includes 1) descriptive information on methods, statistics, and quality assurance of data collection, 2) a glossary of terms, 3) tables that summarize quality assurance, 4) a core set of tabular estimates for a variety of forest resources, and 5) a Microsoft Access database that represents an archive of data used in this report, with tools that allow users to produce customized estimates.

Cover Photo

Maple forest near a pond. Photo by Missouri Department of Conservation.

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Missouri's Forests 2008

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Foreword

Welcome to the second 5-year report from the U.S. Forest Service statewide forest inventory, Missouri's Forests 2008. The 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 by 1.4 million acres since 1989. Missouri's forests are growing more wood than is being harvested. Missouri's forests support a forest products industry that contributes $5.7 billion annually to the Missouri economy (2008 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 threats. Oaks, the dominant species, are menaced by oak decline, and other species such as ash and black walnut face future threats from exotic insect invaders. Land ownership parcelization and forest land conversion to other land uses results 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's Forests 2008 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 G. Allen

Lisa G. Allen
State Forester, Missouri Department of Conservation

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HIGHLIGHTS

On the Plus Side

- Forest land area has increased to 15.4 million acres, more than a third of Missouri's total land area.
- Softwood forests make up about 4 percent of the total forest land area. Oak/hickory forest-type group makes up about 86 percent of the total hardwood forest land area.
- The bulk of Missouri's timberland is in the large stand-size class, increasing from less than 32 percent of the total timberland area in 1947 to 56 percent of the area in 2008.
- Missouri's forests have continued to increase in volume. In 2008, all-live tree volume on forest land in Missouri was an estimated 20.1 billion cubic feet compared to 9 billion cubic feet in 1972. The 2008 total represents an 11.7 percent increase since 2003.
- All-live tree and sapling biomass on forest land in Missouri amounted to 620 million dry tons in 2008. Almost 3 percent was in small-diameter stands, 28 percent was in medium-diameter stands, and 69 percent was in large-diameter stands.
- Missouri's forests have continued to grow. In the latest survey, net softwood growth of live trees on forest land was 58.5 million cubic feet per year and net hardwood growth was 487.6 million cubic feet per year.
- Oak species were represented by five of the top seven species on forest land by volume in 2008.
- More than 82 percent of Missouri's forest land is held by private landowners.

Areas of Concern

- Average annual mortality of all growing stock on timberland was 125.6 million cubic feet per year; a 54 percent increase since 2003. Over 97 percent of the total mortality occurred in hardwood forest types. Over 20 percent occurred on public lands. Looking just at hardwoods, almost 20 percent of the average annual mortality was on public lands. Thirty-nine percent of average annual softwood mortality was on public land. Other red oaks, the species group that includes scarlet and black oaks, had the highest average annual mortality at 54.3 million cubic feet per year.
- The mean age of Missouri's forests is still increasing: the acreage in oak types greater than 65 years is 7.5 million acres, with 6.7 million acres in oak-hickory types. This advancing age has both positive and negative implications: older forests can provide habitat for species that depend upon such age classes for habitat and food sources, yet older forests might be more susceptible to forest health problems.
- Emerald ash borer is approaching Missouri and will have a devastating impact on the nearly 1 million acres of elm/ash/cottonwood forest-type group in the state when it arrives.

Forest in Barry County, MO. Photo used with permission of Missouri Department of Conservation

Raspberries. Photo used with permission of Missouri Department of Conservation.

Introduction

Ozark forest in morning fog. Photo used with permission of Missouri Department of Conservation.

MISSOURI'S LANDSCAPE

Missouri's geology, geography, and location at the boundaries of several ecological regions have combined to create a unique mix of ecosystems. To better organize and describe these natural systems, many state agencies and organizations in Missouri use two references for ecological classification. "The Terrestrial Natural Communities of Missouri" (Nelson 2005) classifies 85 distinct natural communities in Missouri, including 33 forest and woodland communities. The second reference is Missouri's ecological classification system (ECS), modeled after the U.S. Forest Service's approach to ecological classification (Nigh and Schroeder 2002). This hierarchical ecological framework helps describe the relationship between Missouri's natural communities and landscapes.

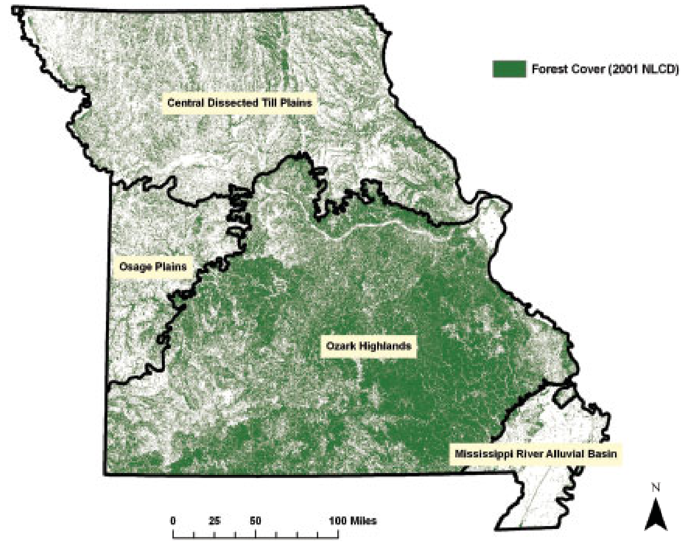

Figure 1.—Missouri's ecological sections. Map produced by Missouri Department of Conservation using 2001 National Land Cover Data and MDC's Ecological Classification System data (Missouri Department of Conservation 2010).

ECS divides the state into four distinct ecological sections (Fig. 1) and helps explain why Missouri has such high levels of 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 Highlands, and Mississippi Alluvial Basin.

The Central Dissected Till Plains includes most of northern Missouri. Soils are mainly comprised of glacial till deposited over 400,000 years ago. Historically, much of this landscape consisted of prairie, especially in the uplands. Sideslopes consisted of transitional savannas and woodlands, and bottomlands and other protected areas consisted of well drained forests and poorly drained wetlands (prairie and forest). Most of this area today is devoted to agriculture. Existing natural communities tend to be somewhat fragmented and isolated. Forests and woodlands make up a relatively small component of the landscape (varying from 5 to 15 percent of the landcover). However, the forests and woodlands found here tend to be highly productive.

The Osage Plains is located in west-central Missouri, and consist of unglaciated soils. This section was historically dominated by prairie and extensive wetland complexes. Currently, most of this section is devoted to agriculture. In fact, more than 60 percent of the section is currently in pasture. Forests and woodlands are currently limited and are found mostly on steeper slopes and valleys.

The Ozark Highlands Section is Missouri's most heavily forested section and makes up most of the southern half of the state. The Ozark Highlands, stretching from southern Missouri across northern Arkansas and containing small portions of Illinois, Kansas, and Oklahoma, is essentially a plateau that has undergone weathering for up to a quarter billion years (McNab and Avers 1994). This process has resulted in a highly diverse landscape containing more than 200 endemic species in the Ozark Highlands Section (Foti and Bukenhofer 1998). The highest and least rugged parts of the Ozarks tend to be flat to gently rolling plains that were formerly covered with prairies, savannas, and open woodlands. Near drainages, the plains give way to rolling hills and then to rugged, highly dissected hills. These hills historically supported oak and oak-pine woodlands and forest with countless springs, caves, fens, cliffs and glades scattered throughout. Many species are associated with these features and with the high quality Ozark streams running throughout the landscape. Much of the area that was historically in forest and woodland is still in forest and woodland cover, though it has been impacted significantly by historical harvesting practices, livestock grazing, and altered fire regimes.

The Mississippi Alluvial Basin is found in Missouri's extreme southeast corner—the "Bootheel"—and consists mostly of alluvial soils with the primary exception of Crowley's Ridge, a narrow hill region that rises above the Mississippi River alluvial plain. Historically, most of this section was poorly drained and consisted of marshes, swamps, and bottomland forests. Earlier in the 20th century, most of these bottomlands were drained and converted to cropland. However, there are still substantial, isolated patches of timbered areas that can serve as core areas for maintenance of the diversity of wildlife indigenous to this region.

Within ecological sections, Missouri is further divided into 31 subsections (Fig. 2). Subsections are delineated with the same criteria as sections (climate, geomorphology, topography, soils, and potential vegetation types), but at a finer scale. Sixteen of these subsections are located in the Ozark Highlands. Of the 31 subsections, several reside mostly in neighboring states with only a small portion extending into Missouri. Examples of subsections include the Current River Hills in the Ozark Highlands, and the Mississippi River Alluvial Plain in the Mississippi Alluvial Basin (Nigh and Schroeder 2002).

Subsections are then further divided into landtype associations (LTAs). LTAs are delineated by similar criteria to sections and subsections, but at an even finer scale. LTAs are landscapes of natural community assemblages with distinctive management challenges and opportunities. Since there are more than 300 LTAs in Missouri, LTAs are sometimes combined into 25 LTA types (Fig. 3). LTA types are groupings of LTAs with similar characteristics and management needs. Detailed profiles of these LTA types are described in Missouri Department of Conservation (2010).

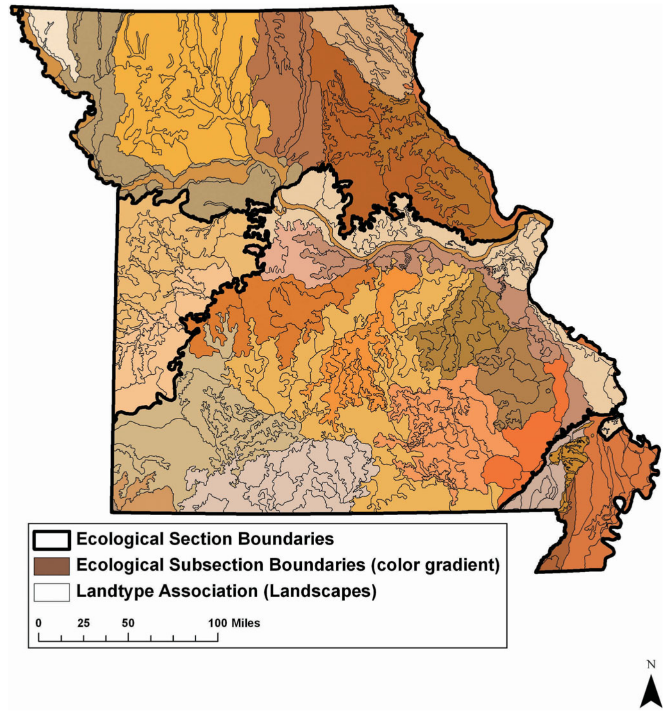

Figure 2.—Missouri's ecological sections, subsections, and LTAs. The shades of brown represent different ecological subsections, within which are demarcated landtype associations. Map produced by Missouri Department of Conservation using MDC's Ecological Classification System data (Missouri Department of Conservation 2010).

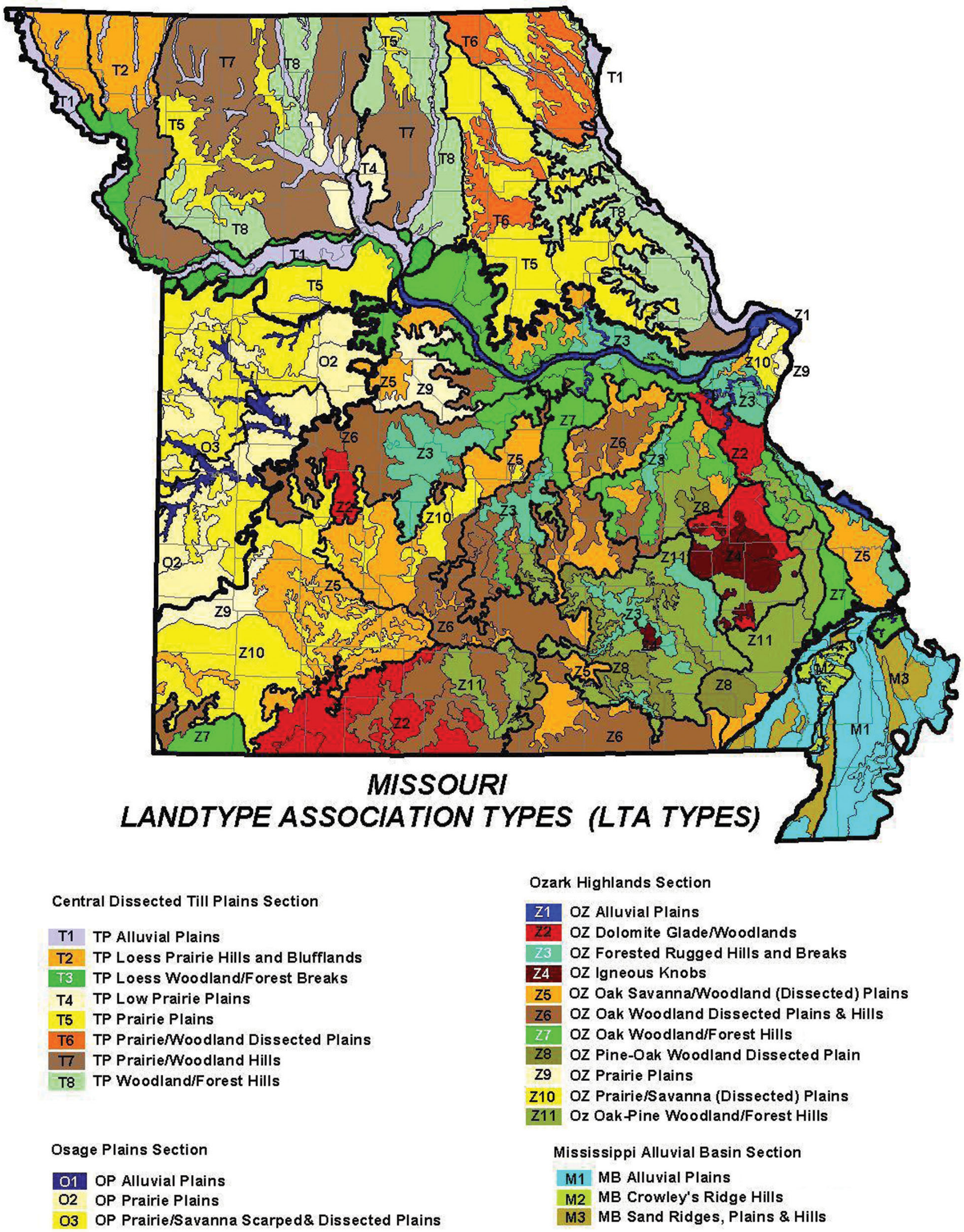

Figure 3.—Missouri's LTA types. Map produced by Missouri Department of Conservation using MDC's Ecological Classification System data (Missouri Department of Conservation 2010).

Forest Features

Forest road. Photo used with permission of MIssouri Department of Conservation.

CONDITIONS, TRENDS, AND THREATS

The Forest Inventory and Analysis (FIA) program of the U.S. Forest Service, divides each state into inventory units, usually with an ecological basis and encompassing a subset of the State's counties (Fig. 4). Forest land[1] covers approximately one-third of Missouri's 44.6 million acres (Fig. 5), and is categorized into nine forest-type groups by FIA. Area and volume are traditional measures of forest trends and have been summarized by FIA since inventory reports on Missouri's forests were published beginning in 1947. In the early reports, the focus was on economic benefits of forests. But over time, the increasingly diverse uses of Missouri's forests and increasingly detailed understanding of linkages and benefits derived from forest land means that these area and volume estimates denote more than economic influences, and now include ecological processes and recreational and other social impacts.

Figure 4.—Missouri inventory units and counties.

Missouri's forests have trees of almost every possible size. To understand trends in stand structure and composition, FIA looks for the plurality of stocking for trees less than 5 inches (seedling/sapling or small diameter), 5 to 9 inches (softwoods), or 5 to 11 inches (hardwoods), respectively (poletimber or medium diameter), and greater than either 9 inches (softwood) or 11 inches (hardwood) inches (sawtimber or large diameter). Sometimes stand size is used as a surrogate for stand age, but this relationship is by no means certain, so estimates of stand age using tree size should be viewed with caution. There is no right or preferred mix of stand-size classes across large or small landscapes; rather, particular combinations or trends might explain observations of forest health, growth, or change.

AREA

Background

FIA differentiates forest land by two criteria: productive/unproductive and reserved/unreserved (Moser et al. 2007). Combining these criteria, we define three components of forest land: 1) Timberland--forest land not restricted from harvesting by statute, administrative regulation, or designation and capable of growing trees at a rate of 20 ft^3 ac^{-1} yr^{-1} at maximum annual increment; 2) Reserved forest land—land restricted from harvesting by statute, administrative regulation, or designation (e.g., state parks, national parks, federal wilderness areas); 3) Other forest land—low productivity forest land that is not reserved. Nearly 98 percent of Missouri's forest land is defined as timberland, so timberland trends correspond closely with forest land trends.

What we found

After a decline in forest land acreage during the 1960s and 1970s, the area in forests has increased to the present day's level of 15.4 million acres (Fig. 6). Timberland acreage has followed a similar trend. As updated satellite imagery and visits to previously unforested land have detected natural and human-caused afforestation, the area in forest and timberland has increased over the last 5 years (Table 1). The number of trees per acre has stayed relatively constant over the past 5 years, with the slight decline perhaps

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[1]FIA defines forest land as land at least 10-percent stocked by trees of any size, including land that formerly had such tree cover and that will be naturally or artificially regenerated. The minimum area for classification of forest land is 1 acre and 120 feet wide measured stem-to-stem from the outer-most edge. Unimproved roads and trails, streams, and clearings in forest areas are classified as forest if less than 120 feet wide.

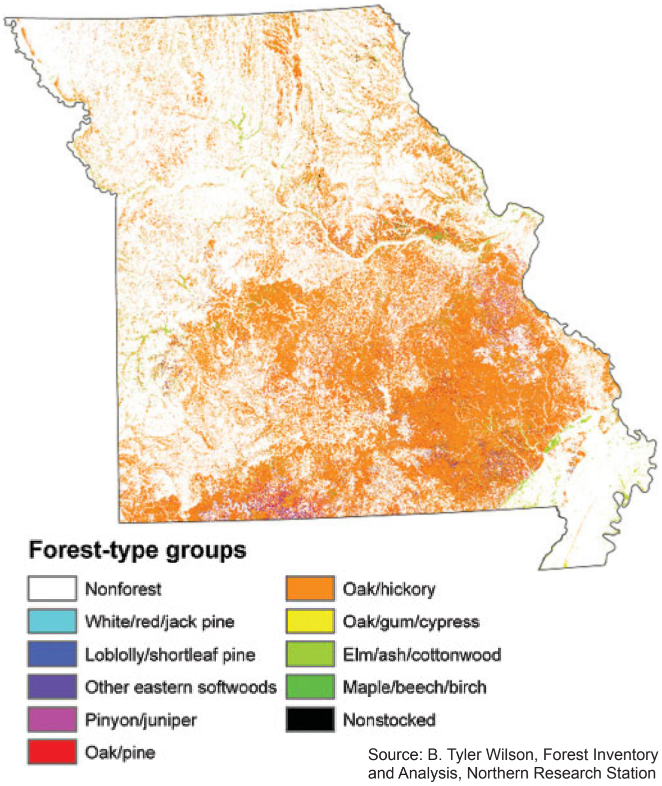


Figure 5.—The extent of forests in Missouri, broken out by forest-type groups using 2006 data.[2]

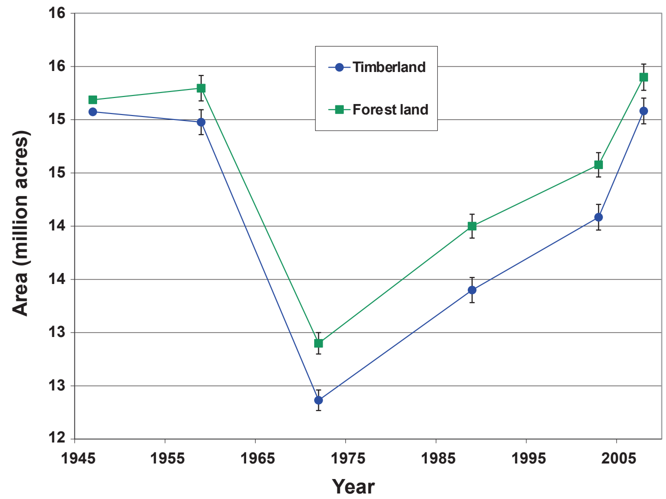


Figure 6.—Missouri forest land and timberland area, 1947-2008. Bars represent 68 percent confidence intervals.

[2]A forest type is a classification of forest land based on the species presently forming a plurality of the live-tree stocking. If softwoods predominate (50 percent or more), then the forest type will be one of the softwood types and vice versa for hardwoods. For the eastern United States, there are mixed hardwood-pine forest types when the pine and/or redcedar (either eastern or southern) component is between 25 and 49 percent of the stocking. If the pine/redcedar component is less than 25 percent of the stocking, then one of the hardwood forest types is assigned. A forest-type group is a combination of forest types that share closely associated species or site requirements and are generally combined for brevity of reporting." (See 'Statistics, Methods, and Quality Assurance" section on the DVD included with this publication).

Table 1.—Total area and number of trees on forest land and timberland in Missouri, 2003 and 2008

	2008 Estimate	Sampling error (percent)	Change since 2003 (percent)	2003 Estimate
Forest land estimates				
Area (1000 acres)	15,396.9	0.8	5.6	14,576.4
Number of all live trees 1 inch diameter or larger (million trees)	8,533.9	1.3	4.4	8,177.2
Live trees per acre on forest land	554.3	--	-1.2	561.0
Timberland estimates				
Area (1000 acres)	15,047.7	0.8	7.0	14,064.9
Number of all live trees 1 inch diameter or larger (million trees)	8,317.2	1.4	5.7	7,869.6
Live trees per acre on timberland	552.7	--	-1.2	559.5

reflecting some level of juvenile tree mortality. The vast majority of total forest land acreage in Missouri is in the oak/hickory forest-type group, with over 2 million acres on public land and almost 11 million acres on private land (Fig. 7).

What this means

Missouri forest land has rebounded from the decline of 30-40 years ago. Since then, two countervailing trends—the gain in forest land due to conversion from other uses, usually agriculture, and the loss of forest land, usually due to development—influence the amount of forest land acreage in the State. While some potential still exists for agricultural land to be (re)forested in the future, it is reasonable to assume that this source of new forest land will decrease and net forest land acreage might well decline sometime in the future if Missouri's population increases.

AREA BY FOREST TYPES

Background

Although there are many tree species on Missouri forest land, some forest types are more prominent than others. In this section, we looked at how the top forest types were distributed by stand size class, an indicator of the dominant tree size in each plot.

What we found

White oak/red oak/hickory was the most prominent forest type on the Missouri landscape (Fig. 8). Totaling almost 7 million acres, it is largely found in large- and medium-sized stands. White oak stands, with almost 2 million acres, is the next most common. This type has little acreage in the smaller size classes, suggesting that there are fewer smaller white oak trees coming into the population, which may result in a decline in white oak forests in the future.

AREA BY STAND SIZE CLASS

Background

Missouri timberland declined to its lowest levels in the 1950s-1970s. Conversion to agricultural and residential uses caused some of timberland loss during this period. Lands that remained in forest were heavily cut over, resulting in stands with low stocking and a decreasing proportion of large trees and an increasing proportion of smaller diameter trees.

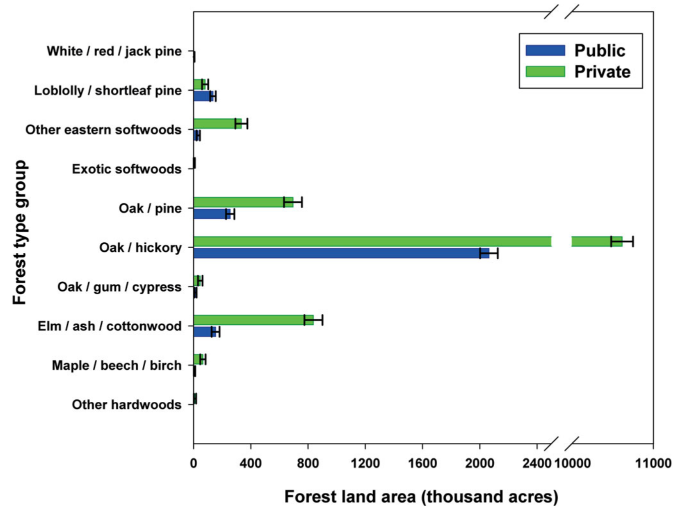


Figure 7.—Forest land area in Missouri, by forest-type group and major ownership group, 2008. Bars represent 68 percent confidence intervals.

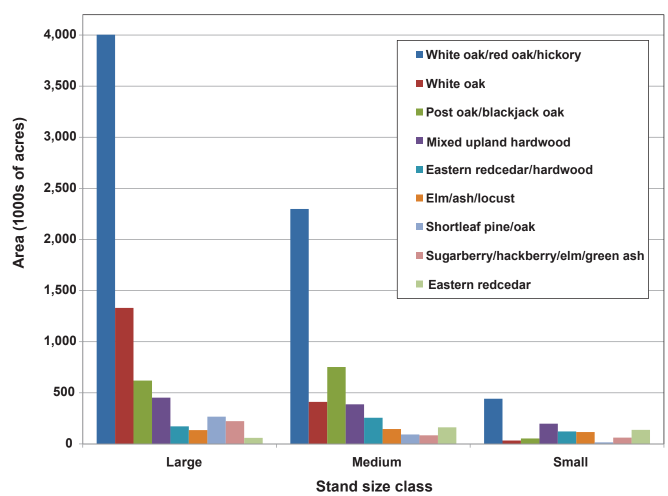


Figure 8.—Area of forest land of top nine forest types, by stand-size class, 2008.

What we found

Acreage of large-diameter stands quadrupled since 1947, while the acreage of medium-diameter stands stayed roughly the same and that of small-diameter stands declined by over 3 million acres (Fig. 9). The most dramatic statistic, however, is the change in the acreage of nonstocked timberland: 3 million acres in 1959 and approximately 50,000 acres in 2008.

Table 2.—Summary of volume and biomass estimates for Missouri, 2003 and 2008

	2008 Estimate	Sampling error (percent)	Change since 2003 (percent)	2003 Estimate
Forest Land Estimates				
Biomass of all live trees 1 inch diameter or larger (oven-dry 1,000 short tons)	620,235.2	1.0	10.2	562,770.7
Biomass of all live trees per forest land acre (oven-dry tons ac^{-1})	40.3	--	4.4	38.6
Net volume of live trees (million cubic feet)	20,143.3	1.2	11.7	18,026.1
Volume of live trees per acre of forest land	1,308.3		5.8	1,236.7
Timberland Estimates				
Biomass of all live trees 1 inch diameter or larger (oven-dry 1,000 short tons)	606,444.0	1.1	11.6	543,225.9
Biomass of all live trees per timberland acre (oven-dry short tons ac^{-1})	40.3	--	4.4	38.6
Net volume of live trees (million cubic feet)	19,703.9	1.2	13.2	17,406.9
Volume of live trees per acre of timberland (ft^3 ac^{-1})	1,309.4	--	5.8	1,237.6
Net volume of growing stock trees (million cubic feet)	16,809.4	1.3	15.1	14,607.3
Volume of growing stock trees per acre of timberland (ft^3 ac^{-1})	1,117.1	--	7.6	1,038.6

What this means

Missouri residents have seen increased economic, ecological, and social benefits from forests due to improved management practices on public and private lands (Gansner 1965, Hahn and Spencer 1991, Moser et al. 2007, Spencer and Essex 1976, USDA 1948).

VOLUME

Background

The volume of trees on forest land was at one time primarily an economic interest but has since evolved as one measure of ecological processes and derivative benefits. As an indicator of benefits such as wildlife habitat and carbon storage, tree volume is an important variable that FIA continues to measure.

What we found

Volume of live trees on forest land and growing-stock trees on timberland has increased by 11.7 and 15.1 percent, respectively, since 2003 (Table 2). Forest land and timberland area have increased 5.6 percent and 7.0 percent, respectively (Table 1). The balance of the total volume increase was made up of an increase in density, measured as volume per acre.

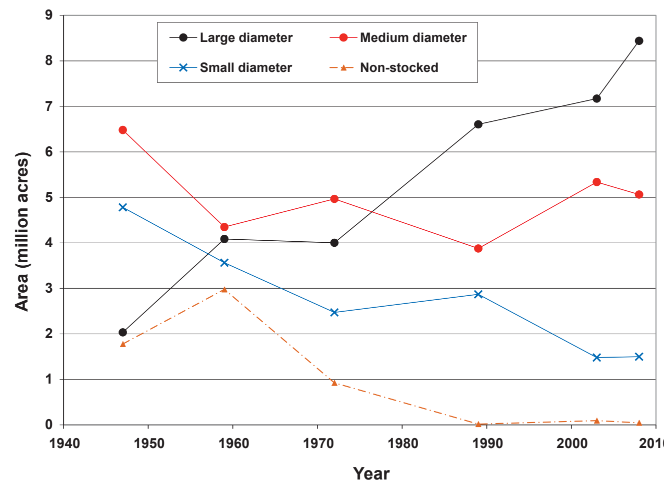


Figure 9.—Area of timberland in Missouri by stand size class, 1947-2008.

Reflecting its dominant position on Missouri's landscape, the oak/hickory forest-type group contains about four-fifths of all volume on Missouri forest land. White oak, black oak, and post oak have displayed significant volume increases in total volume on forest land

Table 3.—Volume of live trees on forest land and sawtimber trees on timberland of the top 10 species in Missouri, 2008 and 2003

Species	Volume of live trees on forest land 2008 (1 million ft^3)	Sampling error (percent)	Change since 2003 (percent)	Net volume of sawtimber trees on timberland (million board feet)	Sampling error (percent)	Change since 2003 (percent)
White oak	4,021.8	2.9	10.7	12,347.3	3.7	20
Black oak	2,941.4	3.2	5.5	9,544.0	4.0	11.4
Post oak	2,095.9	3.6	10.4	4,595.8	4.9	24.2
Northern red oak	1,018.2	5.7	3.5	3,642.6	6.9	8.7
Shortleaf pine	900.6	6.7	11.6	3,753.4	7.1	19
Eastern redcedar	672.6	5.4	24.9	994.9	9.9	5.7
Scarlet oak	654.2	5.7	9.9	2,042.7	6.9	14.8
Black walnut	617.6	6.3	21.2	1,787.7	8.3	35.2
Shagbark hickory	560.9	6.0	21	1,418.5	8.7	34.4
Black hickory	435.8	5.1	7	876.5	8.8	4.3
Other softwood species	15.4	73.3	108.1	68.7	76.3	163.2
Other hardwood species	6,208.8	2.7	15.1	14,094.1	4.1	24.6
All species	20,143.3	1.2	11.7	55,166.2	1.8	19.1

(Table 3). Between 2003 and 2008, five of the top ten tree species in Missouri experienced percentage increases in sawtimber volume on timberland that exceeded the total percentage increase across the State. Black walnut, shagbark hickory, and post oak had the highest percentage increases in sawtimber volume on timberland, while white oak had the largest standing volume.

The proportion of total volume on forest land by ownership category mirrored that of the forest land area, with 16.2 billion cubic feet in private hands and 3.9 billion cubic feet on publicly owned forest land. Of the major forest-type groups, only shortleaf pine, reflected in the loblolly/shortleaf pine forest-type group and the white/red/jackpine group (Figure 10) exhibited greater volumes on public forests than privately owned forest land.

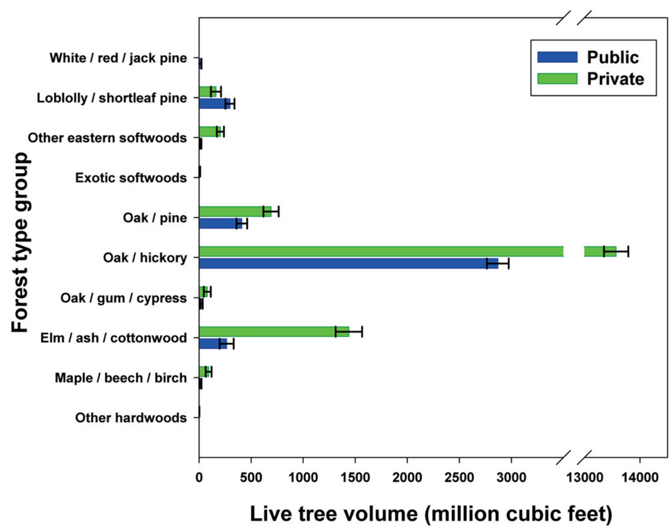


Figure 10.—Live tree volume on forest land in Missouri, by forest-type group and major ownership group, 2008. Bars provided represent 68 percent confidence intervals.

What this means

As stated earlier, oak/hickory forests are the most prominent forest types by far in Missouri. A reflection of many factors, including past management (oak/hickory understories being released when the shortleaf pine overstory was logged off in the late 19th and early 20th centuries), more xeric sites that have inhibited succession by more mesic, shade-tolerant species such as maples, and landowner preference, oak/hickory forests have provided many benefits to Missourians over the years. Such a reliance on one group of species can open up the forests to severe impacts from forest health problems, such as gypsy moth and oak decline.

OWNERSHIP AND LAND USE CHANGE

Background

In addition to an inventory of the biophysical characteristics of the forest, the U.S. Forest Service periodically conducts the National Woodland Owner Survey (NWOS) (Butler 2008) to understand the intentions and actions of the people who own forests. A landowner's actions can have great impact on his or her land.

What we found

Most of Missouri's forests are privately owned (Fig. 11) and of this private forest land, most is owned by families and individuals. Although public landholdings are scattered throughout the State, the two largest public landowners, the U.S. Forest Service (Mark Twain National Forest) and the Missouri Department of Conservation, have a preponderance of their forest land south of the Missouri River (Fig. 12). In 2006, there were an estimated 339,000 family forest owners in Missouri who owned a total of 11.6 million acres of forest land or 77 percent of the State's total forested area (Butler 2008). About one-third of the private forest landowners do not live on or near their forest land and almost 40 percent are full- or part-time farmers (Table 4).

Although the majority of private forest landowners in Missouri own less than 50 acres, the bulk of the private forest land is in parcels of 50 acres or more (Fig. 13). Butler (2008) found that aesthetics, privacy, and family legacy were the top reasons for owning forest land (Fig. 14).

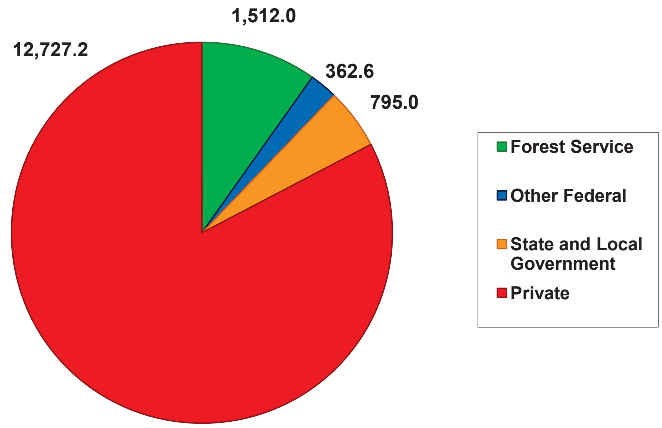


Figure 11.—Missouri forest land ownership, by major ownership group, in thousands of acres.

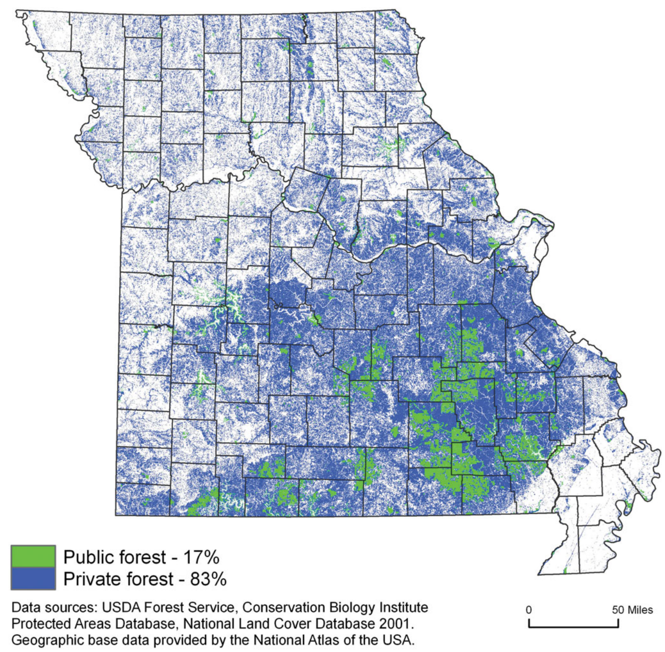


Figure 12.—Forest land in Missouri by major owner group (approximately 34 percent of Missouri is forested). Map by Dacia Meneguzzo, U.S. Forest Service, Northern Research Station.

What this means

According to the U.S. Census Bureau (2008), 13.7 percent of Missouri's population is 65 years and older. Missouri's family forest landowners are older than the general population, with 34.3 percent of the owners and 40.9 percent of the land with owners 65 and older (Fig. 15). This trend, paired with other factors such as increasing land prices, real estate taxes, and economic hardship, is making Missouri's family-owned forest land increasingly vulnerable to threats such as forest conversion, fragmentation, parcelization, and urban development. As these forests are passed on to heirs or sold to new owners, the way the land is managed (or not) can change. These management decisions will have important implications for clean air and water, wildlife habitat, aesthetics, production of forest products, and other services forests provide. One opportunity resulting from land-ownership turnover is the opportunity to form new partnerships between providers of forest management-related knowledge (private consultants, agencies, universities) and new family forest owners. New family forest owners are often eager to gain information and assistance to best manage their forested acres.

Table 4.—Quick facts about Missouri landowners (Butler 2008).

New Owners — 26 percent have purchased their forest land within last 5 years

Absentee Owners — 32 percent do not live on or near (within 1 mile) their land

Farmers — 38 percent have a farm associated with their forest land

Age

- 12 percent are <45 years old
- 54 percent are 45 to 64
- 34 percent are 65 or older

Education

- 32 percent have a college degree

Annual Household Income

- 55 percent under $50,000
- 27 percent $50,000 to $100,000
- 18 percent $100,000 or more

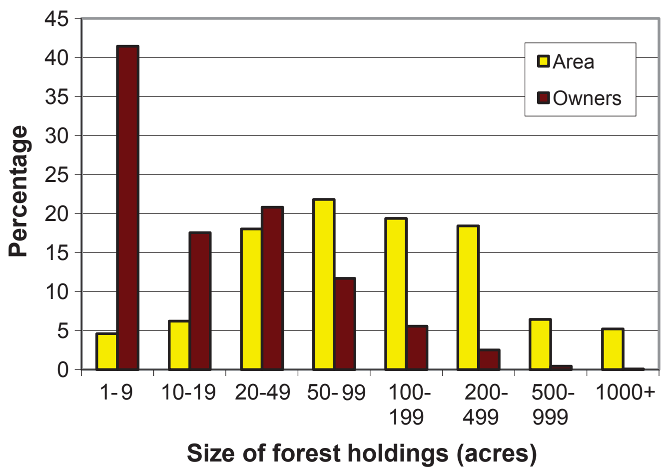


Figure 13.—Area and number of family forests in Missouri by size of forest landholdings (2006).

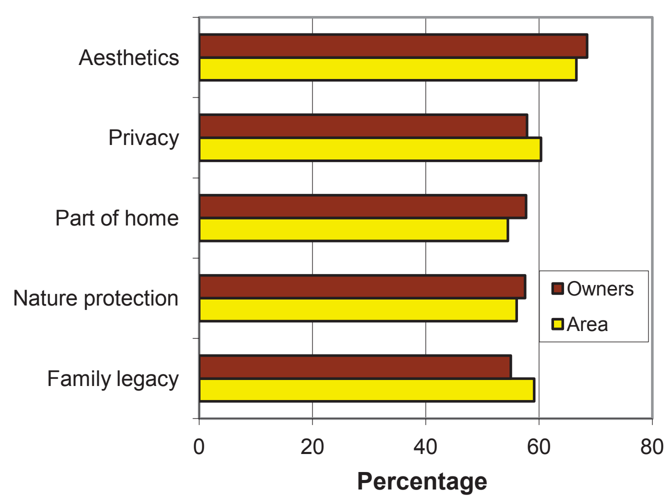


Figure 14.—Area and number of family forests in Missouri by reason for owning forest land (2006). Numbers include landowners who ranked each objective as very important (1) or important (2) on a seven-point Likert scale.

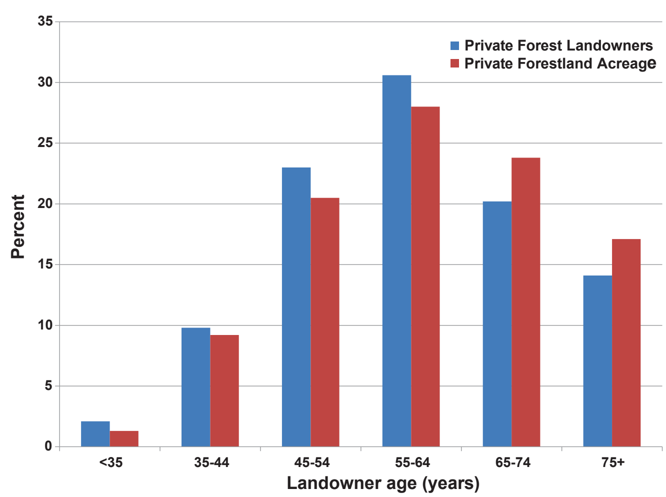


Figure 15.—Distribution of family forest landowners and acreage by landowner age (Butler 2008).

LAND-USE CHANGES: FOREST CONVERSION

Background

Forest conversion is deforestation of land for development, agriculture, and other purposes. Despite previously mentioned assistance through partnerships, economic challenges sometimes make it difficult for family forest owners to manage for their particular objectives. The combination of financial hardships, tax burdens, increasing land ownership turnover rates, and lack of information are making Missouri's forests vulnerable to conversion, fragmentation, parcelization, urban development (Butler 2008), and practices such as timber liquidation. Forest conversion is deforestation of land for purposes such as development and agriculture.

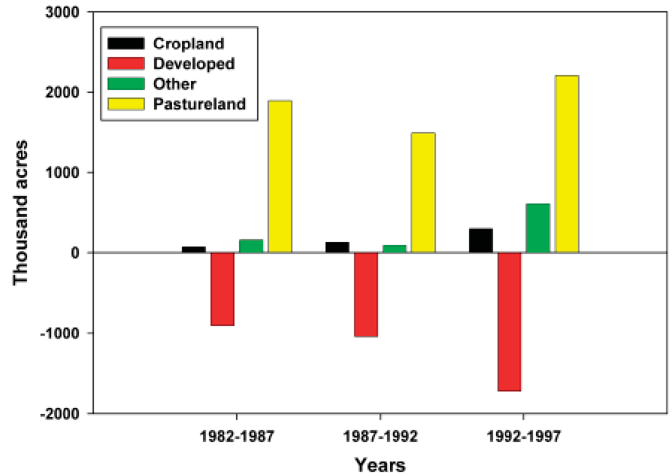


Figure 16.—Net change in forest land to and from other land uses in the Midwest and Northeast United States (Includes 20 states and the District of Columbia ranging from Missouri to Minnesota to Maine to Maryland). Source: USDA Natural Resources Conservation Service-Natural Resources Inventory).

What we found

While many acres of Missouri's forests are being lost or degraded each year, Missouri's net forest acreage has actually increased substantially to 15.4 million acres since bottoming out in the 1980s at about 12.5 million acres (Fig. 6).

However, this statistic is somewhat misleading. Missouri is losing a considerable amount of high quality forest land each year. Between 1992 and 1997 in the Midwest and northeastern United States, 59 percent of forest land loss was due to development, 24 percent was converted to agriculture, and 17 percent was lost to other purposes (USDA 2009) (Fig. 16). While newly forested acres have, for the time being, offset these losses, many of these new forest acres are occurring on abandoned cropland, pastureland, and glades. These new forests frequently consist of less desirable species (e.g., redcedar, locust, boxelder, shingle oak) that are often of lower value for forest products or for promoting biodiversity compared to the forests being lost. In fact, some of these newly forested acres are actually decreasing biodiversity by replacing rare, but important, natural communities such as glades.

What this means

Forest conversion equates to loss of wildlife habitat and important natural communities, decreased capacity for ecosystem services such as water quality, carbon storage, and production of forest products, and exacerbated effects of forest fragmentation. As remaining intact forested areas become smaller in extent, and the State's population continues to increase, these residual forests face more usage demands and, potentially, more stress on the forest ecosystem.

LAND USE CHANGES: FOREST FRAGMENTATION

Background

Forest fragmentation refers to the breaking up of larger forest blocks into smaller, disconnected patches, and also to the increase of forest edge created when sections of a forest are converted from within a larger forest block. Most current fragmentation is caused by residential and commercial development and expansion of utility infrastructure and transportation networks. Continued development near currently undeveloped forest can threaten forest ecosystems (Johnson 2001) and wildlife populations (Soulé 1991). These impacts are particularly important in the wildland–urban interface (WUI), where homes and associated structures are built among forests, shrubs, or grasslands (Radeloff et al. 2005b).

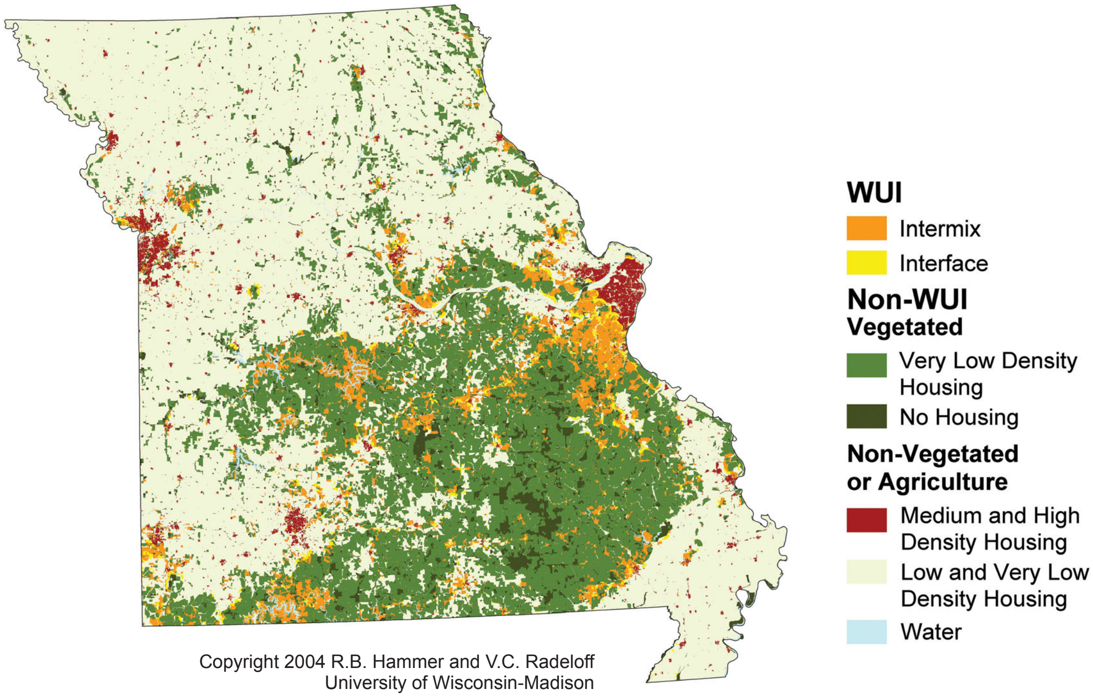


Figure 17.—Delineation of Missouri's wildland-urban interface (WUI) in 2000. Intermix WUI refers to areas where houses and wildland vegetation intermingle. Interface WUI is defined as developed areas that abut wildland vegetation (Radeloff et al. 2005a). Used with permission by R.B. Hammer and V.C. Radeloff.

What we found

Figure 17 shows landscape—not merely forest—fragmentation in Missouri. Although maps like this one present a snapshot from one point in time, Figure 17 illustrates the current pressure on forested resources and help managers and policymakers conjecture where increased development might occur in the future.

What this means

Some of the negative impacts of forest fragmentation include the decline of forest-dependent wildlife species requiring large continuous blocks of forest, increased forest vulnerability to insects and diseases (e.g., oak wilt), introduction of aggressive, opportunistic species such as brown-headed cowbirds, which thrive on forests edges, and exotic plant species such as bush honeysuckle. Fragmentation can also cut off migration corridors for flora and fauna, which could become increasingly important given projected changes in climate. Forest fragmentation also increases the frequency of negative encounters between people and wildlife such as vehicle collisions and wildlife damage to landscaping.

Another way of looking at forest fragmentation is distance from forest edge, as depicted in Figure 18. In this map, fragmentation not only results from commercial and residential development, but also other agents of fragmentation (e.g., cropland, pasture, roads).

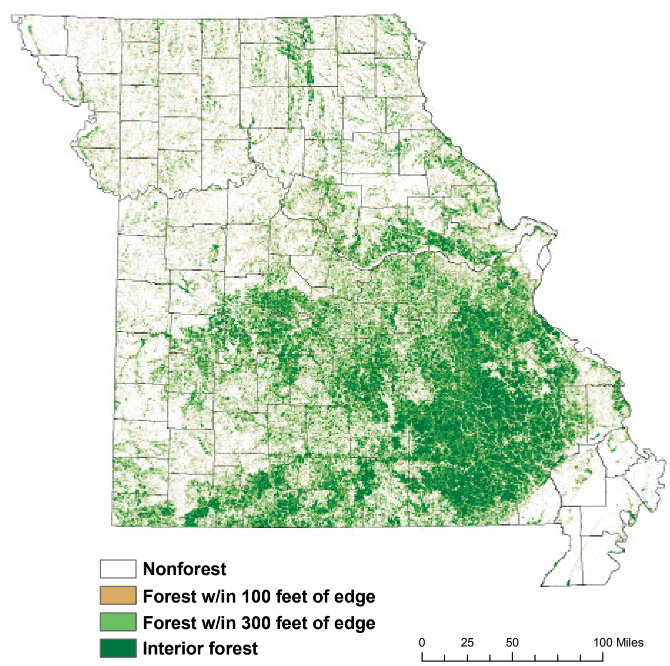


Figure 18.—Extent of forest land in Missouri and related forest fragmentation (Riemann et al. 2009).

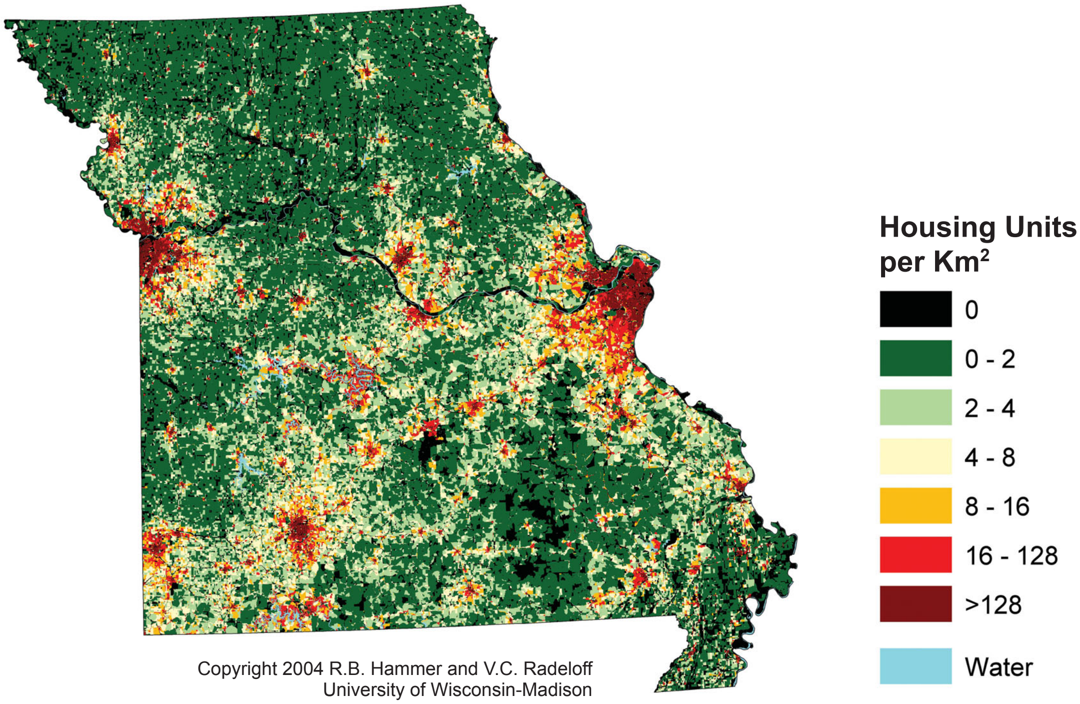


Figure 19.—Missouri's housing density by U.S. Census block in 2000 (Radeloff et al. 2005a). Used with permission by R.B. Hammer and V.C. Radeloff.

LAND USE CHANGES: IMPACT OF URBAN DEVELOPMENT

Missouri's forests are part of a larger landscape. The impact of urban development on forest conversion, fragmentation, and parcelization can change the character of and demands on services from all undeveloped lands, including forests. Figure 19 shows Missouri's housing density in 2000. A significant proportion of Missouri's landscape is in a state of flux and is represented on this map by yellow and light green. These areas could be developed further or preserved, depending upon the choices of the local population.

LAND USE CHANGES: FOREST PARCELIZATION

Background

Forest parcelization involves the division of a tract of forest into several smaller tracts and may involve the conversion of land uses. Forest parcelization can take many forms. A common example of parcelization is when a landowner divides the property into two or more tracts so that it can be passed down equitably to heirs. Another example involves splitting a large block of forest into several 5- to 10-acre lots to maximize revenue (smaller lots often sell for a higher relative per-acre price). Parcelization can have profound effects on forests, depending on the scale and intensity of the change and the value. A forest tract may appear intact with few trees disturbed, however it may be difficult for a logger to economically harvest timber on smaller tracts (Kittredge et al. 1996, Moldenhauer and Bolding 2008, Row 1978). It can also be challenging to manage and improve wildlife habitat on a smaller tract. Wildlife management practices, such as forest thinning, prescribed fire, and food plots, can be financially impractical on smaller acreages.

What we found

As larger forest tracts are subdivided, they become increasingly vulnerable to a variety of other degradations as well. Consider this scenario: An 80-acre tract of forest is sold off into eight 10-acre lots. New roads are put in to provide access. Half of the new owners build a house on their lot. Significant acreage is converted from forest to other uses in the process. Two of the new owners plant bush honeysuckle, an exotic species, in their yards, resulting in bush honeysuckle spreading into the woods. During the road and housing construction, several red oaks were injured and have now acquired oak wilt, which will kill these trees and continue to spread into the surrounding woods. Some wildlife species will succumb, adapt, or migrate away from the new presence of people and their pets. The increase in area with impervious surface increases storm-water flow and erosion and decreases water quality. In very short order, a high quality forest and its services are greatly changed.

What this means

Trends showing a recent increase in total forest land in Missouri mask very dynamic and conflicting processes at the local level (for an example, see Moser et al. 2009). Abandoned agricultural land is becoming forested while intact forest land is being parcelized and developed. Missouri's burgeoning population (U.S. Census Bureau 2010) places greater demands upon the land, not the least of which is a need for housing. Barring wholesale agricultural land abandonment or a cessation in population growth in the State (both highly unlikely), it would not be unexpected to see a smaller total amount of increasingly fragmented forest land in Missouri in the future.

CLIMATE CHANGE

Background

Trends in temperature and other models suggest that our climate is changing (Intergovernmental Panel on Climate Change 2007). Climate change can potentially impact sustainable management of forests and grasslands, because rates of change may well exceed many ecosystems' capabilities to naturally adapt.

Although there is considerable uncertainty as to how this change might take shape at global and local scales, climate change has the potential to affect Missouri's natural resources, including forests. While the overall climatic temperature is expected to rise, some areas of the world might get much warmer, and some areas might actually get cooler.

A resource manager might evaluate the adaptability and resiliency by comparing the forests' future production of benefits—ecological, sociological, and economic—to the production or potential production of such benefits now. There is also considerable uncertainty as to precipitation changes. Even if Missouri's average annual temperature and precipitation stays the same, seasonal patterns could change and may actually have a much more pronounced effect on forest communities than changes in average annual temperature.

Climate change could alter the future health, sustainability, and composition of Missouri's forests and the services they provide. While many of these concepts are speculative and highly complex, it is important that they be considered when planning for long-term forest sustainability.

What we found

Depending upon the localized impacts, climate change could shrink, expand, or shift the suitable habitat ranges of flora and fauna in Missouri. Some of these changes might actually be desirable under certain circumstances. For instance, the suitable habitat range for the exotic invasive species bush honeysuckle could shift northward and perhaps cease to be a problem in Missouri.

Other potential changes raise more concerns. For instance, the habitat suitability for white oak could greatly diminish causing large scale die-offs and forest species composition changes. Some biological changes may already be appearing. A recent analysis by the National Audubon Society concluded that in the last 40 years, land-bird species have shifted their habitat range centers by 48 miles on average (National Audubon Society 2009). A similar study shows some tree species migrating north at a rate of approximately 62 miles per century (Woodall et al. 2009).

Figure 20 displays an index of climate stress as a function of projected climate change, habitat quality, and habitat area (USDA Forest Service 2009). The darkest areas are those in which ecosystems are expected to be under the most climate change-induced stress. Figure 20 shows Missouri is projected to be one of the most vulnerable states in the continental United States. This is primarily due to the fact that Missouri is at the boundary of several

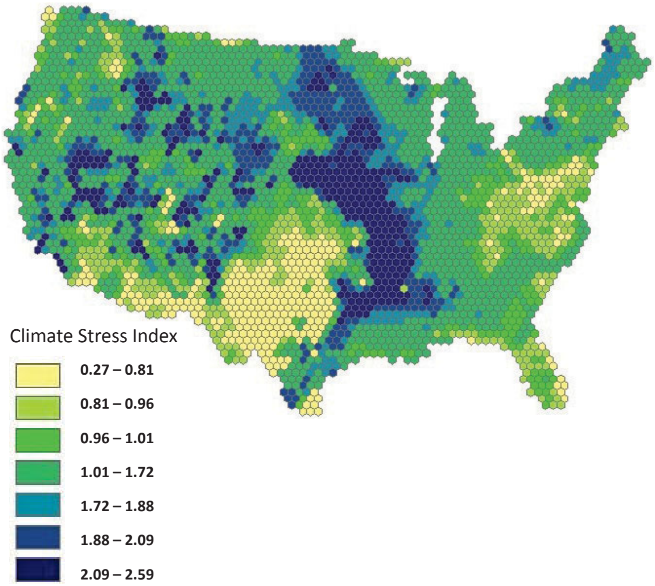


Figure 20.—Climate stress index (Joyce et al. 2008).

ecological zones and thus at the edge of the habitat ranges of many plant and animal species.

While Fig. 20 looks at climate change vulnerabilities to landscapes and communities as a whole, the Northern Research Station has also compiled a "Climate Change Tree Atlas" model which shows how the suitable habitat ranges of 135 different tree species could be altered by climate change (Prasad et al. 2009). Figure 21 displays two examples that are highly pertinent to Missouri. Note the dramatic increase in suitable habitat for shortleaf pine and the large decrease in suitable habitat for white oak. While it is difficult to predict with certainty what will happen to tree species distributions in the future, these maps portray some potential outcomes that should be considered as managers develop forest plans into the future.

Plant communities are not made up of "collaborators" but rather "competitors." If the climate change projections hold true, new "winners" and "losers" will be shaped by the new climate regime. Some trees species stand to gain significant ground, and some could decline (Fig. 21; Prasad et al. 2009). Although different tree species will migrate and eventually fill in the gaps, such mortality could cause significant changes in forest age and size structure and tree species composition. While these altered conditions could actually benefit some wildlife species, others could be adversely affected or possibly go extinct. Therefore, it is important that forest managers consider forest resiliency and adaptability as they prepare management plans. While proactive forest management might not avoid tree species shifts or mortality, it might be able to smooth the transition and help provide a bridge for flora and fauna to adapt to future conditions.

What this means

The continued viability of the forest products industry and the benefits it provides to society are dependent on a healthy, sustainable forest resource. Sustainability might be significantly compromised if climate change causes reduced growth or if more trees die prematurely.

Even if Missouri's forests do not experience such mortality, climate change might increase the vulnerability of trees to borers and other insects which degrade the quality of trees for most forest products. Furthermore, Missouri's forest products industry is accustomed to working with certain tree species and products. If the State were to experience a major shift in forest composition, its industry would need to make adjustments accordingly.

THREATS RELATED TO CLIMATE CHANGE

Background

In addition to the biophysical aspects of potential climate change, numerous other forces are poised to pose a serious threat to Missouri's forests. Furthermore, climate change may alter the forests' natural susceptibility to certain forest health threats.

Exotic/invasive species

Some exotic and invasive species that typically thrive south of Missouri, such as kudzu (*Pueraria lobata*) and Chinese privet (*Ligustrum sinense*), could become major problems in Missouri. Where these species proliferate, they can out-compete native vegetation and diminish wildlife habitat value for many species. On the other hand, some exotic species that are better adapted to colder climates, such as bush honeysuckle (*Lonicera* spp.)

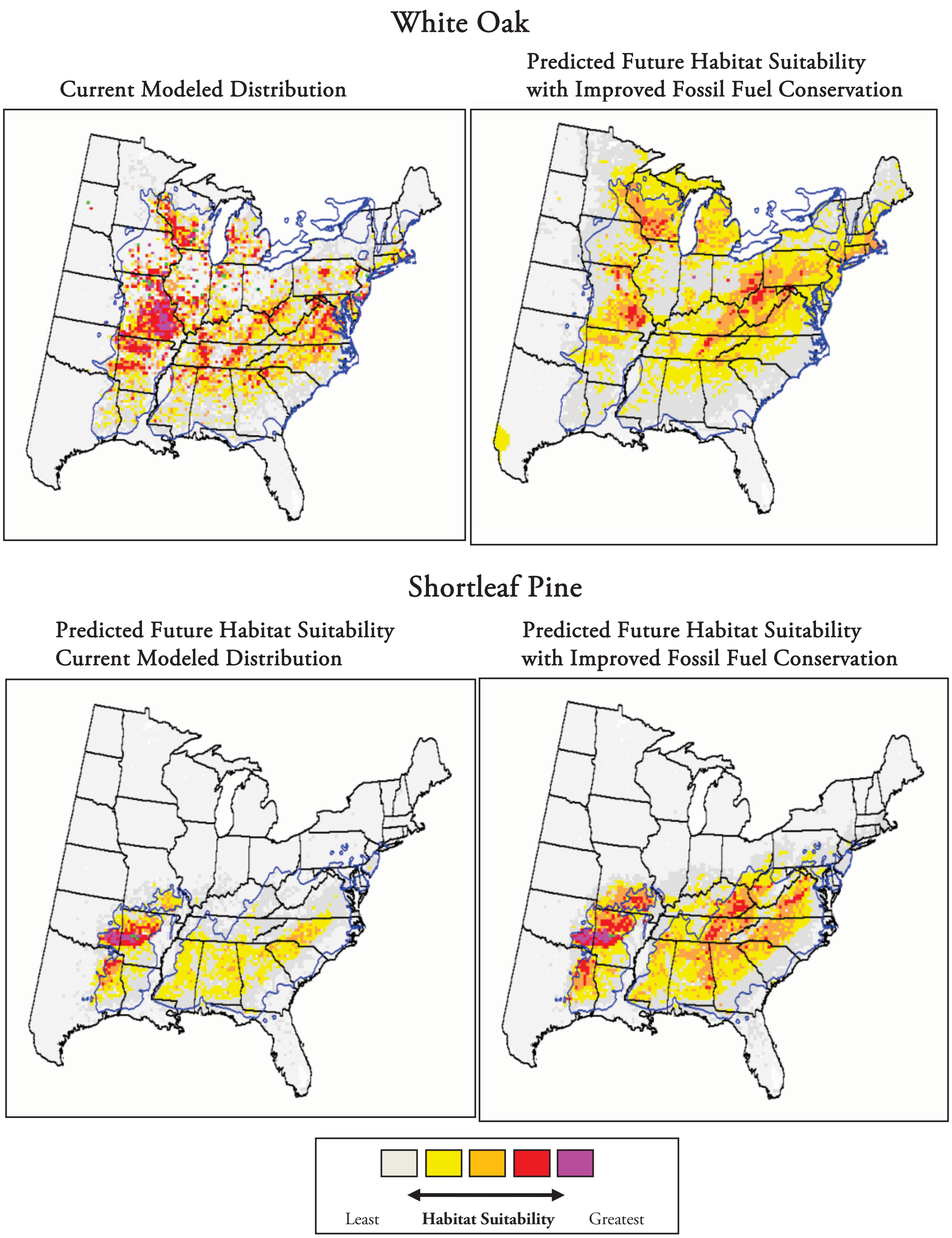


Figure 21.—Climate Change Tree Atlas: current and predicted future distribution of two select tree species (Prasad et al. 2009).

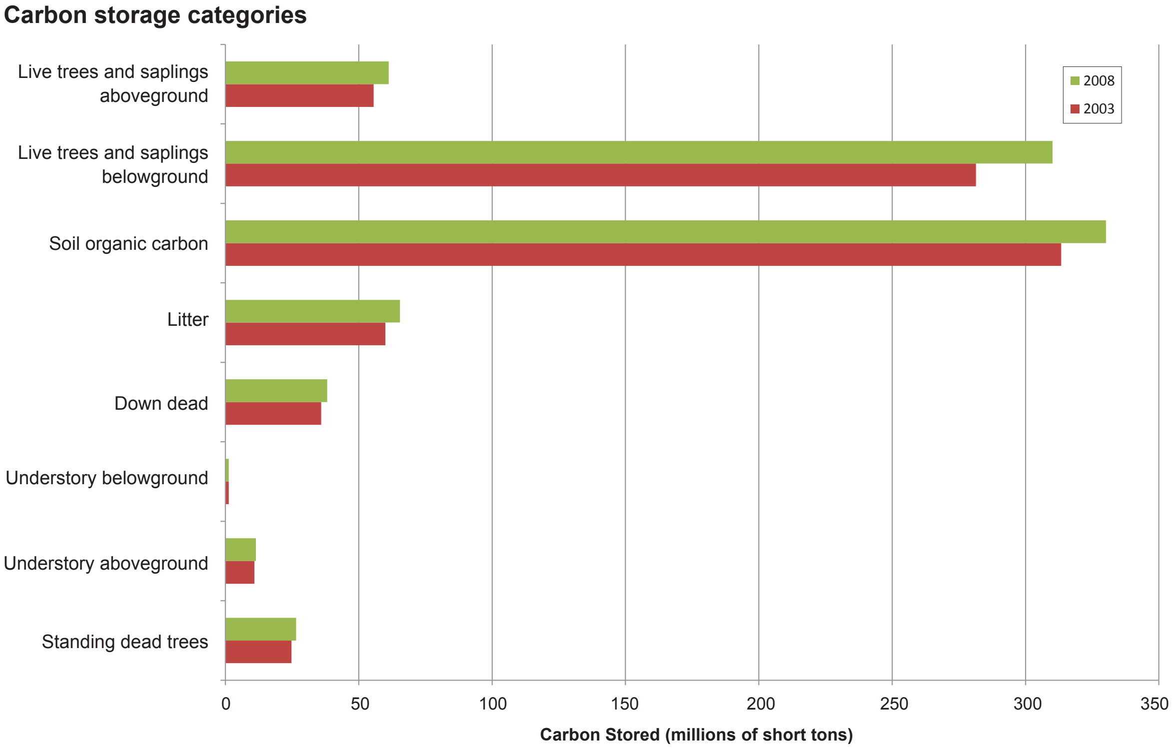


Figure 22.—Tons of carbon stored in Missouri's forest land, 2003 and 2008.

and garlic mustard (*Alliaria petiolata*), could decline or disappear entirely. Similar phenomena are equally possible with insects and diseases affecting forests. Since it is not economically feasible to attempt to eliminate all exotic species in Missouri's forests, resource managers might need to prioritize which outbreaks receive the most attention and limited resources. Moreover, invasive behaviors are not necessarily limited to foreign species. Species currently found in Missouri in small numbers might begin to proliferate in a modified Missouri climate.

Wildfire

New temperature and precipitation patterns could make Missouri's forests more vulnerable to wildfire. Seasonal periods of very warm and dry weather could lead to extreme wildfire conditions. Depending upon localized ecological situations and landowner goals, such conditions could be hazardous and/or beneficial to different combinations of people, personal property, and natural communities.

Carbon storage

Climate change may accelerate growth or mortality of trees, depending on the species, thus changing the amounts and rate of carbon storage in the State's forests. According to the Society of American Foresters' Climate Change and Carbon Sequestration Task Force, "Unique among all possible remedies [to climate change], forests can both prevent and reduce greenhouse gas … emissions while simultaneously providing essential environmental and social benefits…" (Malmsheimer et al. 2008). Missouri's forests currently store a great deal of carbon—844 million tons (Fig. 22). Soil organic carbon is the largest storage category, followed by live trees above ground, leaf litter, the belowground parts of trees, then down dead and standing dead, followed by understory vegetation. Carbon storage is not static, but rather exists in a constant state of flux, representing the difference between inflows from carbon assimilation and conversion and outflows from decay and oxidation and between the different storage categories.

Autumn sugar maples. Photo used with permission of Missouri Department of Conservation.

Soil and Water Resources

Riparian vegetation. Photo used with permission of Missouri Department of Conservation.

Background

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. To enhance soil and water resources for today and ensure that they will be available into the future, existing trees and forests need to be carefully managed and strategic areas should be reforested.

Leaf litter and forest vegetation protect soil from forces that cause erosion so well that erosion from forests is virtually non-existent compared to erosion from crop fields.

What we found

Figure 23 shows estimated soil-loss rates for three land-use types on the same soil type and with the same percent slope. Although actual soil-loss rates can vary considerably by soil type, percent slope, and management practices, this figure illustrates the effectiveness of forests in protecting soil resources and the waters in which eroded soils are ultimately deposited.

To help identify the most important forested watersheds for protecting and enhancing public drinking water supplies, public health and aquatic ecosystems, the U.S. Forest Service conducted a "Forest, Water and People Assessment" (Barnes et al. 2009).

The results of this assessment show Missouri had the two highest-scoring watersheds in the seven-state Midwest Region (Fig. 24). The Meramec watershed, which provides surface drinking water to 587,000 people, received the highest score; the Lower Missouri watershed, which provides surface drinking water to 589,000 people, received the second highest score. Two other watersheds, Missouri's Big River, Cahokia-Joachim River and North Fork-White River, also scored in the top 20.

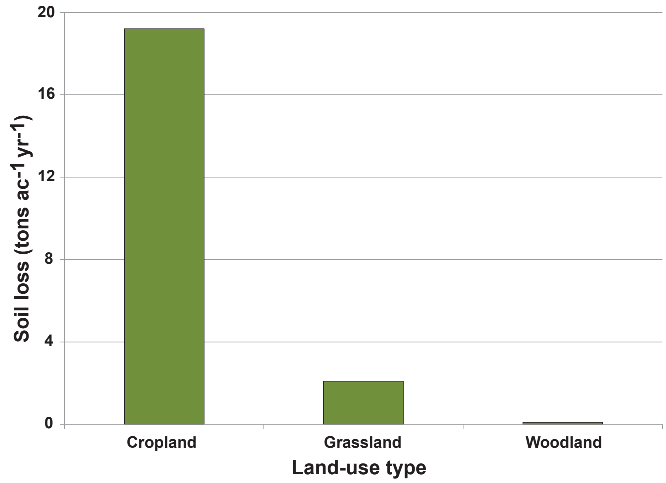


Figure 23.—Soil loss by land-use type (USDA Natural Resources Conservation Service).[3]

[3]This figure was generated by Doug Wallace, NRCS Lead Agroforester at the National Agroforestry Center in Lincoln, Nebraska, using the Universal Soil Loss Equation. All figures were based on an Armstrong silt loam soil, 8 percent slope, 150-feet slope length. Cropland = minimum tillage (30 percent cover after planting), corn-soybean (drilled) rotation, up and down tillage; Grassland = 80 percent ground cover, grass with some weeds and brush, continuously grazed; Woodland = no grazing, low management, 90 percent duff cover; 90 percent canopy cover.

What this means

Changing climate has the potential to significantly impact forest water resources. If the climate gets significantly wetter, riparian forests could become more important than ever for protecting stream banks and providing filtering functions. A significantly drier climate could heighten competition for groundwater supplies.

Future forest management in Missouri might need to consider climate implications for providing adequate drinking water supplies.

Compared to cropland, pasture, turf, and urban developed areas, trees and forests are highly effective at intercepting precipitation and releasing it slowly into the atmosphere, groundwater and streams. In this way, trees and forests help reduce stormwater runoff, and therefore reduce the threat of flooding and the amount of stormwater that must be handled by local governments. By releasing precipitation slowly into groundwater and streams, trees and forests also help moderate stream flow

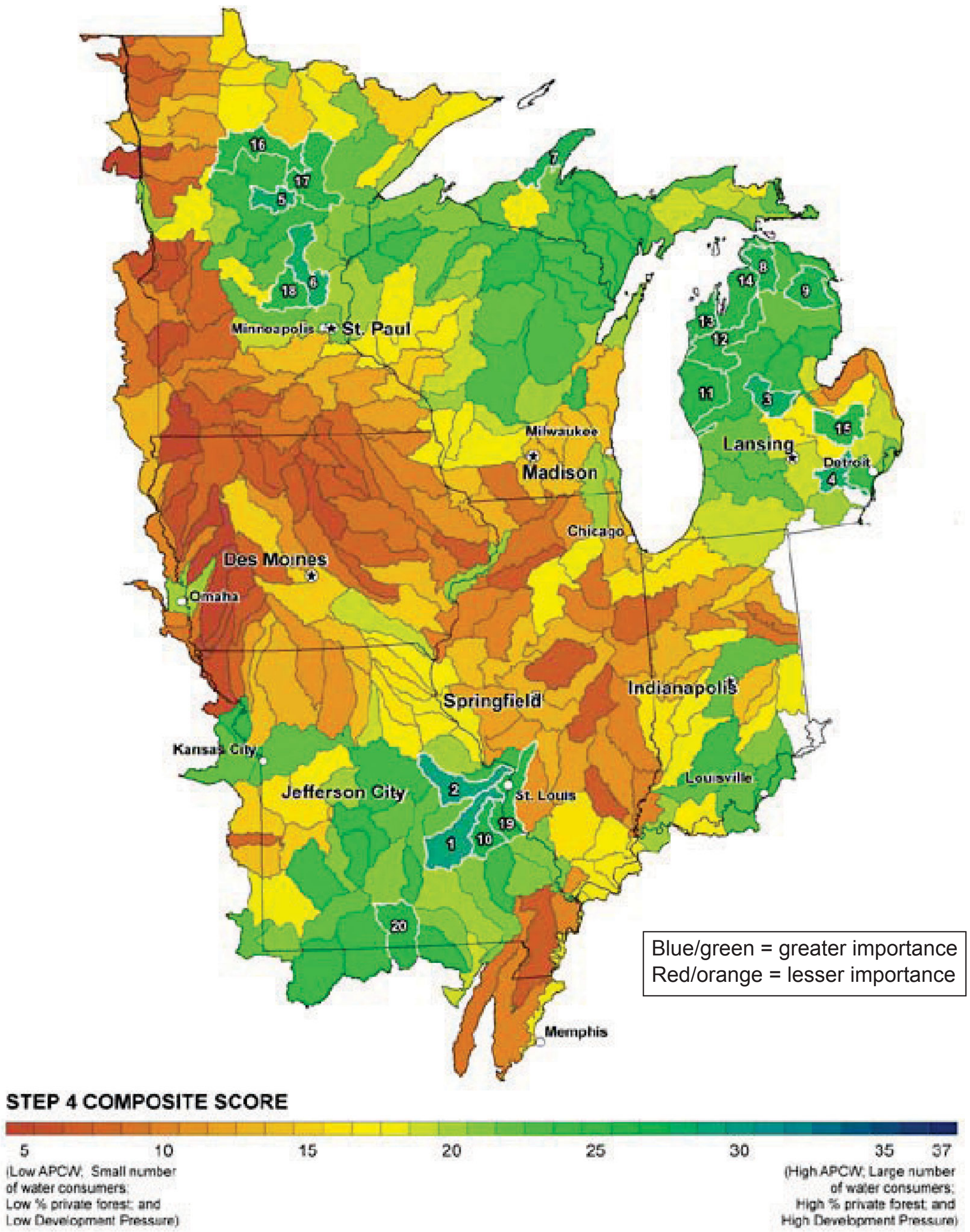


Figure 24.—Important forest watersheds for maintaining drinking water supplies (Barnes 2009). The numbers on the map represent the top 20 watersheds that are most critical to public drinking water systems, based on the assessment parameters. The Meramec River watershed is number 1 and the Lower Missouri watershed is 2.

Steve Hillebrand, U.S. Fish and Wildlife Service

and volume - providing a more consistent and reliable source of water for public drinking purposes as well as for aquatic habitat.

RIPARIAN FORESTS AND FORESTED WETLANDS

Although all wooded areas provide significant soil and water benefits, but riparian forests and forested wetlands are especially important. Riparian forests are forests found adjacent to streams and help armor stream banks to keep them from eroding into streams. They filter out pesticides, nutrients, and sediments before they can reach the stream. They provide shade, which is important for maintaining water temperatures conducive to healthy aquatic ecosystem functioning. Vegetation from riparian forests helps provide the food base and habitat needed by many aquatic and terrestrial organisms. Riparian forests also provide important wildlife travel corridors and can be highly productive for forest products. Of Missouri's 3.2 million acres of potential riparian forest buffer, approximately 1.8 million acres or 55 percent are currently forested.[4] Reforesting much of these currently unforested riparian areas could significantly benefit soil and water resources by providing buffers that protect water quality and temperature.

Similar to riparian forests, forested wetlands filter out sediments, nutrients, fertilizers and pesticides from adjacent fields before they reach streams. They also help moderate stream flow and minimize flooding potential. Forested wetlands frequently provide important habitat for wildlife and can be highly productive for forest products. Throughout the 19th and 20th centuries, most of Missouri's forested wetlands were drained and converted to agriculture (Guyette et al. 1999). A prime example is Missouri's "Bootheel", which was historically dominated by forested wetlands and is now dominated by agriculture.

[4]These figures were generated using National Land Cover Data—2001 and the following two parameters for riparian areas: 200 feet wide on either side of permanent streams, and 100 feet wide on either side of intermittent streams.

The Role of Fire in Missouri's Forests

Prescribed fire. Photo used with permission of Missouri Department of Conservation.

Background

Historically, fire played a large role in shaping Missouri's forests and woodlands (Guyette et al. 1999). The exclusion of fire over the last 50+ years has significantly modified the structure, diversity, and function of many of these communities.

Native Americans used fire frequently for improving wildlife habitat and hunting opportunities, enhancing travel conditions, and defending against rival tribes. These fires resulted in a rich mosaic of prairie, glade, savanna, open and closed woodland, and forest communities across the State. As European settlers displaced Native Americans in the early 1800s, they expanded the use of fire substantially to clear land and improve grazing opportunities for their free-ranging livestock. In the late 1800s and early 1900s these fires were combined with extensive logging of Missouri's forests, largely to support the building of the transcontinental railroad (Guyette et al. 1999).

Largely for safety reasons, wildfires are no longer to be tolerated. In the absence of wildfires, proactive management can be used to restore and/or maintain Missouri's forest resources in a healthy, productive and wildlife-friendly condition, with the intention of mimicking traditional disturbance regimes.

What we found

Today, only about 0.1 percent of Missouri (~50,000 acres) is impacted each year by wildfire (Fig. 25). The severity of these wildfires varies, often a function of contemporary weather conditions, fuel loads, and duration of the fires.

Although Missouri's acreage burned by wildfire has declined recently, wildfires have not been completely eliminated from the landscape. The average number of wildfires per year over the 10-year period 1999-2008 was 2,585. Figures 26 and 27 display the range of fires by cause and fire size (area) over this period. The 10-year average is provided to help account for the way wildfire seasons typically vary with yearly weather patterns.

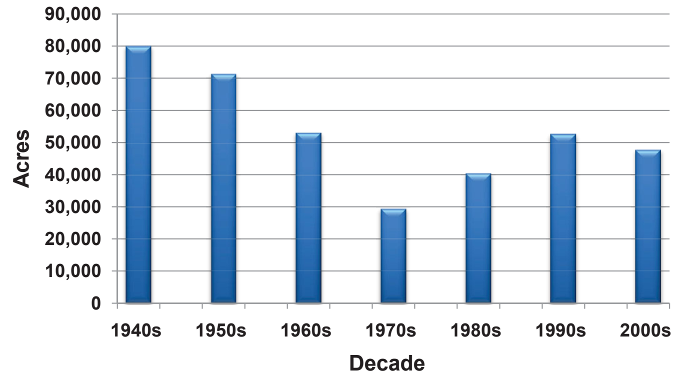


Figure 25.—Average acres burned per year by wildfire in Missouri, 1940s-2000s (through 2008). Data from Missouri Department of Conservation (MDC) using submitted fire reports submitted. Figures do not include unreported fires.

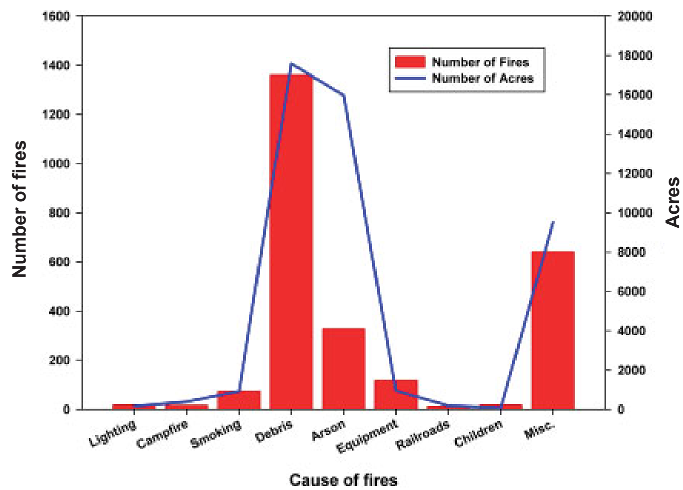


Figure 26.—Wildfires and total acreage burned per year by cause (averaged over 1999-2008). Data calculated by the Missouri Department of Conservation (MDC) from submitted fire reports to MDC. Figures do not include unreported fires.

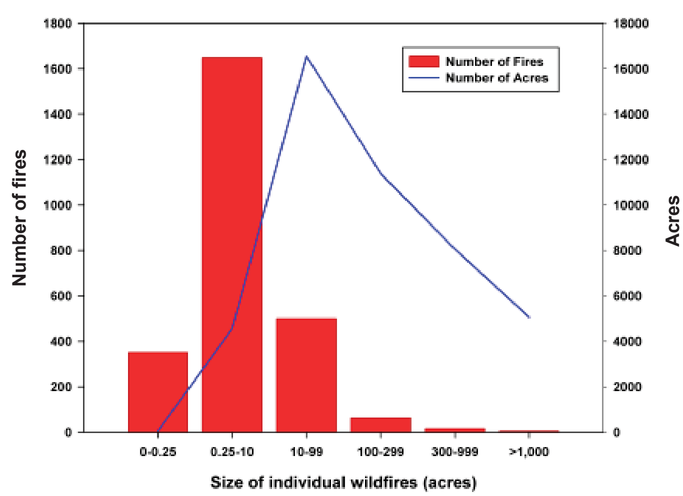


Figure 27.—Wildfires per year by size (averaged over 1999-2008). Data calculated by the Missouri Department of Conservation (MDC) using fire reports submitted to MDC. Figures do not include unreported fires.

What this means

The nature of wildfires in Missouri is changing. Perhaps the biggest change has been the unprecedented expansion of the wildland urban interface (WUI) in the past two decades (see page 15). WUI expansion has had significant impacts on wildfire trends. On one hand, the increased number of people living in or next to the forest has created far greater opportunity for fires to ignite and spread to areas that threaten people and their property. On the other hand, the added presence of humans means that wildfires in or near WUI tend to be reported much more quickly and can often be suppressed before they reach large size.

SPECIES COMPOSITION CHANGES

Background

Although fire suppression activities have greatly benefited public safety, improved Missouri's timber quality, and resulted in other benefits, suppression activities have had some undesirable effects as well.

For thousands of years, much of Missouri's forests and woodlands have evolved with frequent, low- to moderate-intensity fire disturbances, often burning once every 3 to 4 years. Therefore, most of our woodlands and forests contain an abundance of plant and animal species that are well adapted to or at least tolerate fire. Due to fire suppression over the last 50 years, fire has largely been eliminated from our landscapes. As a result, the presence of shade-tolerant, fire-intolerant species has increased dramatically. This category includes species like sugar maple, red maple, cedar, elm, blackgum and ironwood.

What we found

Figure 28 shows the increase of sugar maple by percent change in the number of trees per diameter class. From 2003 to 2008, the number of sugar maple trees increased significantly in every diameter class but one. The number of sugar maple trees in two classes increased by more than 25 percent. While sugar maple is a native species which occurred in Missouri historically, its presence is increasing dramatically.

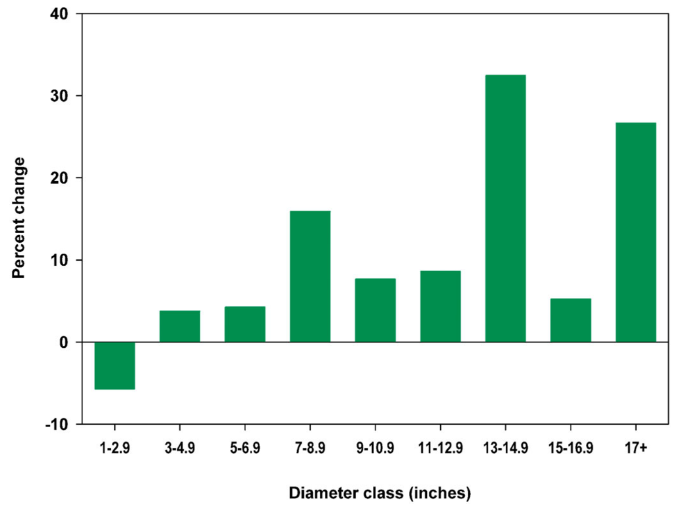


Figure 28.—Percentage change in number of all sugar maple trees on remeasured plots on timberland between the 2003 and 2008 inventories, by diameter class (inches).

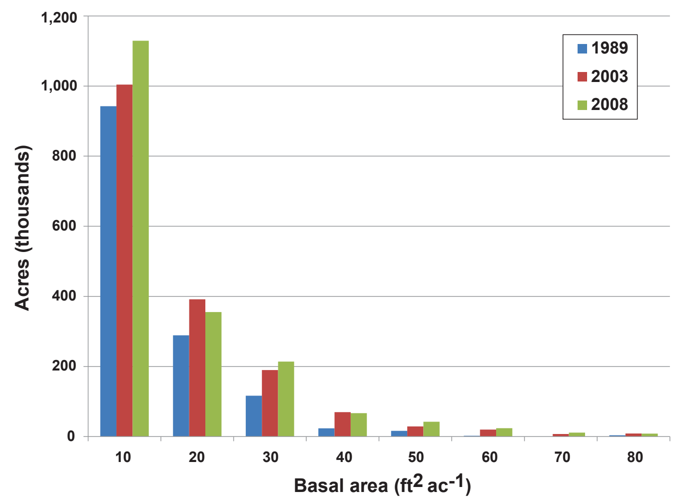


Figure 29.—Sum of timberland acres with sugar maple by sugar maple basal area class, in 1989 - 2008.

Figure 29 shows the increase of sugar maple by basal area per acre. From 1989 to 2003, timberland containing sugar maple basal area of at least 10 ft^2 ac^{-1} increased by approximately ~500,000 acres and from 2003-2008 there was an additional ~100,000 acre increase.[5] This surge in maple acreage equates to a current total of ~2 million forest and woodland acres with at least 10 ft^2 ac^{-1} of sugar maple.

[5]Missouri Department of Conservation. 2009. Forestry Division fire program review. Jefferson City, MO: Missouri Department of Conservation unpublished report.

What this means

At first glance, 10 ft^2 ac^{-1} may not sound like much, but in terms of natural communities, wildlife habitat, and oak regeneration, this increase is very important. Sugar maple trees have extremely dense canopies. Therefore, a small amount of sugar maple in the overstory or midstory can place so much shade on the ground that many trees, shrubs, and herbaceous vegetation cannot survive, including oak seedlings. As sugar maple encroaches on a forest or woodland, wildlife habitat dramatically is altered, impacting many species that require abundant ground-layer vegetation for food and cover. Furthermore, as overstory oaks die, they are replaced by more shade-tolerant species. These shade-tolerant species might not have the same value for wildlife or other purposes as the oak trees that currently tend to dominate Missouri's forests and woodlands. For instance, the acorns produced by oaks are a staple food source for many species of wildlife. Acorns are highly nutritious and are available throughout the winter. Maple seed, on the other hand, lasts only a short while and does not have the same nutritional value. If oaks decline in dominance, wildlife might need to adjust to other food sources, which may not be as plentiful or nutritious as acorns.

CROWDED FORESTS AND WOODLANDS

Background

Prior to European-American settlement and in the early years of our country, Missouri's forests were much more open than the younger, denser forests of today (Moser et al. 2006). Also, the forests were less fragmented than the forests of the 21st century. One observer noted that riders on horseback could easily ride between trees in this early landscape (Beilmann and Brenner 1951). Likely reflecting the Native American practice of setting fires in the woodlands (Guyette et al. 1999), the understory flora of such groves of trees included many species of prairie grasses (Schoolcraft 1821). Once European-Americans began taking possession of the land in southern Missouri starting in the 1850s and altering the fire regime, the tall grass prairies of the Ozark Plateau gave way to encroaching forest and agricultural fields.

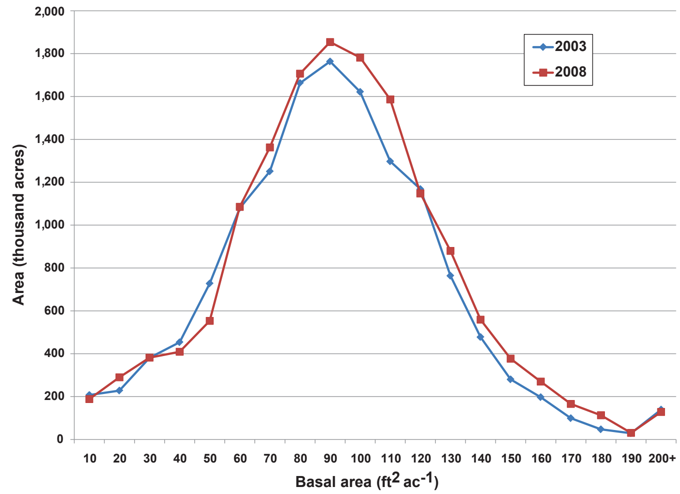


Figure 30.—Distribution of forest land in Missouri, by basal area (ft^2/ac^{-1}), 2003 and 2008.

What we found

In the absence of fire and other active management, Missouri's forests are becoming denser (Fig. 30). In dense forests, trees are in greater competition with each other for limited resources such as space, light, water, and nutrients. In such environments, trees might grow more slowly and become more vulnerable to insects and diseases. Production of acorns and other mast for wildlife is reduced. Ground vegetation, which is important for wildlife habitat and natural community plant diversity, becomes largely shaded out. Conversely, by restoring forests and woodlands to densities that result in less stress to the component trees, forests can quickly become more productive for forest products and wildlife, and more resilient to insects, diseases, and climatic changes.

Why this matters

In denser forest stands, trees compete more vigorously for resources—light, water, nutrients. How successfully trees compete for these resources will determine species composition, growth, and general forest health. High-density stands can result in increased competition that may predispose the constituent trees to stress (Oliver and Larson 1990), reducing their ability to resist forest health attacks, such as that of the oak decline complex (Lawrence et al. 2002). There is no one "appropriate" stocking or density level. For each tract of forest land, the appropriate levels of density depend upon local site, species composition, climate, and landowner goals.

Missouri's Growth, Harvest, and Consumption of Forest Products

Sunny woodland, Photo used with permission of MIssouri Department of Conservation.

Background

Missouri's forest products industry is an important contributor to Missouri's economy, and supports a number of economic, social, and environmental values.

In 2008, Missouri's gross domestic product (GDP) was approximately $238 billion (U.S. Bureau of Economic Analysis 2010). A recent analysis by the Missouri Department of Conservation showed that the forest products industry contributed $5.7 billion annually to the Missouri economy in 2006 dollars (Missouri Dept. of Conservation 2008). The industry supports more than 31,700 jobs with a payroll of about $1.25 billion and is responsible for more than $465 million in taxes, including $57 million in sales tax (Missouri Dept. of Conservation 2008). These number not only includes the direct effect of jobs in the primary wood processing industry (such as logging and sawmill operations) but also indirect and "induced" effects in the secondary wood products industry (e.g., cabinet shops, paperboard manufacturing) and in the economy as a whole via the economic relationships with suppliers and the purchasing power of employees in all of these industries (Minnesota IMPLAN Group 2010).

Ensuring that these values are maintained into the future means carefully balancing harvest and consumption rates with available growth, and assuring that harvest practices account for long-term productivity and sustainability of all forest benefits and services.

Missouri's forests are an important supplier of numerous wood products used not only in-state, but also nation- and worldwide. Some of the many products originating from Missouri's forests are furniture and cabinets, flooring, barrels, tool handles, charcoal, pallets, shavings, and firewood.

Besides the social and economic benefits of Missouri's forest products industry, there are some less obvious benefits. When done properly, the harvest of forest products can provide an economical means of improving forest health and wildlife habitat. Harvesting can be used to mimic the historic disturbances that maintained diverse forest structure and composition, important to both forest health and wildlife.

Forest products can have several environmental advantages over alternative resources, including:

- Trees and forests are renewable resources. As trees are harvested, new trees quickly emerge and fill in the gaps left behind.
- Harvesting trees is generally much easier and leaves less of a human footprint than does the extraction of other resources, such as metals, coal, and oil.
- Forest products are generally biodegradable and/or recyclable.
- Forest products and biofuels help reduce greenhouse gasses through carbon storage in forest products and through avoided use and extraction of fossil fuels. Carbon released from tree harvesting is quickly taken back up by new forest growth.

WOOD CONSUMPTION RATES

Background

Sustaining the economic, social and biological benefits of Missouri's forest products industry requires maintaining a careful balance of forest growth, natural mortality, and harvesting.

What we found

Missouri's population density is relatively low (compared to the global population), and as a result, Missourians benefit from more forest per person than the world as a whole (presently about 2.5 acres of forest per Missouri resident; global forest land is 1.6 acres per capita and falling) (Shifley 2007; Fig. 31).

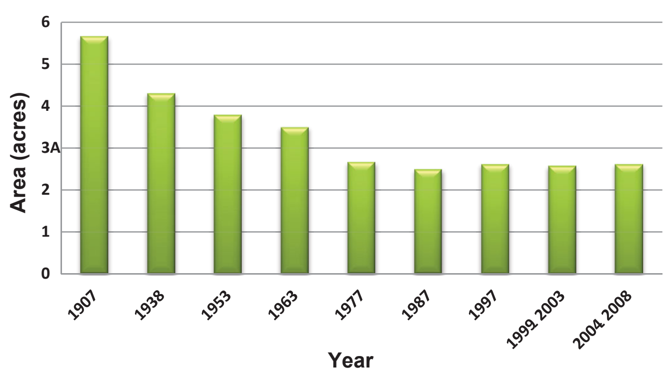


Figure 31.—Area of forest land per person in Missouri.

Table 5.—Average net growth and removals per year of growing-stock trees on timberland in Missouri, 2008, and consumption of forest products, 2005. (Net growth per year = Total growth minus natural mortality.) Missouri data are from U.S. Forest Service Forest Inventory and Analysis Program (annual averages for 2008); United States data are from 2007 Resource Planning Act Report (includes 2006 data only). Wood consumption data were calculated using U.S. Census data (U.S. Census Bureau 2010) and Howard (2007).

	Net growth/year (million ft^3)	Removals/year (million ft^3)	2005 wood consumption (million ft^3)
Missouri	517	174.3	411
United States	26,744	15,533	20,985

Given that Missourians have more forest land per person than most of the global population, it could be inferred that local demand for wood products should be satisfied mostly from within Missouri. However, Missourians are currently consuming more than twice as much wood as they are harvesting (Shifley 2007) (Table 5).

In 2005, the U.S. annual wood consumption rate was approximately 71 cubic feet per person, far more than the global average of 21 cubic feet per person (based on 1995 figures; Gardner-Outlaw 1999). Because of increased paper recycling and increased processing efficiency, the U.S. consumption per capita in roundwood equivalent has actually decreased from 83 ft^3 per capita in 1987. However, despite this decrease in per capita consumption, total consumption is expected to increase in the future due to projected increases in population and potential emerging markets, such as energy derived from woody biomass (Fig. 32).

Missouri's overall growing-stock volume has steadily increased over the last 50 years (Fig. 33). Although there are different levels of production and utilization for individual types of forest products, should this overall trend continue, Missouri's forests should be able to help the state meet various economic, social and biological needs now and into the future.

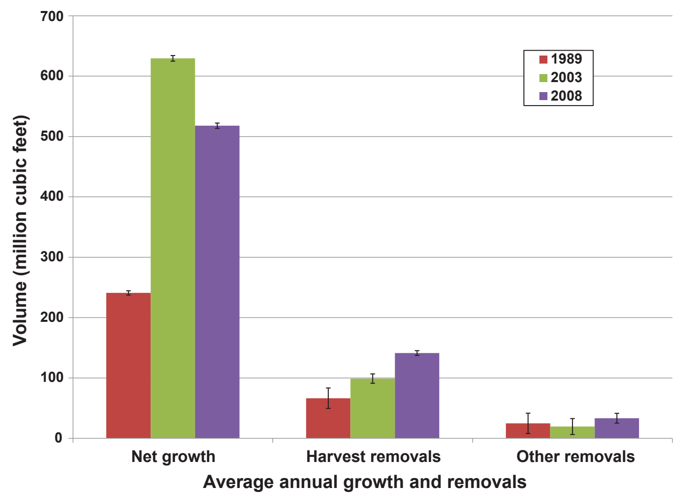


Figure 32.—Net annual growth and removals of growing stock on Missouri timberlands, 2003 and 2008. Bars represent 68 percent confidence intervals.

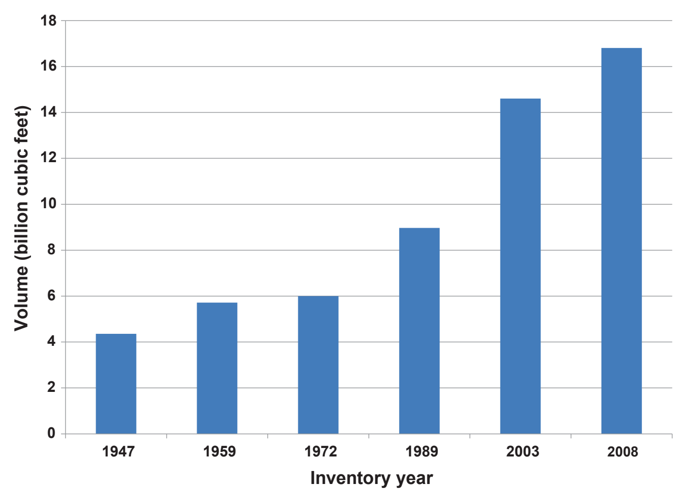


Figure 33.—Growing-stock volume on timberland in Missouri, 1947-2008.

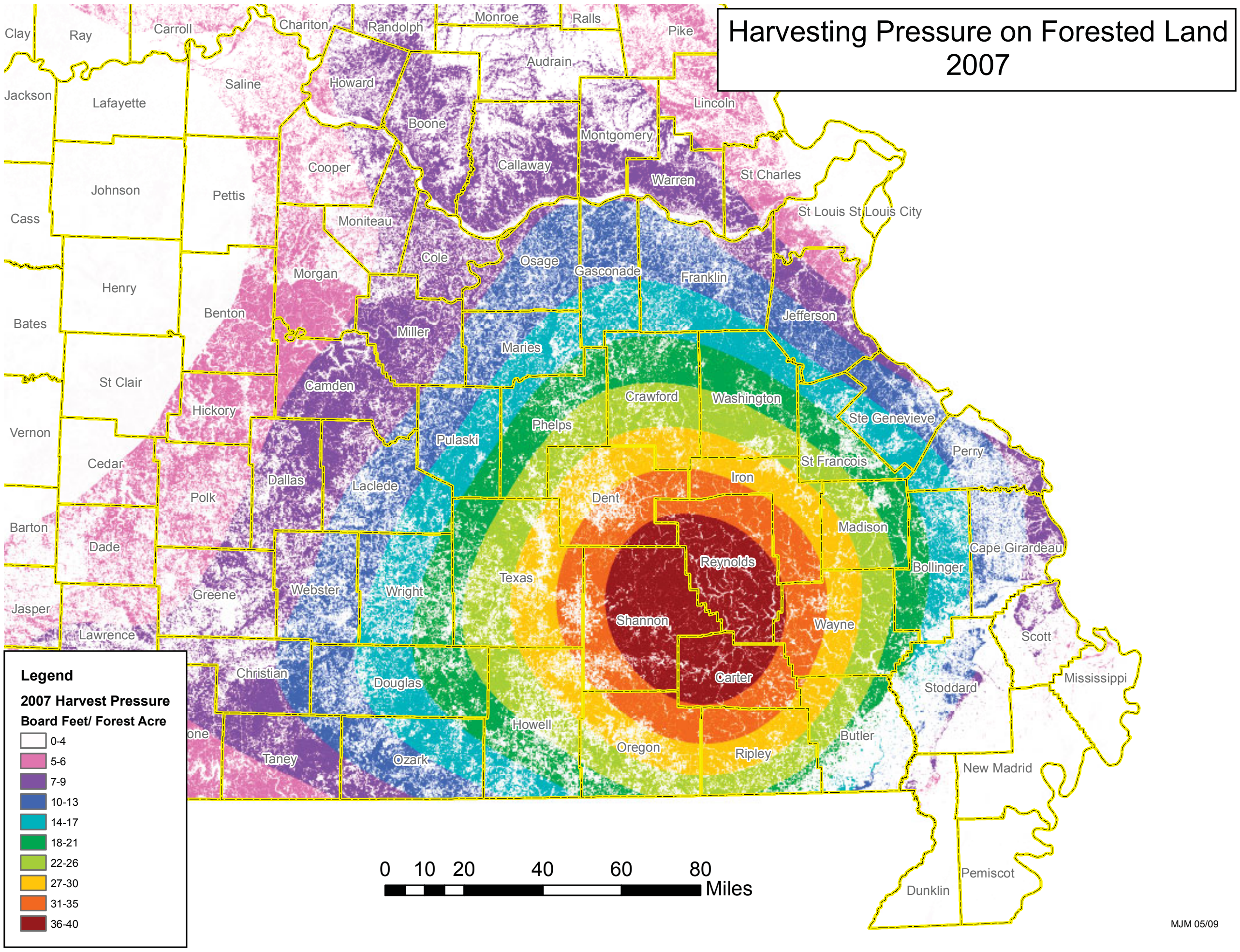


Figure 34.—Harvest pressure on Missouri's Forested Land - 2007 (Source: Mike Morris and Steve Westin of MDC using Timber Product Output Data).

What this means

While this increasing growing-stock volume is certainly encouraging, several factors must be considered. First, not all of this added growth is available for harvest:

- Some of this added growth takes place on forests which are inaccessible for harvesting due to steep slopes, poor road access, etc.
- Some of this growth takes place on forests in which harvesting is either not allowed, or not desired by the landowner. The 2006 Woodland Owners Survey reveals that only 19 percent of family forest owners plan to harvest timber in the next 5 years. The same survey also states that only 19 percent of family forest owners consider production of saw logs or other timber products to be one of the top two reasons they owned forest land (Butler 2008).
- Some of this growth is in trees which will never grow to a merchantable size.

Beyond the state totals, there is within-state variation. Figure 34 suggests that harvesting levels are much greater in some parts of the state than others. Thus, some locations in Missouri may suffer severe harvest pressure while other locations may experience net growth. Estimated harvest pressure appears to be highest in the heart of the Missouri Ozarks in southeast Missouri. Many communities in this region are highly dependent on the forest products industry and could suffer if there were a decline in trees for harvesting.

MORTALITY

Background

Trees die from many other causes besides harvesting, even in healthy, well managed forests. Common causes can include insects and diseases, severe weather events, competition and age. As trees die from natural causes, they quickly degrade and decay to the point that they are unavailable for harvesting. Under ideal conditions, natural mortality is kept at a low but stable level, small enough to avoid significantly impacting timber resources but large enough to meet other forest needs such as coarse woody debris and snags for wildlife habitat.

Often landowners do not have much control over mortality in the short term. A prominent example is red oak decline. Red oak decline, which primarily effects scarlet oak, black oak, and northern red oak, is caused by several factors including the maturity and density of these trees, red oak borers, *Armillaria* root rot, periods of drought, and the fact that many of these trees are growing on droughty and/or poorer sites that historically were dominated by shortleaf pine (Lawrence et al. 2002). While it may be possible to improve the health and vigor of some of these trees, many of them will not survive. The resulting spike in mortality and decline has and will continue to have a significant impact on the forest products industry.

As trees decline, they must be harvested quickly or else they will become too rotten or degraded for utilization. Where there is a large amount of red oak decline-caused mortality, sizeable volumes of Missouri's red oaks would need to be harvested over a short period of time if they are ever going to be utilized. However, as the harvest of red oak increases, supply outstrips demand and prices plummet. It becomes uneconomical to harvest such trees, so many of them will be left in the woods. These trees will serve other valuable purposes such as providing wildlife habitat and contributing to nutrient cycling. However, if oak decline-associated mortality continues, a considerable volume of growing stock will no longer be available in the future.

What we found

Average annual mortality of live trees on forest land was 212.1 million ft^3 yr^{-1}. Average annual mortality of all growing stock on timberland was 125.6 ft^3 yr^{-1}; a 54 percent increase since 2003. Over 98 percent (123.4 ft^3 yr^{-1}) of the total growing stock mortality occurred in hardwood forest types, while the remaining 2.2 million ft^3 yr^{-1} was from softwood types (Fig. 35). Almost 20 percent occurred on public lands. Looking just at hardwood forest types, again, almost 20 percent of the average annual mortality was on public lands. Forty-two percent of average annual softwood mortality was on public land. Other red oaks, the species group that includes scarlet and black oaks, had the highest average annual mortality at 54.3 million ft^3 yr^{-1}. Other species groups with high mortality included other eastern soft hardwoods, select white oaks and select red oaks.

Stand stocking plays a natural role in mortality. Denser stands increase competition and accelerate mortality among those trees that lose the competition for light, water, and/or nutrients. The challenge is to match the appropriate density levels to ecological conditions and management goals. Almost 63 percent of growing-stock volume on Missouri's timberland is in overstocked or fully stocked stands. So, it is not surprising that more than half of the mortality on forest land (Fig. 36) or timberland (Fig. 37) occurred in overstocked or fully stocked stands. The higher proportions of overstocked stands in forest land than in timberland might reflect the presence of more older, unmanaged forest stands in the reserved land class, such as wilderness areas.

What this means

The high levels of mortality in other red oaks and select red oak types continues to reflect the effects of the 1999-2002 drought and resulting oak decline in certain regions (Lawrence et al. 2002), as well as the extensive presence of this species group in Missouri. Mortality is a natural process in forest ecosystems; nonetheless, landowners can adopt certain practices to keep their forests as healthy and

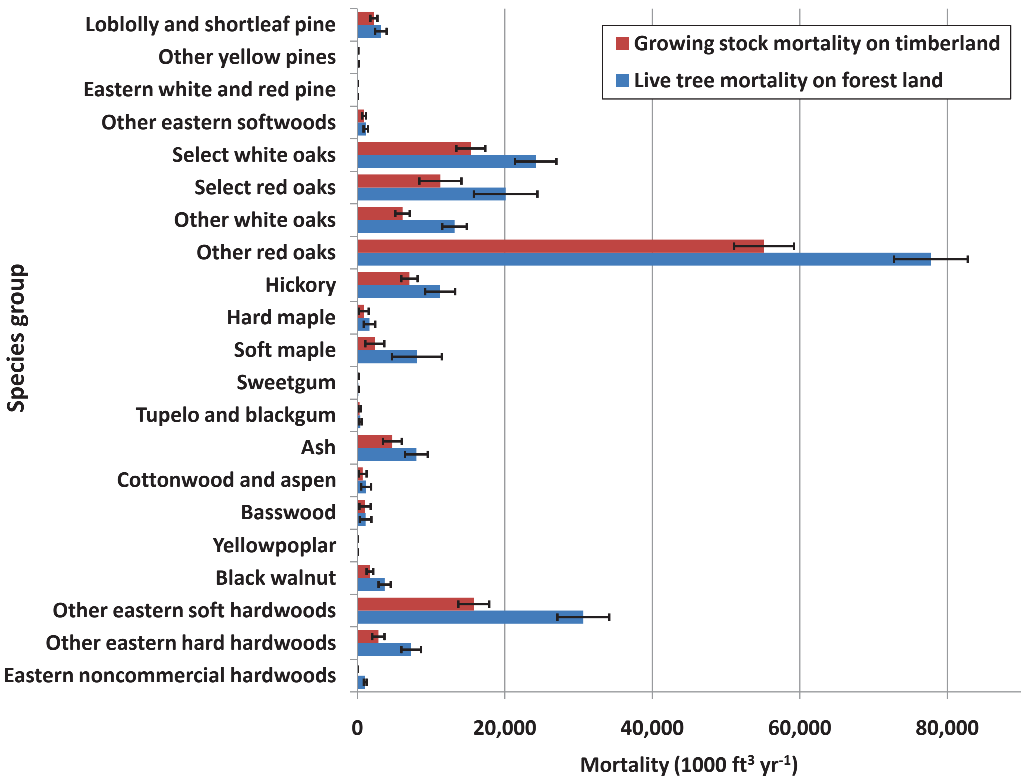


Figure 35.—Live tree mortality on forest land ($ft^3\ yr^{-1}$) and growing stock mortality on timberland ($ft^3\ yr^{-1}$) in Missouri, by species group, 2008. Bars represent 68 percent confidence intervals.

resilient as possible in order to minimize future large scale die-offs. Some examples include:[6]

- Maintaining a high diversity of tree species. Many insects and diseases are species specific. By maintaining greater diversity in both the trees in the overstory as well as the understory vegetation, our woods will not be totally devastated if one species is heavily impacted by a forest health problem.
- Maintaining appropriate stocking. Crowded forests are much more vulnerable to decline and mortality. Every acre only has so much water, nutrients, sun and space. The greater the competition that trees in crowded stands face, the less resources that are available to fight off insect and disease attacks.
- As forests are harvested and new forests emerge, it is important that methods are used to ensure that tree species which inhabit the new forest are desirable and well suited to the site. For a variety of reasons, this process does not always happen on its own. A common example includes some oak-dominated forests which have developed understories of sugar maple due to the elimination of wildfire. As overstory oaks are harvested in such forests, the remaining sugar maple trees quickly gain dominance unless management practices are used to avoid this conversion.

[6]Moser, W.K.; Melick, R. 2002. Management recommendations for oak decline. Unpublished Missouri Department of Conservation memo to all field personnel outlining suggested silvicultural strategies for managing Missouri oak forests in the face of oak decline complex. 3 p.

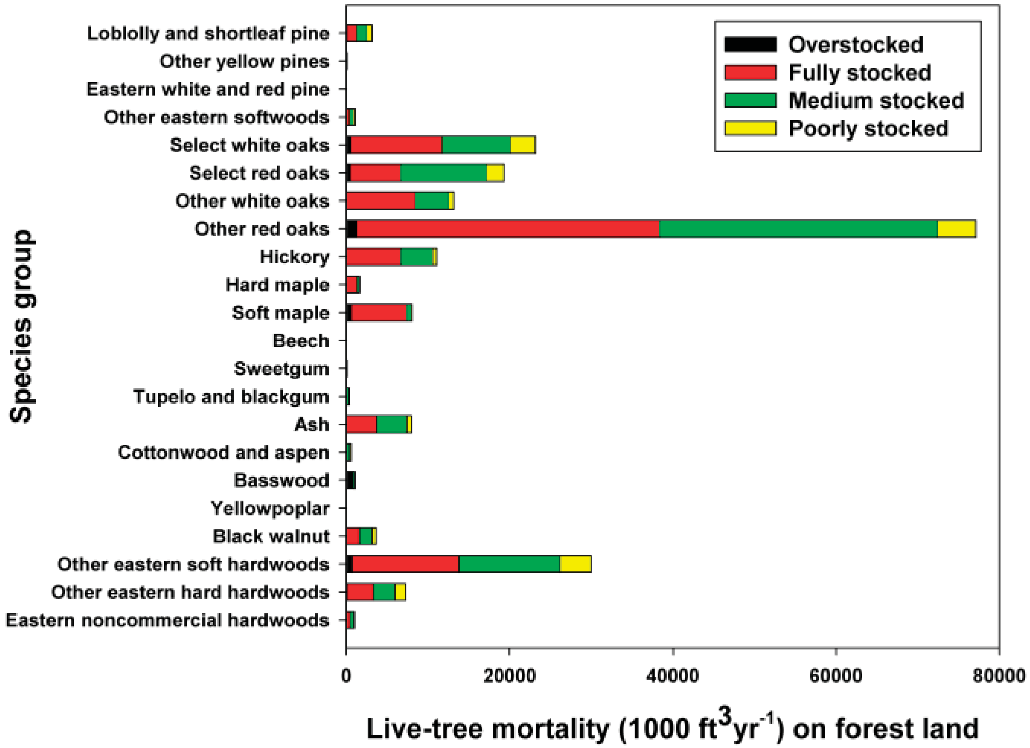


Figure 36.—Annual live-tree mortality (ft^3 yr^{-1}) on forest land in Missouri, by species group and live-tree stocking condition, 2008.

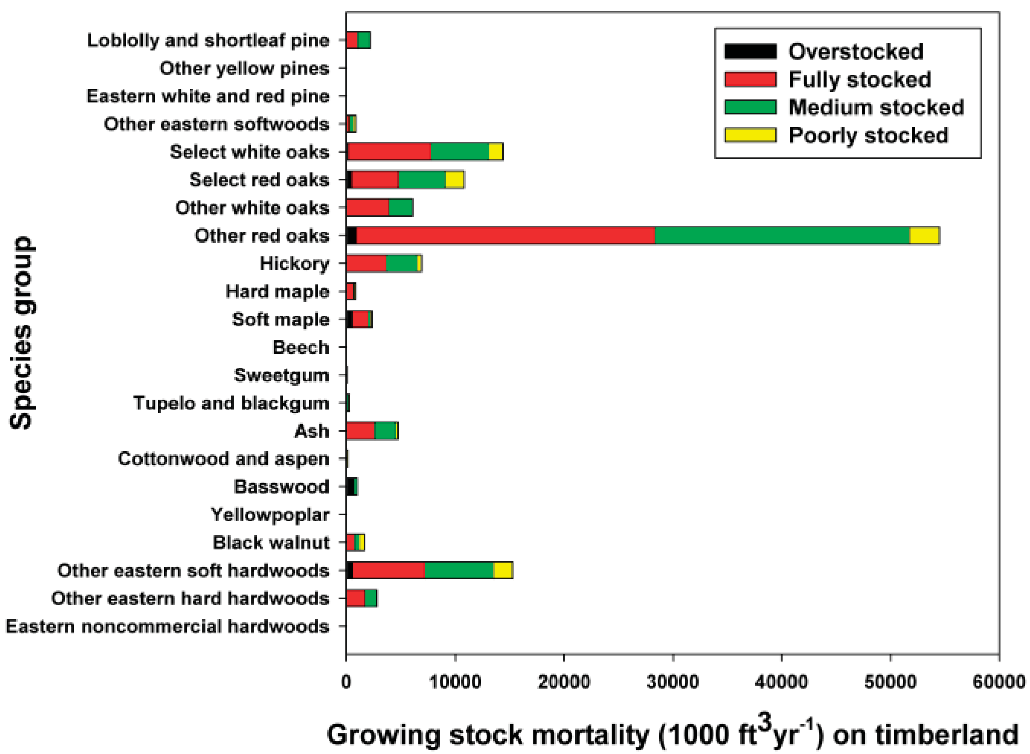
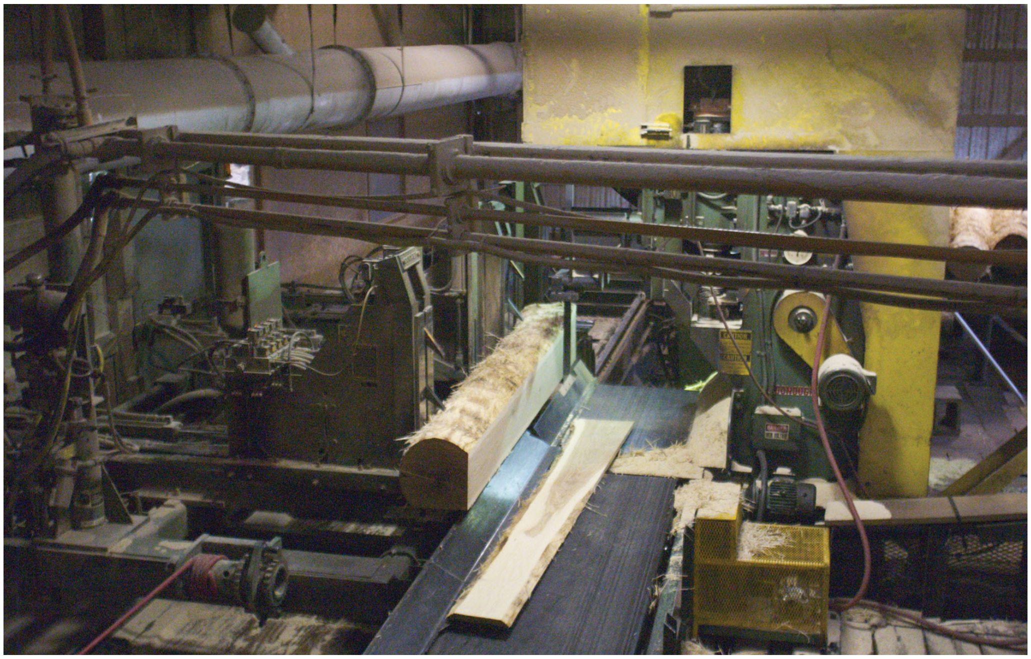


Figure 37.—Annual growing-stock mortality (ft^3 yr^{-1}) on timberland in Missouri, by species group and live-tree stocking condition, 2008.



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

Firewood. Photo by Joseph O'Brien, U.S. Forest Service, Bugwood.org

Forest Health Threats

Trees impacted by oak decline. Photo used with permission of Missouri Department of Conservation.

Missouri's forests are home to over 90 tree species (Appendix I). The State's forest resources are vulnerable to a number of current and potential forest health stressors as well as combinations thereof that tend to have the greatest impacts. Both nonnative and native invasive plants (e.g., honeysuckle, garlic mustard, ironwood), insects and diseases (e.g., emerald ash borer, gypsy moth, thousand cankers disease), large animals (e.g., feral hogs, livestock, deer), and extreme weather events can result in detrimental impacts to our forests. Although some of these impacts are unavoidable, there exist some practices that can either reduce the susceptibility to forest health issues or minimize the impact from health stressors that arise.

NONNATIVE INVASIVE PLANTS

Background

Numerous "exotic" or nonnative invasive plant (NNIP) species are capable of crowding out native plants, impeding tree regeneration, reducing forest management options, degrading forest health and wildlife habitat quality, and, by changing current and future forest structure, impacting recreational opportunities. Of Missouri's more than 800 nonnative plant species, some 37 have become a nuisance to the extent that they crowd out native flora and impede tree regeneration (pers. comm. Paul Nelson, Mark Twain National Forest). Some of the most damaging species include nonnative bush honeysuckle (*Lonicera* spp.), garlic mustard (*Alliaria petiolata)*, Japanese honeysuckle (*Lonicera japonica)*, Nepalese browntop (*Microstegium vimineum)*, autumn olive (*Elaeagnus umbellata)*, and multiflora rose (*Rosa multiflora)*.

Certain areas are especially prone to exotic plant infestations. Urban habitats often have extensive populations of exotic plants, and infestations are common in wildland urban interface areas as well. Exotic plant infestations are more variable in rural landscapes (see Fig. 17). Additionally, areas closer to forest edges are often more vulnerable to exotic plant infestations (Fig. 18). These areas are typically subjected to more exposure to people, livestock, or various disturbances which can encourage exotic plant species.

Understory vegetation plays many important roles in forested areas. Within forests the vegetation mitigates erosion and runoff, regulates soil temperature, sequesters carbon, and provides habitat and forage. Data on the vegetation in forested areas can be used to characterize biodiversity and site quality, among other attributes. Certain plants have distinct roles in the forested community and are site specific. Plants are also able to filter pollutants, indicate air quality, nutrient availability, and/or provide species-specific habitat niches. Plant communities were documented in Missouri on phase 2 invasive plots (approximately 20 percent of all phase 2 or inventory field plots, where the only understory vegetation documented is the presence of the 43 invasive species.) and phase 3 (forest health monitoring) plots (approximately 6.25 percent of field plots, where all understory vascular plants are documented). The results below will summarize the phase 3 vegetation (invasive and native) and the phase 2 invasive plot data.

What we found

During this latest inventory, understory ground flora was sampled on only the last two of the five panels. For 2007-2008, ground flora was sampled in 88 phase 3 plots. Nonnative invasive plants were sampled in 156 phase 2 plots during the same period. On the phase 3 plots, 584 species were found. The forbs/herbs growth habit contained the largest number of species classified, based on classification by the USDA Natural Resources Conservation Service's PLANTS Database (NRCS 2011; Table 6). Seventy-eight plants were classified as graminoids (grass or grass-like plants). There were an additional 93 species of trees, 51 of shrubs, and 33 of vines.

For the phase 3 plots, 479 (82 percent) of the 584 plant species were native to the U.S. and 62 species (11 percent) were definitively identified as introduced (Table 7).

On phase 3 plots, the most commonly observed understory species was Virginia creeper which occurred on 81 plots (Table 8). The most common tree species observed was eastern redcedar (72 plots). Nonnative

Table 6.—Number of species on Missouri phase 3 plots by growth habit (NRCS 2010), 2007-2008

Growth habit	Number of species or undifferentiated genuses
Forb/herb	294
Graminoid	78
Shrub	17
Shrub, forb/herb	1
Shrub, subshrub	1
Shrub, subshrub, vine	5
Subshrub, forb/herb	5
Subshrub, shrub	8
Subshrub, shrub, forb/herb	14
Tree	43
Tree, shrub	48
Tree, shrub, subshrub	2
Vine	13
Vine, forb/herb	15
Vine, shrub	3
Vine, subshrub	2
Unclassified	35
Total	584

Table 7.—Number of species on Missouri phase 3 plots by domestic or foreign origin (NRCS 2010), 2007-2008

Origin	Number of species
Cultivated or not in the U.S.	3
Introduced to the U.S.	62
Native and introduced to the U.S.[a]	7
Native to the U.S.	479
Probably introduced to the U.S.	1
Unclassified	32

[a]A category of in the USDA PLANTS database where some infra-taxa are considered native and others as introduced in the lower 48 states

Table 8.—The most common plant species found on Missouri phase 3 plots, 2007-2008

Species	Number of plots
Virginia creeper (*Parthenocissus quinquefolia)*	81
Eastern redcedar (*Juniperus virginiana*)	72
Coralberry (*Symphoricarpos orbiculatus*)	69
Summer grape (*Vitis aestivalis*)	62
Black cherry (*Prunus serotina*)	59
Black oak (*Quercus velutina*)	59
Eastern poison ivy (*Toxicodendron radicans*)	59
Common hackberry (*Celtis occidentalis*)	58
White oak (*Quercus alba*)	57
Flowering dogwood (*Cornus florida*)	55
Fragrant sumac (*Rhus aromatica*)	50
Black hickory (*Carya texana*)	48
Sassafras (*Sassafras albidum*)	48
Black raspberry (*Rubus occidentalis*)	47
Common persimmon (*Diospyros virginiana*)	44
Black walnut (*Juglans nigra*)	44
Saw greenbrier (*Smilax bona-nox*)	42
White ash (*Fraxinus americana*)	41
Licorice bedstraw (*Galium circaezans*)	40
Post oak (*Quercus stellata*)	39
Common cinquefoil (*Potentilla simplex*)	38
Slippery elm (*Ulmus rubra*)	38
Ebony spleenwort (*Asplenium platyneuron*)	37
Carolina buckthorn (*Frangula caroliniana*)	37
Eastern redbud (*Cercis canadensis*)	34
American elm (*Ulmus americana*)	34
Mockernut hickory (*Carya alba*)	33
Red mulberry (*Morus rubra*)	33
Blackgum (*Nyssa sylvatica*)	33
Perplexed ticktrefoil (*Desmodium perplexum*)	32
Northern red oak (*Quercus rubra*)	32
White avens (*Geum canadense*)	31

invasive plants monitored by FIA (Table 9) were not among the 32 most commonly observed species on phase 3 plots in Missouri.

On the phase 2 invasive plots, multiflora rose was the most commonly occurring invasive plant species (57 plots; Table 10), followed by bull thistle and Japanese honeysuckle (5 plots). Five of the eight invasive species found on Missouri phase 2 invasive plots were of woody growth form.

On the phase 3 vegetation plots, multiflora rose was again the most prominent invasive plant (Table 11). This species is a good model for the challenges posed by nonnative invasive species. Figure 38 summarizes data from phase 2 Invasive and phase 3 vegetation plots and illustrates the widespread extent of multiflora rose in Missouri. Multiflora rose is a woody shrub originally imported as a root stock for ornamental roses in 1866 (Plant Conservation Alliance 2009) and later widely planted in Missouri for erosion control, “living fences”

Table 9.—Invasive plant species target list for FIA phase 2 Invasive plots, 2007 to present

Tree Species	Vine Species	Woody Shrub Species	Herbaceous Species	Grass Species
Acer platanoides (Norway maple)	*Celastrus orbiculatus* (Oriental bittersweet)	*Berberis thunbergii* (Japanese barberry)	*Alliaria petiolata* (garlic mustard)	*Microstegium vimineum* (Nepalese browntop)
Ailanthus altissima (tree-of-heaven)	*Hedera helix* (English ivy)	*Berberis vulgaris* (common barberry)	*Centaurea biebersteinii* (spotted knapweed)	*Phalaris arundinacea* (reed canarygrass)
Albizia julibrissin (silktree)	*Lonicera japonica* (Japanese honeysuckle)	*Elaeagnus umbellata* (autumn olive)	*Cirsium arvense* (Canada thistle)	*Phragmites australis* (common reed)
Elaeagnus angustifolia (Russian olive)		*Frangula alnus* (glossy buckthorn)	*Cirsium vulgare* (bull thistle)	
Melaleuca quinquenervia (punktree)		*Ligustrum vulgare* (European privet)	*Cynanchum louiseae* (Louise's swallow-wort)	
Melia azedarach (Chinaberry)		*Lonicera x.bella* (showy fly honeysuckle)	*Cynanchum rossicum* (European swallow-wort)	
Paulownia tomentosa (princesstree)		*Lonicera maackii* (Amur honeysuckle)	*Euphorbia esula* (leafy spurge)	
Robinia pseudoacacia (black locust)		*Lonicera morrowii* (Morrow's honeysuckle)	*Hesperis matronalis* (dames rocket)	
Tamarix ramosissima (saltcedar)		*Lonicera tatarica* (Tatarian bush honeysuckle)	*Lysimachia nummularia* (creeping jenny)	
Triadica sebifera (tallow tree)		*Rhamnus cathartica* (common buckthorn)	*Lythrum salicaria* (purple loosestrife)	
Ulmus pumila (Siberian elm)		*Rosa multiflora* (multiflora rose)	*Polygonum cuspidatum* (Japanese knotweed)	
		Spiraea japonica (Japanese meadowsweet)	*Polygonum x.bohemicum* (Bohemian knotweed)	
		Viburnum opulus (European cranberrybush)	*Polygonum sachalinense* (giant knotweed)	

for livestock, and wildlife cover (Keefe 1987). Spreading quickly and shading out other plants, the seeds are dispersed by birds and remain viable in the soil for many years. Typical of most NNIPs, control methods are very expensive and require repeated application of mechanical and chemical methods for success (Evans 1983). In Moser et al.'s (2008) analysis of the presence of select NNIP on FIA plots, multiflora rose was the most frequently found NNIP in the Upper Midwest.

What this means

Missouri's forests have a diverse array of species covering five growth habits (forb/herb, graminoid, shrub, tree, and vine). The presence of NNIP in these states is a risk to the forests as these plants can inhibit regeneration and change forest structure. Additionally these species can alter resource availability and the habitat quality for flora and fauna.

NATIVE INVASIVE PLANTS

Plants need not be exotic to act like an invasive. Due to changing land use patterns, forest landowners face similar problems with many native species such as red and sugar maple, ironwood, and eastern redcedar. In the absence of fire and other historic disturbances that kept them suppressed, these native invasive species can overwhelm plant communities which have traditionally dominated the landscape. Native invasive plants often

Table 10.—Invasive plant species found on Missouri phase 2 invasive plots and the number of plots with each species, 2007-2008

Species	Number of plots
Multiflora rose (*Rosa multiflora*)	57
Bull thistle (*Cirsium vulgare*)	5
Japanese honeysuckle (*Lonicera japonica*)	5
Morrow's honeysuckle (*Lonicera morrowii*)	3
Nepalese browntop (*Microstegium vimineum*)	2
Tree-of-heaven (*Ailanthus altissima*)	2
Black locust (*Robinia pseudoacacia*)	2
Reed canarygrass (*Phalaris arundinacea*)	1

Table 11.—Nonnative invasive plant species found on Missouri phase 3 plots and the number of plots with each species, 2007-2008

Species	Number of plots
Multiflora rose (*Rosa multiflora*)	55
Tall fescue (*Schedonorus phoenix*)	16
Japanese honeysuckle (*Lonicera japonica*)	12
White mulberry (*Morus alba*)	12
Spreading hedgeparsley (*Torilis arvensis*)	12
Queen Anne's lace (*Daucus carota*)	11
Black medick (*Medicago lupulina*)	10
Narrowleaf plantain (*Plantago lanceolata*)	9
Kentucky bluegrass (*Poa pratensis*)	9
Sericea lespedeza (*Lespedeza cuneata*)	8
Stinging nettle ((*Urtica dioica*)	8
Red clover (*Trifolium pratense*)	7
Deptford pink (*Dianthus armeria*)	6
Amur honeysuckle (*Lonicera maackii*)	5
White clover (*Trifolium repens*)	5

follow different distribution patterns than exotics, and tend to be most prevalent in areas in which fire has been excluded for a longer period of time.

INSECTS AND DISEASE

Missouri trees and forests face a large number of insect and disease pests. Damage from these pests can range from cosmetic inconvenience to widespread destruction of entire forest communities. Sometimes these pests act independently, and sometimes they work in concert with a complex of other forest health stressors. Some of our most prominent insect and disease threats are exotic species which have not yet developed many natural predators to keep their numbers in check (i.e. emerald ash borer, gypsy moth, Asian longhorn beetle). However, native insects and diseases can cause major damage as well, especially when paired with other stressors such as drought or site disturbance (e.g., red oak borer, oak wilt).

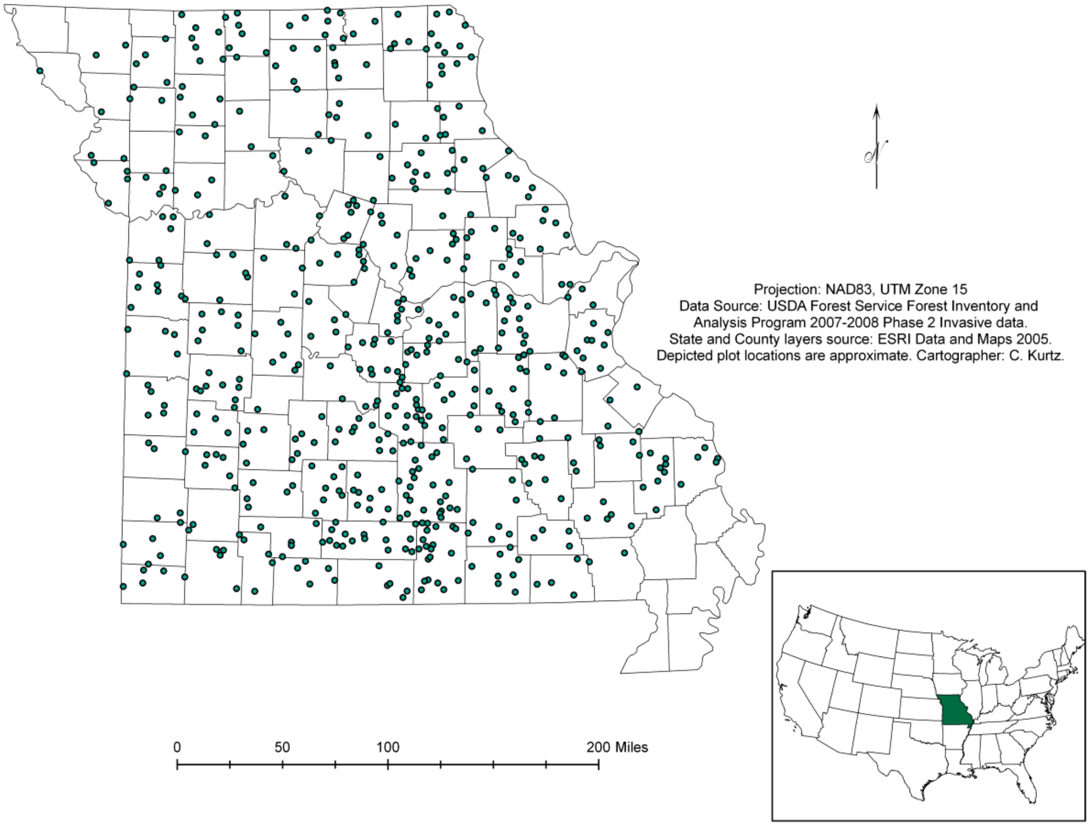


Figure 38.—Map of the distribution of multiflora rose (*Rosa multiflora*), the most frequently occurring invasive species observed on 2007-2008 Forest Inventory and Analysis phase 2 invasive plots in Missouri, approximate plot locations are depicted.

The following three examples illustrate the extent and impact of forest health issues in Missouri.

RED OAK DECLINE AND SHORTLEAF PINE RESTORATION OPPORTUNITIES

In Missouri's rural and urban forests, the greatest insect and disease threat currently impacting forests is red oak decline. Forestry professionals and residents are witnessing wide-scale decline and mortality of red oak group trees (in particular: northern and southern red oaks, black oak, scarlet oak) due to a complex combination of factors such as the age of the trees, red oak borers, *Armillaria* root rot, drought, and trees growing on sites better suited to shortleaf pine. Missouri contains a large amount of red oak group trees (Figure 39; Moser et al. 2007) shows, and these forests will be susceptible to oak decline in the coming years.

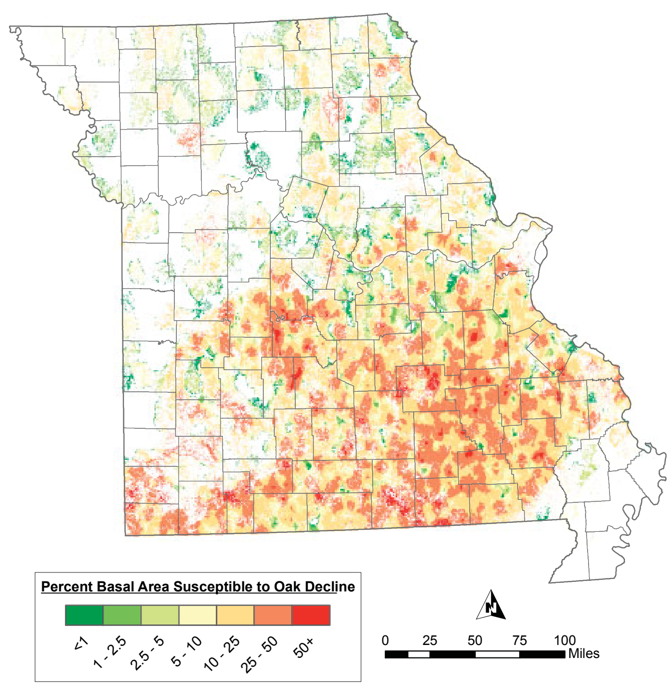


Figure 39.—Percent of total basal area in red oak species (scarlet oak, southern red oak, northern red oak, black oak) susceptible to oak decline, 2008.

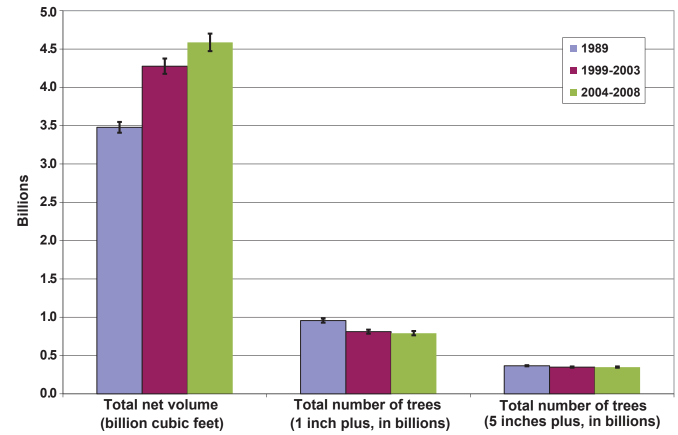


Figure 40.—All-live volume (in billion cubic feet) of major upland red oak species (scarlet oak, southern red oak, northern red oak, black oak) susceptible to oak decline and total number of trees (in billions of trees) 1 inch and larger and 5 inches and larger on timberland in Missouri, 1989, 2003 and 2008. Bars represent 68 percent confidence intervals.

Figure 40 shows that Missouri's total volume of red oak has increased in the past decade. However, Figure 41 shows that the total number of red oak group trees is diminishing, as is the number of smaller diameter red-oak group trees. Two conclusions can be drawn. First, the increased volume growth is concentrated in larger-diameter (and, presumably, older) trees which are more vulnerable to red oak decline. Therefore, the impacts of red oak decline are likely to accelerate in the coming years. Second, as red oak mortality in large trees increases, there may be fewer younger red oaks to take their place.

Red oak decline occurs throughout the state, but the hardest hit areas are typically sites which were historically dominated by shortleaf pine. Of the estimated 6.6 million acres of shortleaf pine in pre-settlement Missouri (Treiman et al. 2007), only 1.5 million acres exist today. Major upland red oak species (scarlet, black, northern red, and southern red oak) currently found on these sites generally became established because their major competitor, shortleaf pine, was preferentially logged and because they were better able to tolerate the land management practices that took place at the turn of the century rather than because they were best suited to the site.

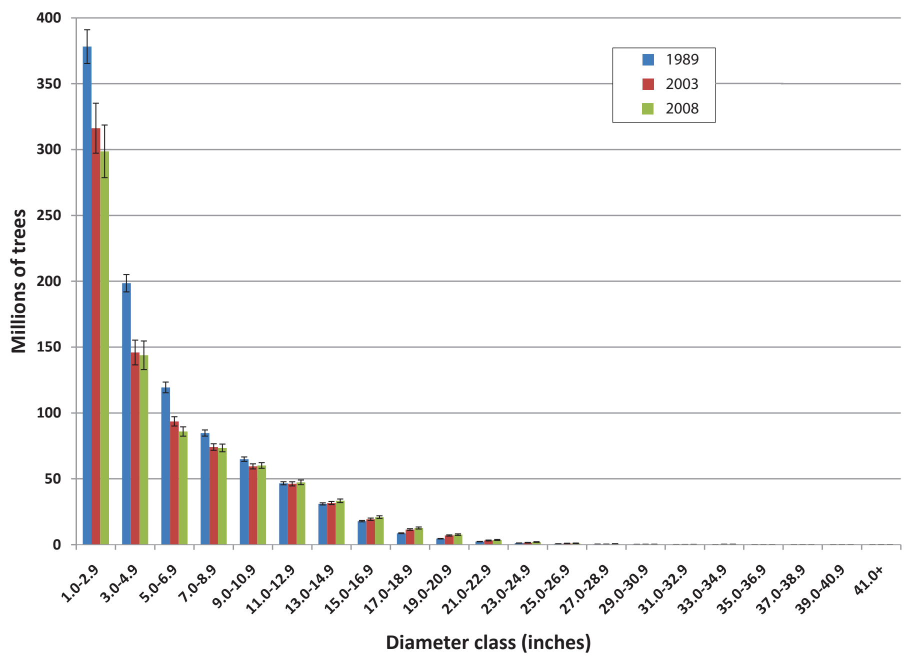


Figure 41.—Number of live trees of major upland red oak species most susceptible to oak decline (scarlet, black, northern red, and southern red oak), by diameter class, 1989, 2003, and 2008. Bars represent 68 percent confidence intervals.

As these red oak trees die, a great opportunity presents itself to restore shortleaf pine back onto some of these sites (Fig. 42). Restoring pine on these sites is challenging, requiring a combination of management practices such as tree thinning, tree planting, and prescribed fire. However, these efforts have many rewards. Natural communities are restored to their historic conditions, which could benefit many wildlife species that depend on the conditions (e.g., pine warbler, brown-headed nuthatch). Restoring shortleaf pine also would help increase tree species diversity and, as a consequence, species-specific diseases or insects will have less impact in such forests. Finally, according to the Climate Change Tree Atlas, while the projected future habitat suitability for many oak species is expected to decline due to climate change, the suitability for shortleaf pine is expected to increase. Therefore, restoring shortleaf pine to the landscape could help make Missouri's woodlands more adaptable to potential changes in climate.

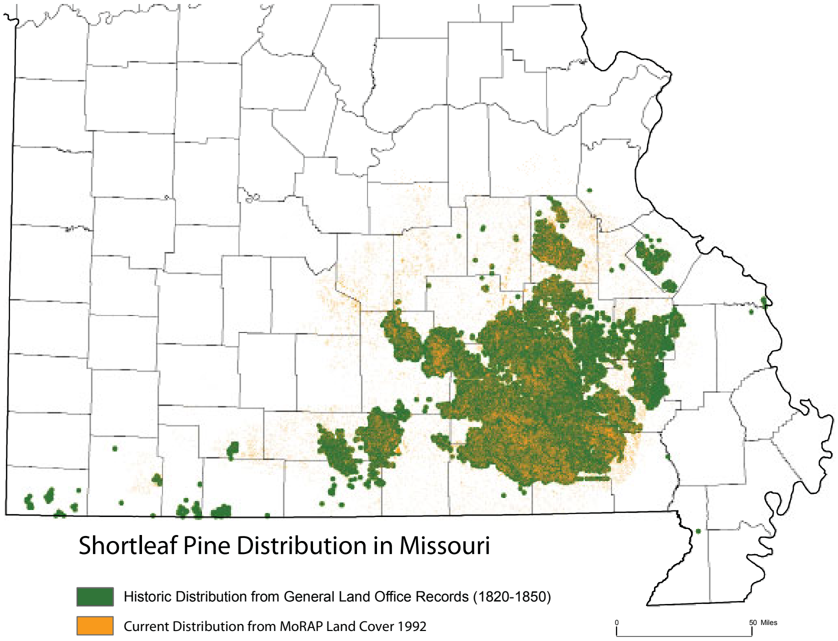


Figure 42.—Current and historic distribution of shortleaf pine in Missouri. (Map generated using General Land Office Records (1820-1850) and Missouri Resource Assessment Partnership Land Cover Data - 1992).

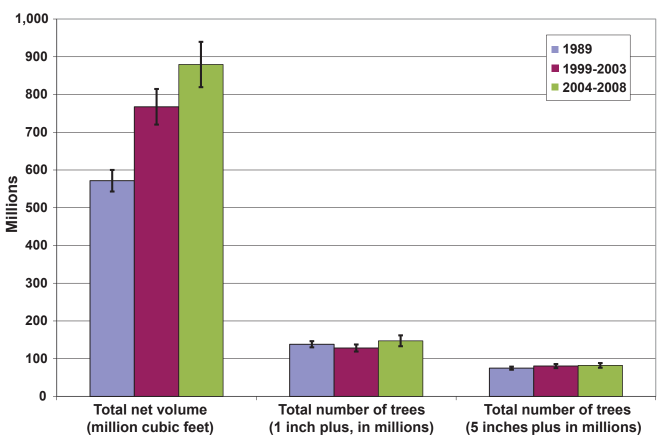


Figure 43.—Total net all-live volume and total number of trees 1 inch and larger and 5 inches and larger of shortleaf pine in Missouri, 1989, 2003, and 2008. Bars represent 68 percent confidence intervals.

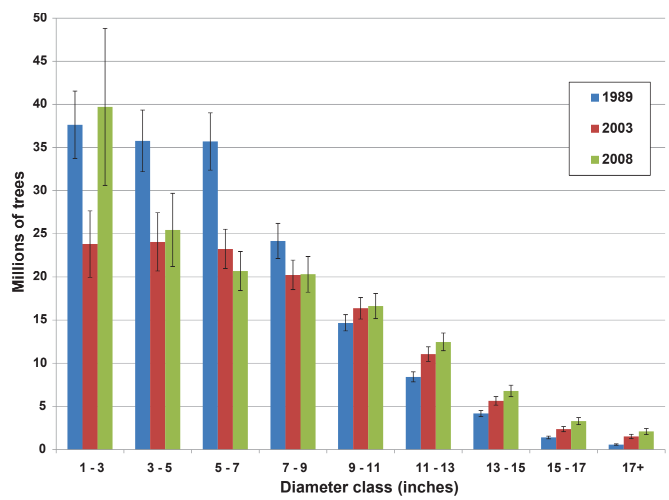


Figure 44.—Diameter distribution of shortleaf pine trees in Missouri, 1989, 2003 and 2008. Bars represent 68 percent confidence intervals.

What we found

FIA data shows that some resurgence of shortleaf pine is already taking place (Fig. 43). From 1989 to the present, there has been an increase in the net volume of shortleaf pine and total number of trees. The increase in number of trees is consistent throughout most tree diameter size classes, but includes a noticeably large increase in the number of 1-3 inch diameter trees (Fig. 44). This could indicate that some of Missouri's shortleaf pine restoration efforts are working.

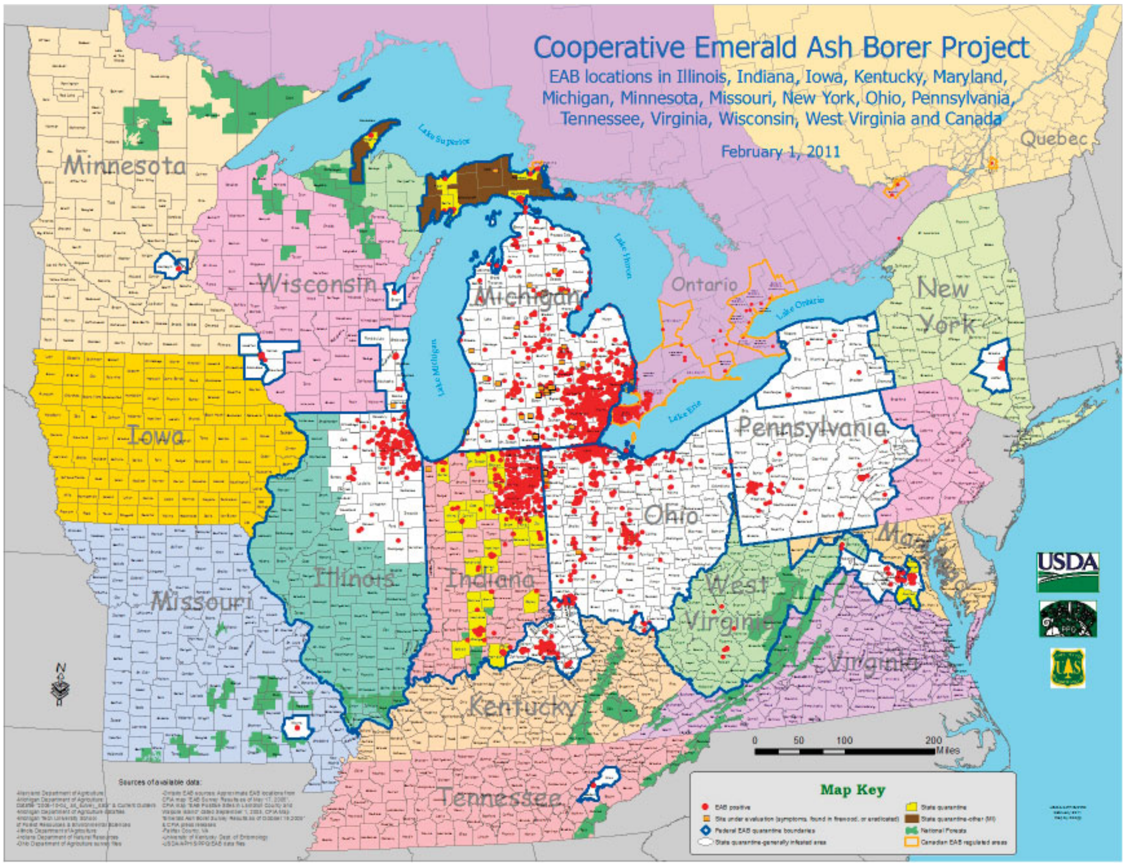


Figure 45.—Emerald ash borer locations, March, 2010 (U.S. Animal and Plant Health Inspection Service 2011).

EMERALD ASH BORER

Background

The emerald ash borer (EAB) is an exotic bark-boring beetle that was discovered in southeastern Michigan in 2002. EAB is a small green exotic insect native to Russia, China, Japan and Korea. Since that time, EAB has killed tens of millions of ash trees in the north-central and eastern portions of the United States. EAB has been 100 percent fatal to infected trees. In 2008, Missouri's first documented outbreak of EAB was discovered in Wayne County. By March 2010 it had been detected throughout the Upper Midwest and portions of the northeastern United States (Fig. 45). All ash trees are believed to be vulnerable to EAB regardless of species, size or general health. As a result, there is wide concern that most if not all of Missouri's ash trees could be eliminated.

What we found

Roughly 3 percent of Missouri's forest trees are ash species. Although this loss would be significant, the greatest concern is the potential impacts of EAB in Missouri's urban areas. MDC surveys reveal that approximately 14 percent of Missouri's street trees and 21 percent of park trees are ash. The percentage rises to well above 30 percent in some parks and residential subdivisions. Numbering over 281 million trees (1 inch in diameter or greater), ash represents approximately 3 percent of all species on forest land and accounts for 462 million cubic feet of live-tree volume. Ash density is concentrated in the central and southeastern portions of the state (Fig. 46). When ash is present in a stand, it is rarely the most dominant species; in general, ash makes up less than 25 percent of total live-tree basal area in a stand.

David Cappaert
www.invasive.org

Emerald ash borer.

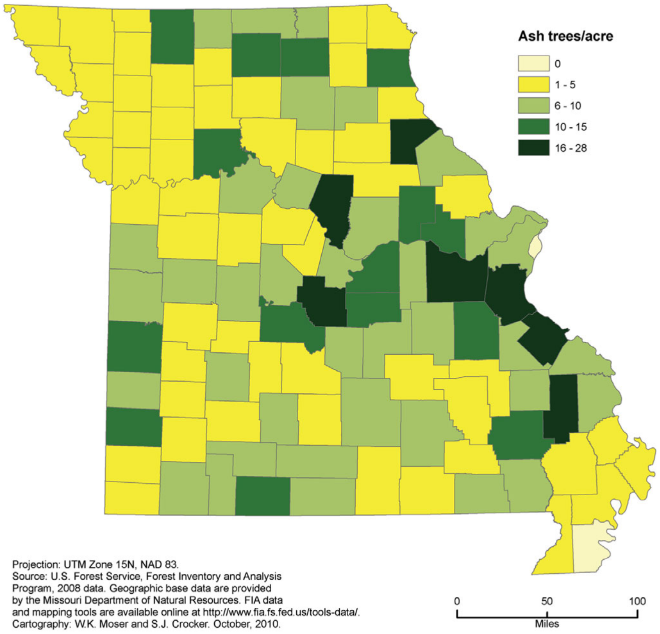


Figure 46.—Ash density by county as a percentage of all county land, Missouri, 2008.

John H. Ghent, U.S. Forest Service, www.forestryimages.org

Gypsy moth

What this means

The potential economic impact of EAB is substantial. Treiman et al. (2008) estimated that if EAB becomes established statewide, Missouri's economy will lose more than $6.7 million annually in the future. Treiman et al. (2008) calculated a one-time cost of the economic impact to Missouri due to the loss of ash street trees, spread out over 20 years, of $20.3 million.

GYPSY MOTH

The gypsy moth was introduced to the East Coast of the United States in 1869 and since then has been spreading slowly westward. When it arrives, the gypsy moth could be especially devastating to Missouri forests because one of its preferred foods is oak leaves, particularly white oaks. Mortality in our forests will likely be high due to the high density and advanced age of our forests, all factors that currently stress individual trees, and because most of our forests have a high percentage of oak species. MDC and numerous other state and Federal agencies cooperate on a monitoring program to detect any introductions of gypsy moth. Each year, a small number of moths are found that have been accidentally brought into Missouri from infested states. Spot infestations of gypsy moth were found in the 1990s in Dent County and in northern Arkansas near Branson, MO. These infestations were controlled, delaying the introduction of gypsy moth into Missouri for the time being. Education programs are informing citizens how to recognize the gypsy moth and instructing them to inspect their vehicles and belongings after visiting an infested state.

Figure 47 displays the extent of gypsy moth in the northeast United States in 2006. The counties under quarantine generally have an established gypsy moth population.

What this means

Gypsy moth is not in Missouri at the present time but will substantially impact the ecology and economics of Missouri's forested landscape when it arrives. There are analyses and guidelines developed for reducing the impact of gypsy moth on forests by manipulating species composition and stand density (e.g., Gottschalk 1993) that landowners may wish to reference as they consider their alternatives in the face of this impending threat.

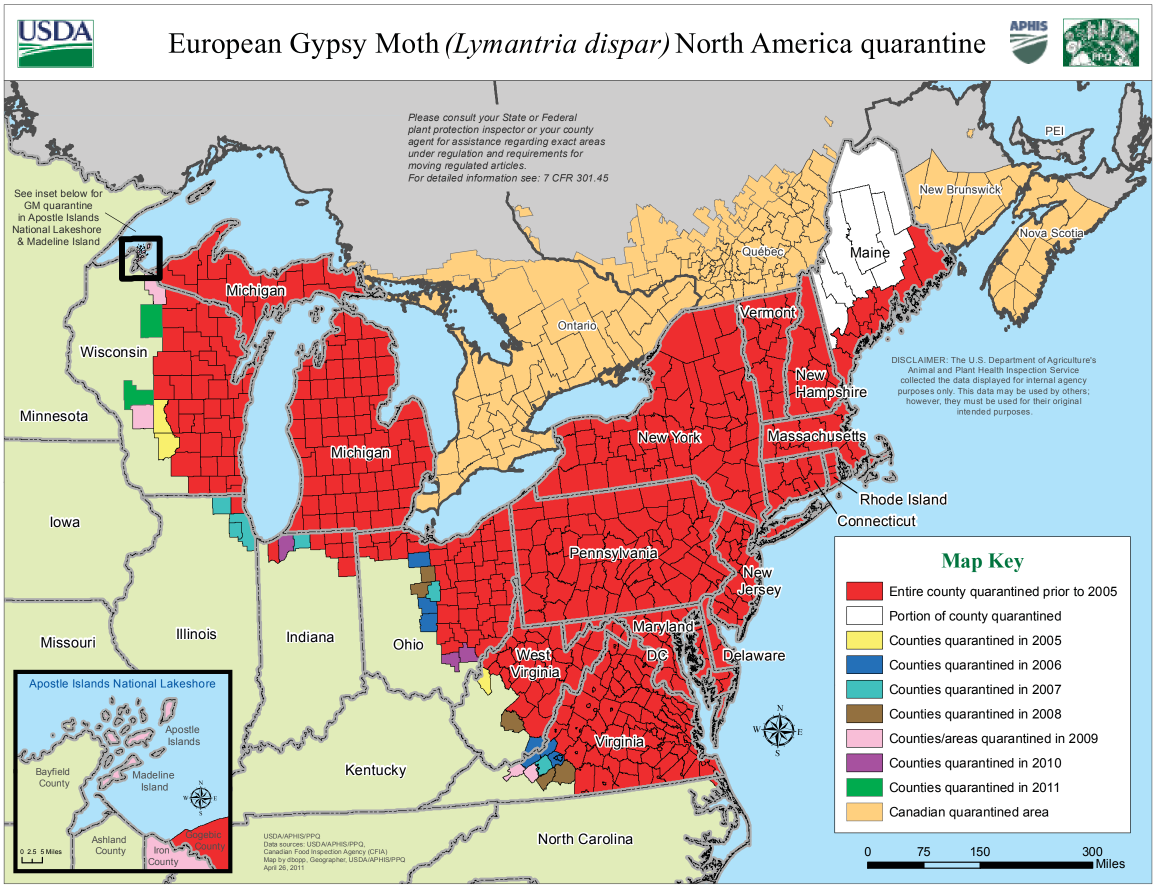


Figure 47.—Gypsy moth quarantine areas. The orange areas represented quarantined areas in Canada at the time the map was created.

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APPENDIX I.—TREE SPECIES IN MISSOURI, 2008

Common name	Scientific name
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*
northern catalpa	*Catalpa speciosa*
sugarberry	*Celtis laevigata*
hackberry	*Celtis occidentalis*
eastern redbud	*Cercis canadensis*
flowering dogwood	*Cornus florida*
hawthorn spp.	*Crataegus spp.*
cockspur hawthorn	*Crataegus crus-galli*
downy hawthorn	*Crataegus mollis*
common persimmon	*Diospyros virginiana*
American beech	*Fagus grandifolia*
white ash	*Fraxinus americana*
black ash	*Fraxinus nigra*
green ash	*Fraxinus pennsylvanica*
blue ash	*Fraxinus quadrangulata*
waterlocust	*Gleditsia aquatica*
honeylocust	*Gleditsia triacanthos*
Kentucky coffeetree	*Gymnocladus dioicus*
butternut	*Juglans cinerea*
black walnut	*Juglans nigra*
sweetgum	*Liquidambar styraciflua*

Common name	Scientific name
yellow-poplar	*Liriodendron tulipifera*
Osage-orange	*Maclura pomifera*
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*
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*
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*
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*
smoketree	*Cotinus obovatus*

Coarse woody debris. Photo used with permission of Missouri Department of Conservation.

Raeker, Gus; Moser, W. Keith; Butler, Brett J.; Fleming, John; Gormanson, Dale D.; Hansen, Mark H.; Kurtz, Cassandra M.; Miles, Patrick D.; Morris, Mike; Treiman, Thomas B. 2011. **Missouri's forests 2008.** Resour. Bull. NRS-54. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 55 p. [DVD included].

The second full annual inventory of Missouri's forests (2004-2008) reports more than 15 million acres of forest land, almost all of which is timberland (98 percent), with an average volume of more than 1,117 cubic feet of growing stock per acre. White oak and black oak are the most abundant in terms of live tree volume. Eighty-three percent of the State's forest land is owned by private landowners. This report includes additional information on forest attributes, land use change, carbon, timber products,climate change, forest health, and the role of fire. A DVD included in this report includes 1) descriptive information on methods, statistics, and quality assurance of data collection, 2) a glossary of terms, 3) tables that summarize quality assurance, 4) a core set of tabular estimates for a variety of forest resources, and 5) a Microsoft Access database that represents an archive of data used in this report, with tools that allow users to produce customized estimates.

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

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