

Missouri's Forests 1999-2003

Part A




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Abstract

The first completed annual inventory of Missouri's forests reports more than 14.6 million acres of forest land. Softwood forests make up 4 percent of the total forest land area; oak/hickory forest types make up about three-fourths of the total hardwood forest land area. Missouri's forests have continued to increase in volume, with all-live tree volume on forest land in Missouri an estimated 18 billion cubic feet compared to 9 billion cubic feet in 1972. All-live tree biomass on forest land in Missouri amounted to 573 million dry tons in 1999-2003. Almost 9 percent was in small trees, 74 percent was in growing-stock trees, and 17 percent was in non-growing-stock trees. Softwood growth was 44.1 million cubic feet per year and hardwood growth was 585.3 million cubic feet per year. Oak species constitute roughly three-fourths of the volume and three-fourths of the harvest. Total net all-live volume of oaks on timberland increased by 24 percent between 1989 and 2003. More than 82 percent of Missouri's forest land is held by private landowners.

Acknowledgments

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Note: A companion (Part B) of this document, available online, contains sample design and estimation procedures, quality of estimates analysis, and core tables of forest attributes.

MISSOURI'S FORESTS

1999-2003

PART A

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FOREWORD

Welcome to the first 5-year report from our new system of statewide forest inventory, *Missouri's Forests 1999-2003*. The inventory is conducted as a cooperative program between the Missouri Department of Conservation and the Forest Inventory and Analysis program of the USDA Forest Service. Results of the inventory show that Missouri's forests have increased by more than half a 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 \$4.9 billion annually to the Missouri economy (2006 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 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 1999-2003* 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.

Please read and reflect upon the results of *Missouri's Forests 1999-2003* and then join in the discussion about Missouri's forests.

Lisa Allen

State Forester – Missouri Department of Conservation

HIGHLIGHTS

ON THE PLUS SIDE

- Forest land area has increased to 14.6 million acres, roughly a third of Missouri's total land area.
- Softwood forests make up 4 percent of the total forest land area. Oak/hickory forest types make up about three-fourths of the total hardwood forest land area.
- The bulk of Missouri's timberland is in the larger stand-size classes, increasing from 31.7 percent of the total timberland area in 1947 to 51 percent of the area in 1999-2003.
- Missouri's forests have continued to increase in volume. In 1999-2003, all-live tree volume on forest land in Missouri was an estimated 18 billion cubic feet compared to 9 billion cubic feet in 1972.
- All-live tree biomass on forest land in Missouri amounted to 573 million dry tons in 1999-2003. Almost 9 percent was in small trees, 74 percent was in growing-stock trees, and 17 percent was in non-growing-stock trees.
- Missouri's forests have continued to grow. In the latest survey, softwood growth was 44.1 million cubic feet per year and hardwood growth was 585.3 million cubic feet per year.
- Oak species constitute roughly three-fourths of the volume and three-fourths of the harvest. Total net all-live volume of oaks on timberland increased by 24 percent between 1989 and 2003.
- More than 82 percent of Missouri's forest land is held by private landowners.

AREAS OF CONCERN

- Missouri's forests are getting denser, increasing individual tree stress and susceptibility to forest health problems. While timberland acreage has increased by 14 percent since 1972, the number of growing-stock trees has increased by 86 percent.
- Average annual mortality of all growing stock on timberland was 81.8 million cubic feet per year, a 10 percent increase since 1989. Almost 94 percent of the total mortality was from hardwoods. Nineteen percent occurred on public lands. Looking just at hardwoods, almost 18 percent of the average annual mortality was on public lands. Forty-seven 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 26.5 million cubic feet per year.
- The mean age of Missouri's forests is slowly increasing, and certain age groups have shifted: the acreage in oak types greater than 60 years old has increased by 30 percent.
- Indiana bat is a species of special concern in the oak-hickory region of the United States. Although a great many Missouri counties have potential Indiana bat habitat, suitable tree species are clumped in certain locations. All-live volume of species suitable for Indiana bat roost trees has increased since the previous inventory, but the number of trees greater than 5 inches in diameter has barely changed.
- Between inventories, the volume of hickories, maples, and eastern redcedar increased faster than that of oaks.

FEATURES OF MISSOURI'S FOREST RESOURCES

Missouri's forests are a valuable part of the State's natural resource wealth. Providing shelter and food for wildlife, water for drinking and for recreation, scenery for enjoyment, as well as wood products for consumption, construction, and fuel, Missouri's forested resource has played an integral role in the economic and social well-being of the State.

This is a report of Missouri's first 5-year forest inventory (1999-2003). Under the new annual inventory design, approximately 20 percent of the State's plots are measured each year, resulting in total coverage over a 5-year period. This new design ensures that all parts of the State are sampled with equal probability, except where the plot sample was increased in the southeastern inventory units.

Missouri is divided into five inventory units, based somewhat on ecological characteristics (Fig. 1): Eastern Ozarks, Southwest Ozarks, Northwest Ozarks, Prairie, and Riverborder.

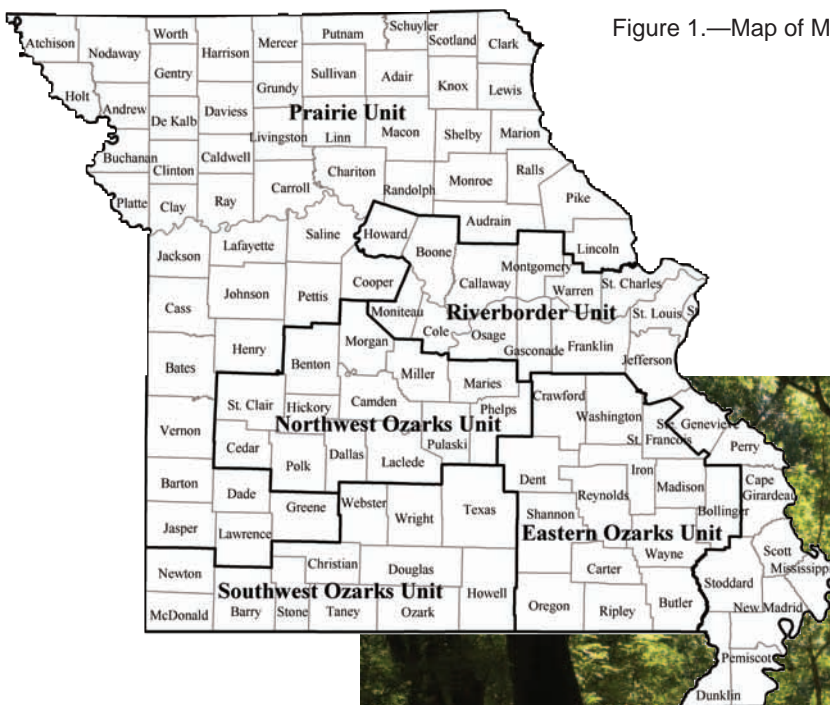


Figure 1.—Map of Missouri inventory units and counties.



AREA

Forest Land¹ Area

Background:

Missouri's forests are a source of wildlife habitat, watershed protection, recreational opportunities, and economically valuable resources. Although Missouri has more forest land area than many States, it faces increasing pressure from an expanding and mobile human population.

What We Found:

Almost one-third of Missouri's land area of more than 44 million acres is currently forest land (Fig. 2). Missouri's forest land, since a low point in the early 1970s, has increased to 14.6 million acres covering a significant portion of the State's landscape. Most of the forest land is dominated by various hardwood forest types. Only 4 percent of the forest land is covered by softwood forest types, such as shortleaf pine or eastern redcedar (Table 1).

What This Means:

As in most Eastern States, Missouri's forest land is primarily held by private landowners, ranging from small farmers and vacation-home owners to timber products companies and trusts. This means that thousands and thousands of individual decisions over the years have shaped Missouri's forests into the mosaic of structures, species, and ages seen today. In some ways, Missouri's forests have changed greatly over the last two centuries, but in others they have stayed the same. We will explore these factors in terms of forest species, size, age, ownership, and diversity.

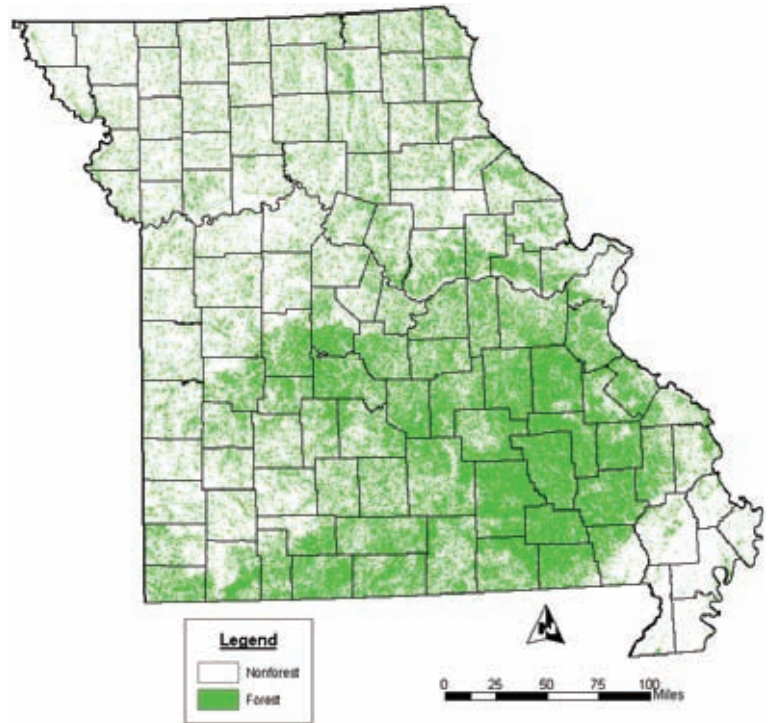


Figure 2.—Forest land in Missouri, 1999-2003.²

Table 1.—Forest land acreage by forest type group, Missouri, 1999-2003

Forest type group	Forest land area (in thousand acres)
Softwood type groups	
White/red/jack pine	1.5
Loblolly/shortleaf pine	163.5
Pinyon/juniper	456.1
Exotic softwood	1.4
All softwood types	622.6
Hardwood type groups	
Oak/pine	1,035.5
Oak/hickory	11,496.3
Oak/gum/cypress	68.0
Elm/ash/cottonwood	939.6
Maple/beech/birch	317.6
Exotic hardwood	2.3
All hardwood types	13,859.3
Nonstocked	94.5
All forest types	14,576.5

¹Forest Inventory and Analysis defines forest land as land with trees on it that is at least 1 acre in size, at least 120 feet in width, and possessing a minimum of 10 percent stocking of live trees.

²Data sources and acknowledgments for maps are summarized on page 74.

Timberland Area

Background:

FIA separates forest land by two criteria: productive/unproductive and reserved/unreserved. 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 cubic feet per acre per year 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); and Other forest land—low productivity forest land not capable of growing trees at a rate of 20 cubic feet per acre per year. Nearly 96 percent of Missouri's forest land is defined as timberland, so timberland trends correspond closely with forest land trends.

Missouri's forests have trees of almost every possible size. FIA looks for the plurality of stocking for less than 5 inches (seedling/sapling or small diameter), 5 to 9 or 11 inches for softwoods or hardwoods, respectively (poletimber or medium diameter), and greater than either 9 or 11 inches (sawtimber or large diameter). Sometimes we use stand size 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" mix of stand-size classes across the State; rather, particular combinations or trends might explain observations of forest health, growth, or change.

What We Found:

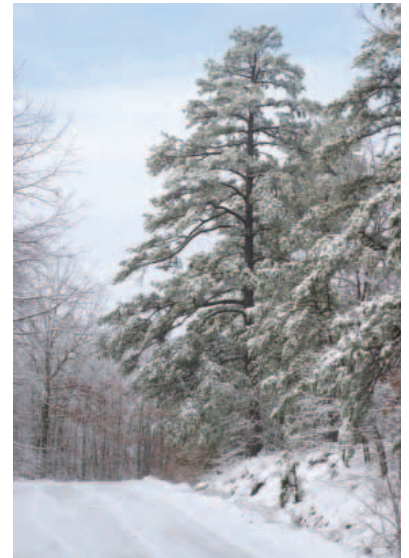
Timberland has increased by more than 14 percent since its low point in 1972 and by 5 percent since 1989. Nonetheless, timberland area in 2003 (14.1 million acres) was still less than the 15 million acres estimated in the 1947 survey (USDA 1948) (Fig. 3). Like forest land, Missouri's timberland was dominated by hardwoods, particularly the oak/hickory forest type group (11.1 million acres in 2003). Hardwoods made up 95 percent of total acreage, 94 percent of all public land, and 95 percent of all private landholdings.

Most of Missouri's timberland was in the medium- and large-diameter stand-size classes in 1999-2003 (Fig. 4). Large-diameter acreage stood at 7.1 million acres or 51 percent of the total timberland acreage, an increase of 5 million acres since 1947. The proportion of small-diameter acreage declined to 10.5 percent, or 1.5 million acres. Large-diameter acreage appeared to significantly increase between 1947 and 1959 and between 1972 and 1989, likely because of medium-diameter stands growing into large-diameter stands.

What This Means:

The increasing timberland base bodes well for the industries that rely on Missouri's wood. While some factors in the definition of forest land are fixed for a particular site, like maximum potential growth rate, others can be influenced by human activities. A landowner in Missouri can change the land use of a particular tract, such as by allowing fallow pasture land to seed into eastern redcedar stands, increasing the amount of timberland, or by taking lands out of potential production forever. Like forest land, timberland has increased since its low point in the 1970s. Some of the increase in timberland acreage reflects these types of decisions.

Many benefits received from Missouri's forests depend upon the size of the trees. Many communities of birds or other animals prefer open forests or forested lands with small trees. Other communities prefer forests with larger, taller trees and a closed canopy. Some mammals also use forests with large trees as potential den sites. Larger trees, particularly oaks, produce more mast than smaller trees, an important source of food for wildlife. A dispersed mix of tree sizes should benefit all of Missouri's inhabitants, depending on the health and arrangement of larger trees and their younger counterparts.



Features

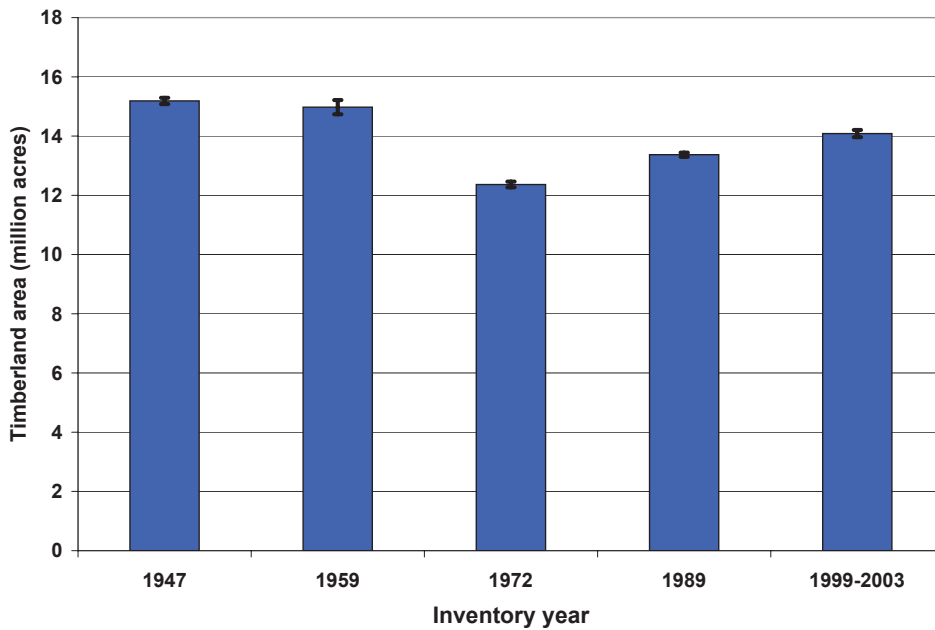


Figure 3.—Area of timberland in Missouri by inventory year, 1947–2003. In this and subsequent graphs, the vertical line at the top of each bar represents the sampling error associated with each estimate.

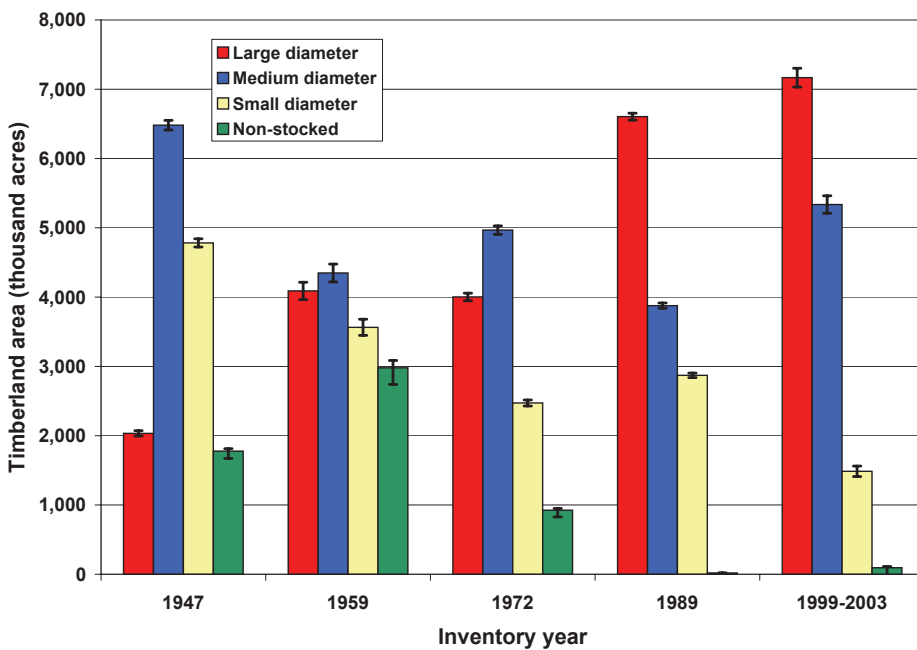


Figure 4.—Area of timberland in Missouri by stand-size class, 1947–2003.



WHO OWNS MISSOURI'S FORESTS?

Background:

Forest land ownership in Missouri is dynamic, especially among private forest land owners. Forest land changes hands often, and different landowners have differing motivations and reasons for owning forest land. The goods and services produced by a given unit of forest are related to owner objectives, practices, and perception of cost and benefits.

What We Found:

Most of Missouri's forest lands—83 percent—are privately owned (Fig. 5). Family and individual owners hold 10.5 million acres of forests, which totals three-fourths of Missouri's forest land. Private businesses own 8 percent and public agencies control the remaining 17 percent. Between 1993 and 2003, owners of family forests in Missouri increased by an estimated 17 percent, from 302,600 to 355,000 owners. The number of owners of small-tract family forests increased substantially, especially among those holding 1 to 9 acres (Fig. 6).

Fifty-two percent of the family forest owners now hold fewer than 10 acres each of forest land; however, their holdings account for only 6 percent of family forest lands. The most common reasons for owning forest land in Missouri are scenic beauty, recreation, privacy, and family legacy (Fig. 7). Only 7 percent of family forest owners hold forest land for timber production,

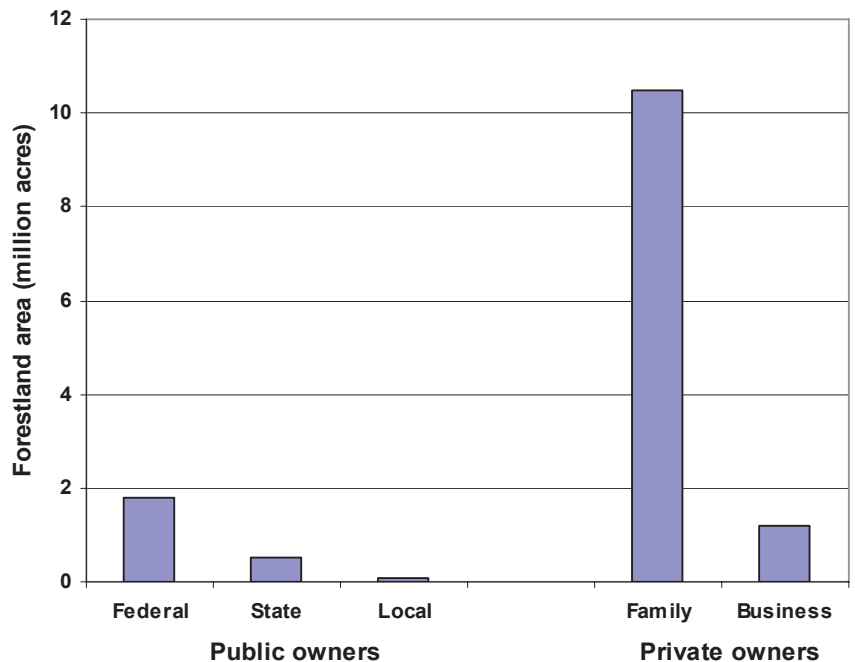


Figure 5.—Forest land area (millions of acres) in Missouri, 1999-2003, by ownership type.

Features

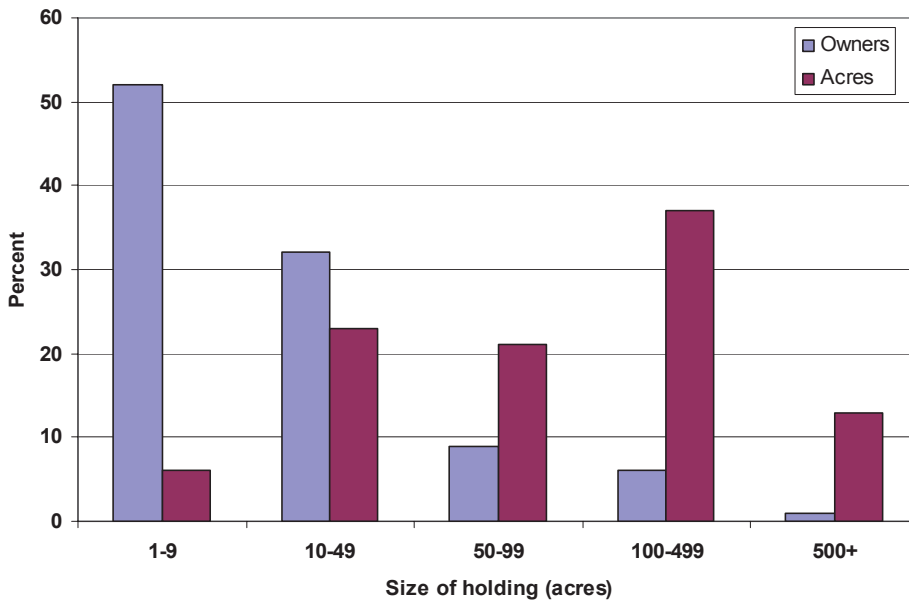


Figure 6.—Distribution of family forest owners by size of holding, Missouri, 1999-2003.

but this ownership purpose accounts for 20 percent of all family forest land. Tree removals (harvesting saw logs and cutting firewood) have occurred on 39 percent of the family forest land within the past 5 years. Only 6 percent of the family forest land is owned by people with a written management plan; however, 25 percent of the forest land is owned by those who have sought management advice. Seven percent of owners plan to harvest saw logs in the next 5 years; these owners hold 22 percent of all family forest land. Owners of family forest land have several concerns about ownership, but paramount is being able to leave land to heirs; owners holding 57 percent of the family forest land are concerned about family legacy (Fig. 8).

What This Means:

Missouri's forest land is being broken into smaller tracts and the number of owners is increasing. This fragmentation is occurring throughout the State,

but is most prevalent in the Ozark region and near metropolitan areas. This has implications for utilization, as studies have found that timber harvesters tend to have larger holdings than non-harvesters (Leatherberry 2003). Timber production and harvest is generally not a primary reason for owning forest land. Timber production is not rated high as a reason for owning land, but the relatively small number of large tract owners will likely harvest timber from their forest land in the future, particularly if they have mature merchantable timber. In the short term, healthy markets will continue to influence harvest decisions along with owners' need for income. In the long term, incentive to landowners may be needed to ensure land units remain viable timber production units. Public forests, especially the Mark Twain National Forest, are valuable assets that are heavily used by the public for recreation, and they represent the largest contiguous tracts of forests in the State.

Features

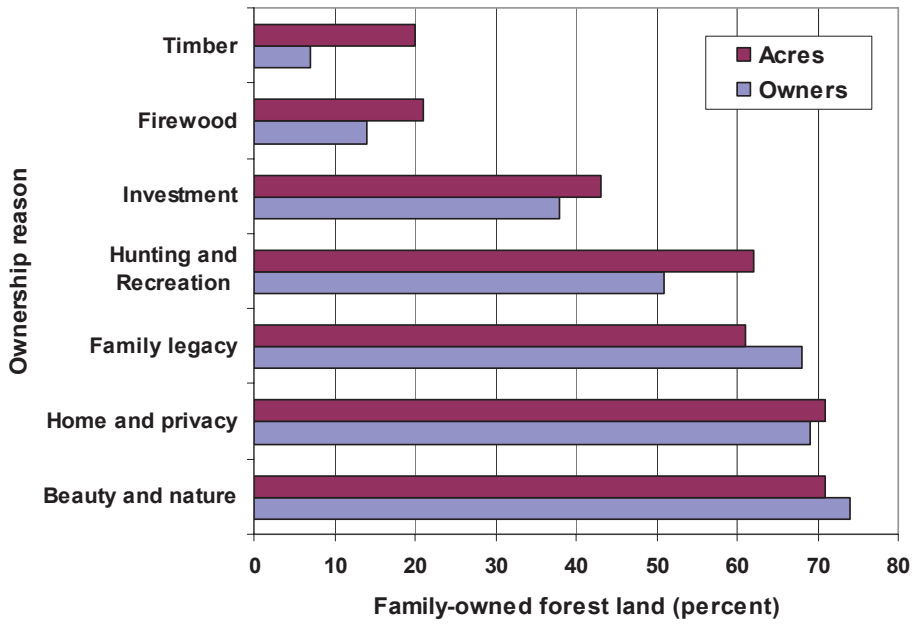


Figure 7.—Primary reason for owning forest land, Missouri, 1999-2003.

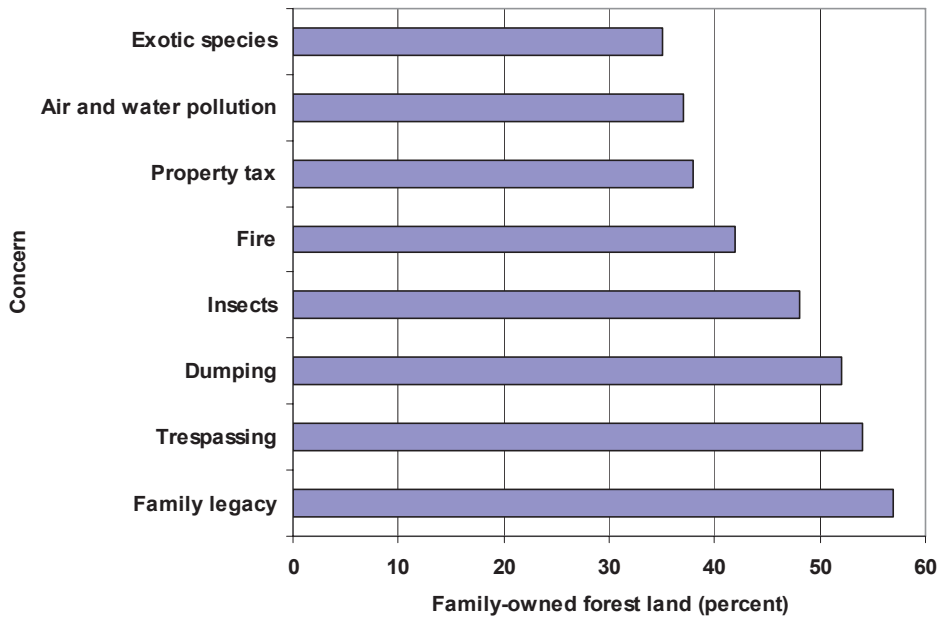


Figure 8.—Percentage of family owned forest land by landowner concerns, Missouri, 1999-2003.



DENSITY

Background:

Before European settlement, Missouri forests had a more widespread open-woodland character than the stark contrasts of agricultural land and dense forest seen today. In what is now southern Missouri, early explorers spoke of being able to ride horses easily between the trees (Beilmann and Brenner 1951). The botanist Henry Schoolcraft (1821) found widely spaced groves of trees over a carpet of prairie grasses, although even these conditions likely reflected the impact of earlier activities, such as prescribed fire, of Native Americans. During the settlement of the Ozark region in the mid-1850s and the resulting modification of the historic fire regime, the forest slowly encroached on the tall grass prairies of the Ozark Plateau.

What We Found:

Figure 9 is a snapshot of basal area distribution in Missouri in 1999-2003. During that period, we estimated there were 8.2 billion live trees in Missouri.

Almost 10 percent, or 0.8 billion trees, were in the softwood species group; the remaining 7.4 billion trees were hardwoods. If we look only at growing-stock trees, the total number drops to 1.6 billion trees. The softwood portion of growing stock increases to 12.1 percent or 0.2 billion trees, and the hardwood portion decreases to 87.9 percent. In 1972, the breakdown of the 0.8 billion growing-stock trees was 7.6 percent for softwoods and 92.4 percent for hardwoods.³

Between the 1989 and 1999-2003 inventories, the number of growing-stock trees increased across diameter classes (Fig. 10). Yet density is not a function just of the horizontal occupancy of the trees, but also of the vertical space the forest occupies. Along with the increase in the number of growing-stock trees has come the increase in the average volume per tree over the last 40 years (Fig. 11).

³In the 1972 report, growing-stock trees were calculated to 1-inch diameter, whereas in 2003, the minimum diameter was 5 inches. We adjusted the 1972 numbers to a common 5-inch minimum diameter.

Features

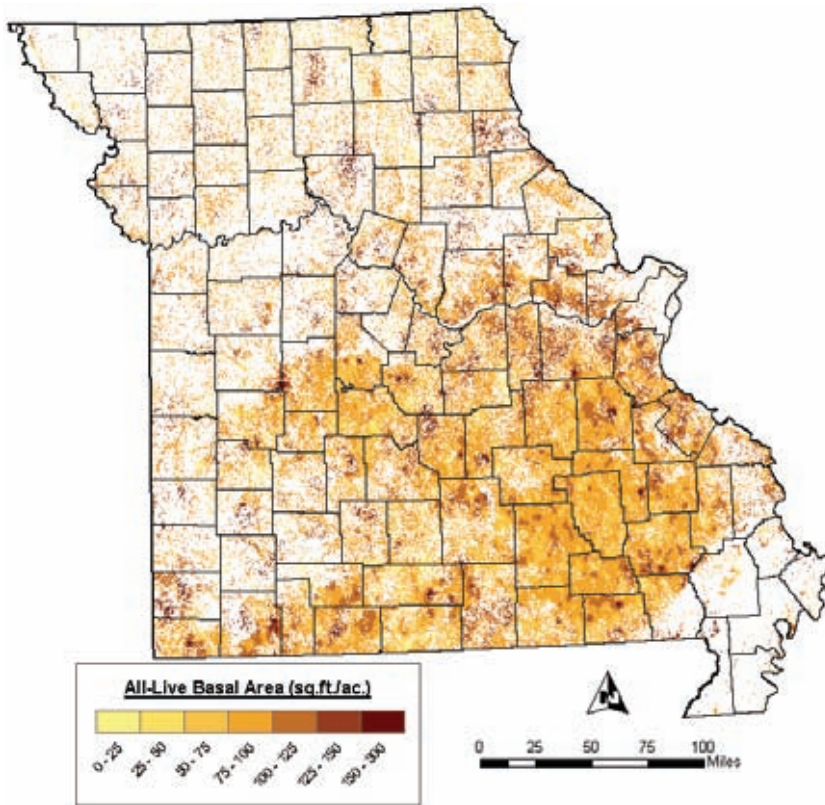


Figure 9.—Basal area of all live trees in Missouri, 1999-2003.

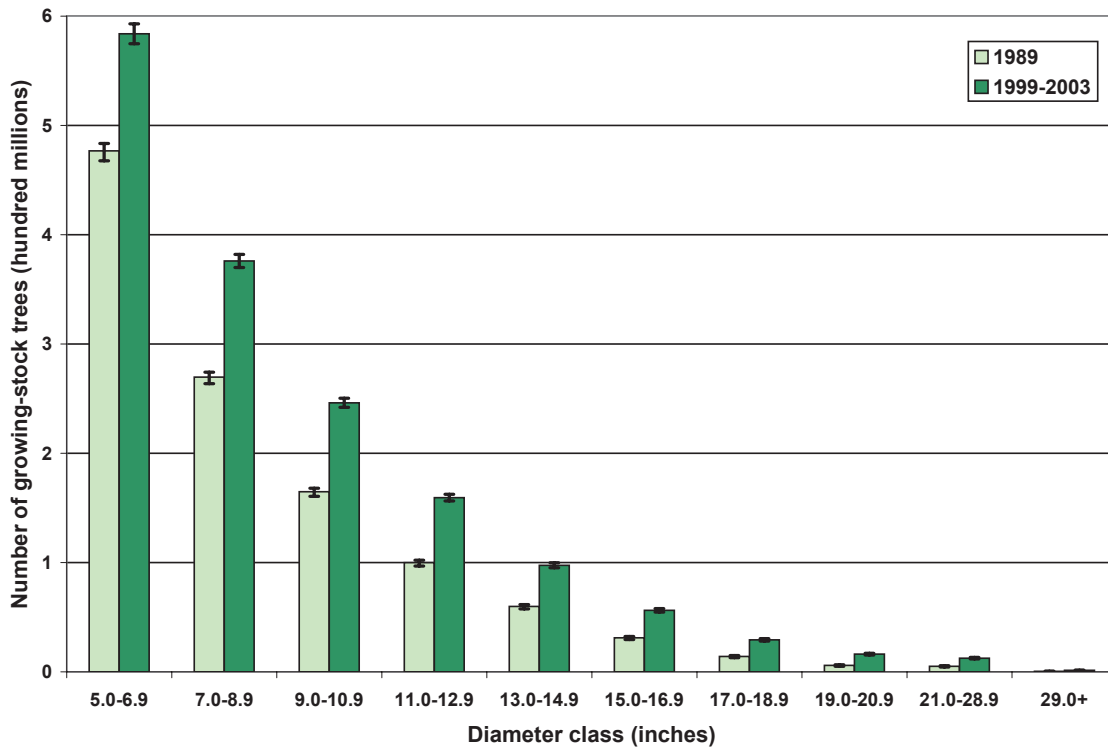


Figure 10.—Number of growing-stock trees by diameter class, Missouri, 1989 and 1999-2003.

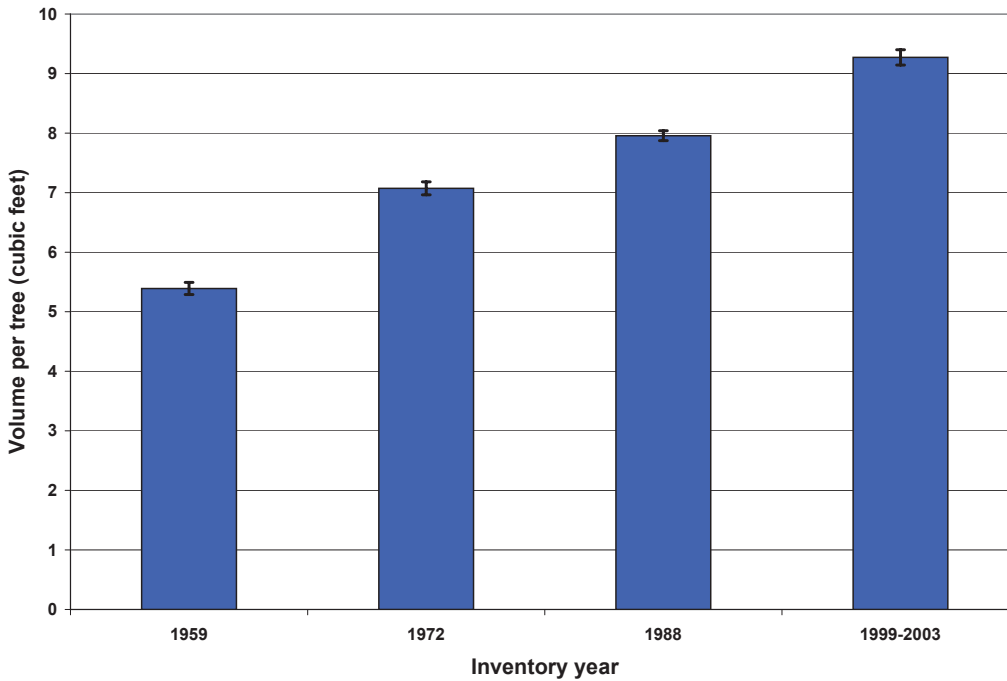


Figure 11.—Per tree volume of growing-stock trees on timberland for Missouri, 1959, 1972, 1989, and 1999-2003 inventories.

What This Means:

Basal area and number of trees are indicators of density in Missouri’s forests. While timberland acreage has increased 14 percent since 1972, the number of trees has increased at a much higher rate, suggesting a dramatic increase in per acre density. Obviously, denser forest stands compete more vigorously for resources—light, water, nutrients. How successfully trees compete for these resources will determine species composition, growth, and general forest health.

A fully stocked forest can be healthy or unhealthy depending on the condition of individual trees, which in

turn depends on the species, site, and age characteristics of the stand. Where excessive density stresses trees, individual trees may be weakened and subject to attack by insects and diseases. On the other hand, very low density stands can have trees with excessive branches, making them unsuitable for forest products. Landowners interested in economic returns from their land should strive for optimal stocking of preferred species to take best advantage of a site’s productive potential. Landowners interested in wildlife might modify the stocking and species mix to increase the potential for suitable habitat.



VOLUME

All Live Trees

Background:

The volume of all live trees on forest land is a sum of the annual growth of each tree since it germinated. Forest volume also incorporates the residual impact from past natural disturbances such as weather, fire, or insects and disease, as well as from human activities, such as harvesting or planting.

What We Found:

All-live volume has steadily increased since its low point in the 1972 inventory. In 1999-2003, all-live tree volume on forest land in Missouri was an estimated 18 billion cubic feet. Most of this volume was in the southern half of the State (Fig. 12). Softwoods made up 7 percent (1.3 billion cubic feet) and hardwoods constituted 93 percent (16.7 billion cubic feet). Net volume of all live trees and salvable dead trees on timberland was 17.6 billion cubic feet (Fig. 13). All live trees made up 17.4 billion cubic feet or 99 percent. Of the 14.6 billion cubic feet of volume in growing-stock trees⁴, 66 percent (9.7

billion cubic feet) was sawtimber volume. Cull trees, at 2.8 billion cubic feet, made up 16.1 percent of all-live tree volume on timberland. The cull tree volume in softwoods in 1999-2003 represented 7.0 percent of the total softwood live tree volume, whereas hardwood culls represented 16.8 percent of the total hardwood volume.

What This Means:

While all-live volume has steadily increased since 1972, a significant portion is still in cull trees, which are rough and rotten trees that are less desirable from a forest products standpoint. Reducing the percentage of volume in cull trees could allow more room for more high-quality trees of desirable species for more high-quality wood products.

⁴Growing-stock volume is defined as wood volume in standing trees of suitable species that are healthy, sound, reasonably straight, and greater than 5 inches in diameter at 4.5 feet above the ground. The difference between all-live volume and growing-stock volume could result from many different factors. For example, species may not be considered commercially exploitable, or individuals may be of poor form. A tree may have a defect, like rot, or its bole length might not meet minimum standards of length and soundness.

Features

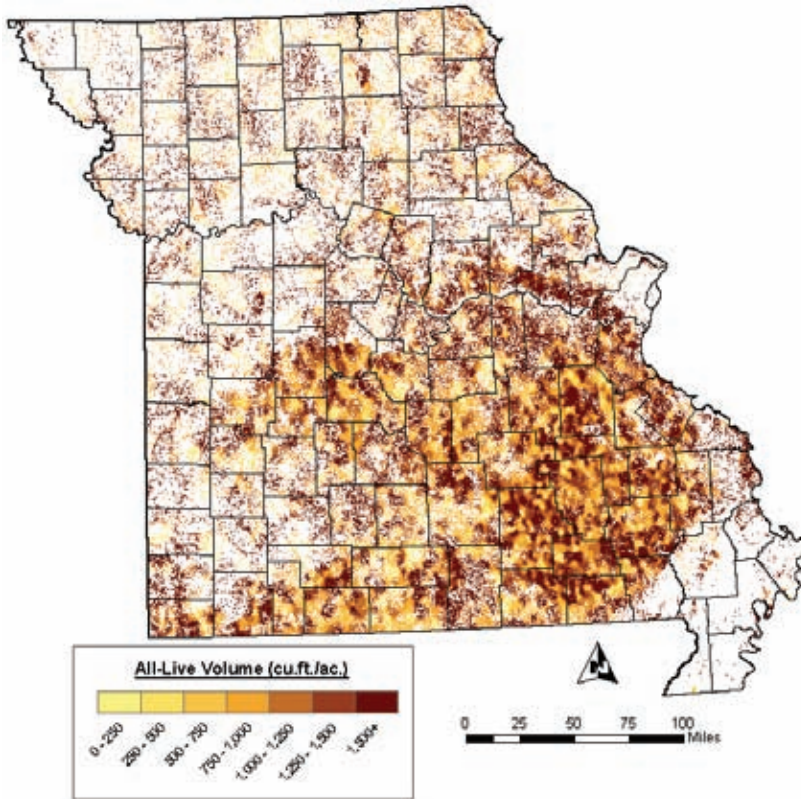


Figure 12.—Map of net volume of all live trees in Missouri, 1999-2003.

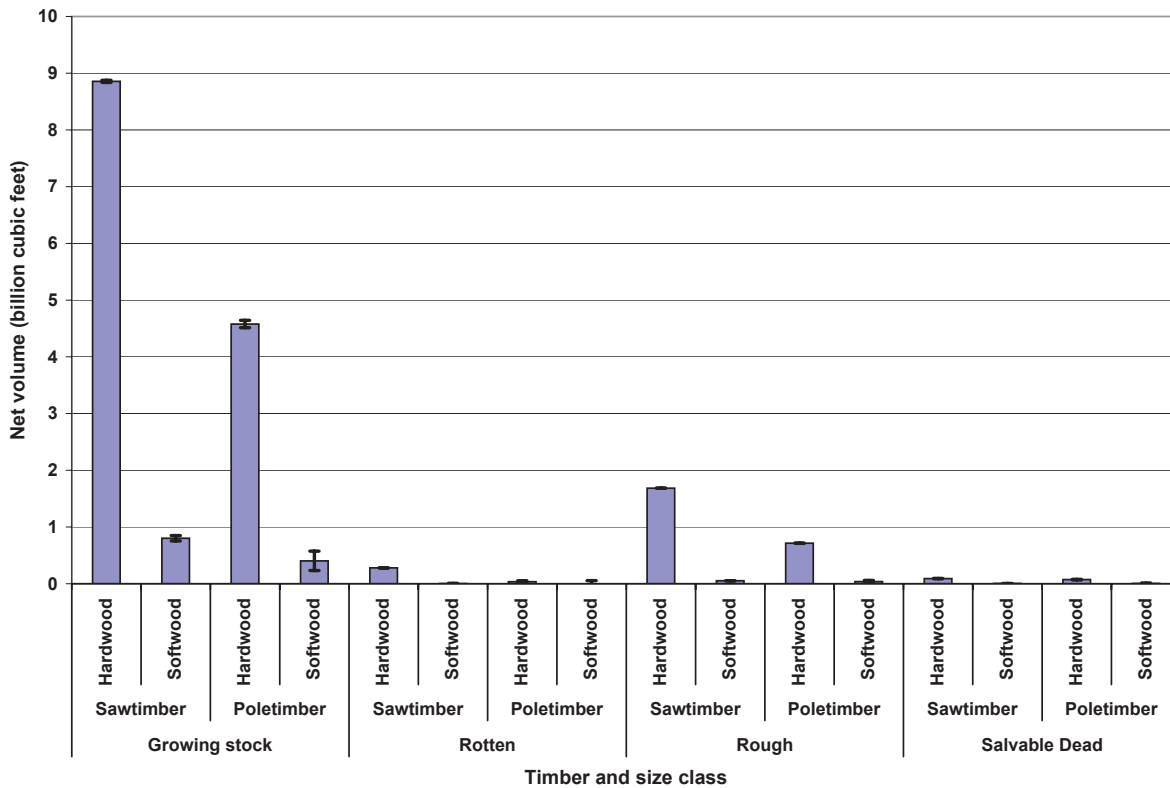


Figure 13.—Net volume of all live trees and salvable dead trees on timberland in Missouri by class of timber and softwood/hardwood category, 1999–2003.

The proportion of cull trees can be reduced in many ways. Softwood trees in general grow a single, straight stem and, barring some sort of disturbance, are not as prone to creating multiple stems as are hardwoods. Denser forests increase the shading on branches, encouraging self-pruning and somewhat limiting any tendency toward multiple stems. Human intervention, by harvesting cull trees or encouraging growing-stock trees, can influence cull proportions. However, “cull” is an economic classification, not an ecological one. Tree form and stem quality rarely affect seed production or ecological attributes. In fact, cull trees are a valuable source of wildlife habitat and aesthetic variability. Balancing these ecological and economic attributes is important when managing Missouri’s forests.

Growing Stock

Background:

Historically, we measured growing-stock volume to get an idea about the potential resource for manufacturing wood-based products. Even as we have expanded to a more ecological-based inventory, growing-stock volume tells us about the sustainable use of Missouri’s forest resources. Growing-stock volume is defined here as wood volume in standing trees that are healthy, sound, reasonably straight, and greater than 5 inches in diameter at a height of 4.5 feet above the ground.

The difference between all-live volume and growing-stock volume could result from different factors. For example, species may not be considered commercially exploitable, or individuals may be of poor form. A tree may have a defect, like rot, or its bole length might not meet minimum standards of length or soundness.

A wide disparity between all-live volume and growing-stock volume is just one of many factors we look at to determine the ecological and economic health of Missouri’s forests.

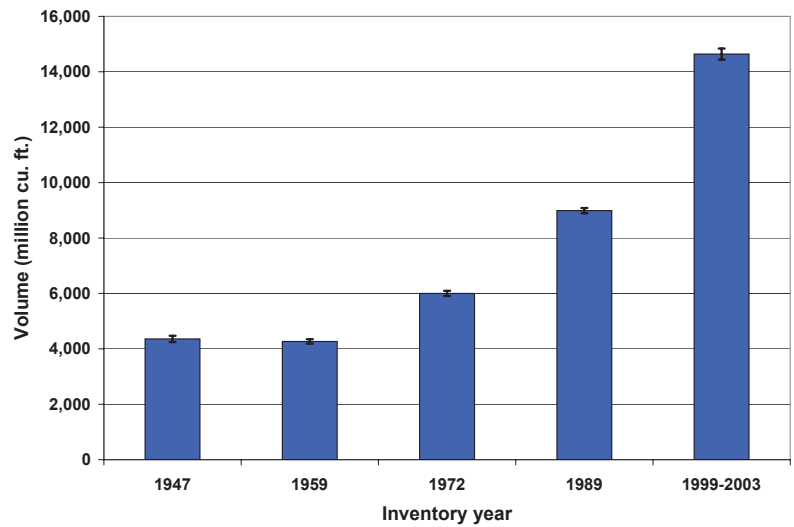


Figure 14.—Growing-stock volume on timberland in Missouri, 1947–2003.

What We Found:

More than 96 percent (14.1 billion cubic feet) of the total growing-stock volume was hardwood species and 3.4 percent (501 million cubic feet) was softwood species. Growing-stock volume has been steadily increasing in Missouri over the last 55 years (Fig. 14).

There were 9.0 billion cubic feet of growing-stock volume in 1989 and 14.6 billion cubic feet in 1999-2003 (Fig. 15). The amount of volume in overstocked stands was 143 million cubic feet in 1989 and 361 million cubic feet in 1999-2003; both represented about 2 percent of their respective total growing-stock volumes. The volume in fully stocked stands jumped dramatically between the two inventories, from 1.5 billion cubic feet in 1989 (17 percent of the total growing stock) to 7.1 billion cubic feet in 1999-2003 (49 percent of the 1999-2003 total).

What This Means:

Missouri’s forests have responded to the low density conditions present in the middle of the 20th century by an increase in total volume, aided by the actions of landowners and foresters. As many of the forest stands reach full stocking, these increases in volumes probably will slow.

Features

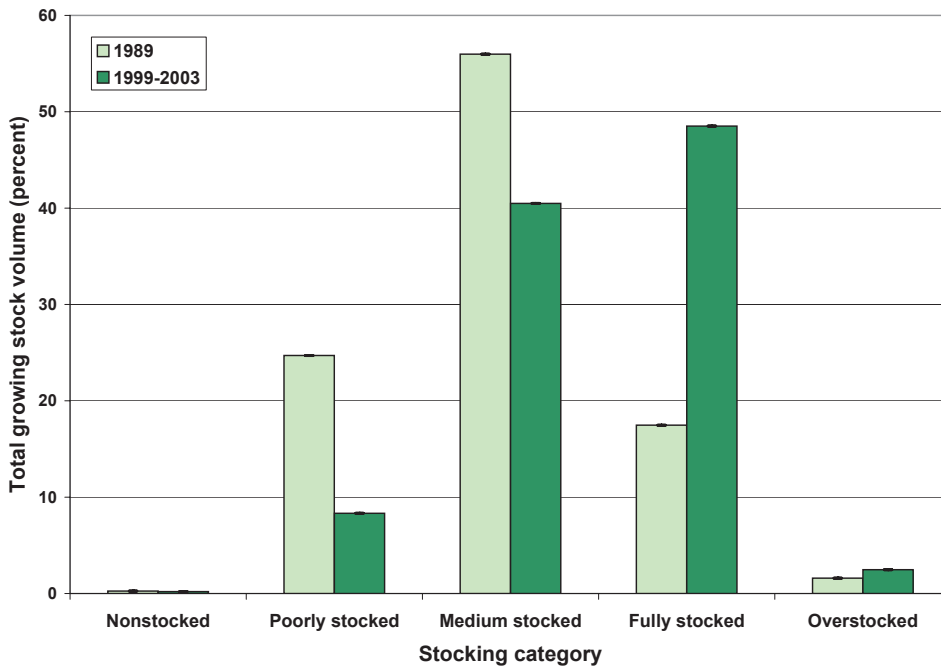


Figure 15.—Percentage of total growing-stock volume by stocking category, Missouri, 1989 and 1999-2003.

This shift in stocking levels indicates a pattern of increasing density on timberland in Missouri. These data do not suggest an alarmingly high proportion in overstocked stands but do show much volume in such stands.

BIOMASS

Background:

We define tree biomass as the total dry weight of all-live aboveground components of forest trees. These days, traditional forest products companies are moving to weight as a measure of productivity. On the horizon, we see newer industries based on biocomposites and biofuels that may utilize Missouri's forest biomass more completely. Finally, as we look beyond the traditional value of trees as a source of forest products to one that includes the value of storing carbon and protecting the environment, forest biomass estimates will assume increasing importance.

What We Found:

In 1999-2003, there were 573 million (dry) tons of all-live tree biomass on forest land in Missouri (Fig. 16). Of this total, more than 96 percent (554.3 million tons) was on timberland. Almost 9 percent of that total

(48.6 million tons) was in 1- to 5-inch trees, 74 percent (409.6 million tons) was in growing-stock trees, and 17 percent of total aboveground biomass (96.1 million tons) was in non-growing-stock trees greater than 5 inches in diameter. Private landowners held 82 percent or 456.3 million tons, and public owners held 18 percent (97.9 million dry tons).

Almost 72 percent of the total biomass of the growing-stock trees was in the stems, and the remaining 28 percent was in stumps, tops, and limbs. Similar proportions existed for the 96 million dry tons of non-growing-stock trees. Ninety-nine percent or 562 million dry tons of the total forest land biomass was on unreserved forest land (Fig. 17).

What This Means:

Biomass includes more of the woody material than forest volume. It is also a good indicator of trends in carbon sequestration, forest health, and management. The bulk of Missouri's forest biomass was in the southern part of the State and on private land. The ratio of biomass in growing-stock trees vs. biomass in 1- to 5-inch trees or non-growing-stock trees was much higher on private lands than on public lands.

Features

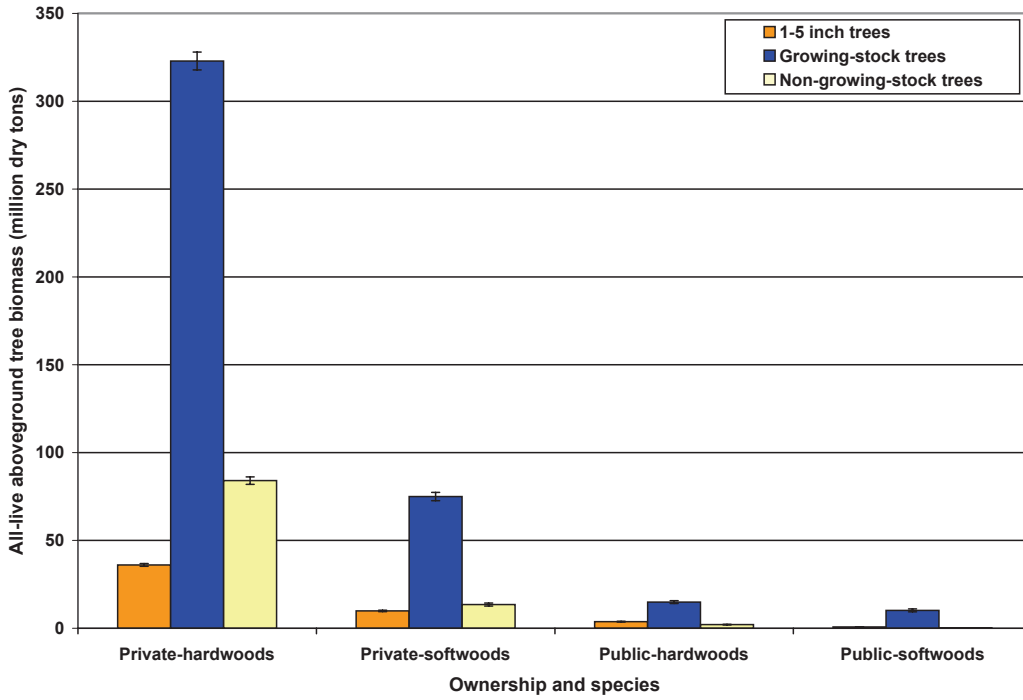


Figure 16.—All-live aboveground biomass on forest land in Missouri by ownership type and forest type, 1999-2003.

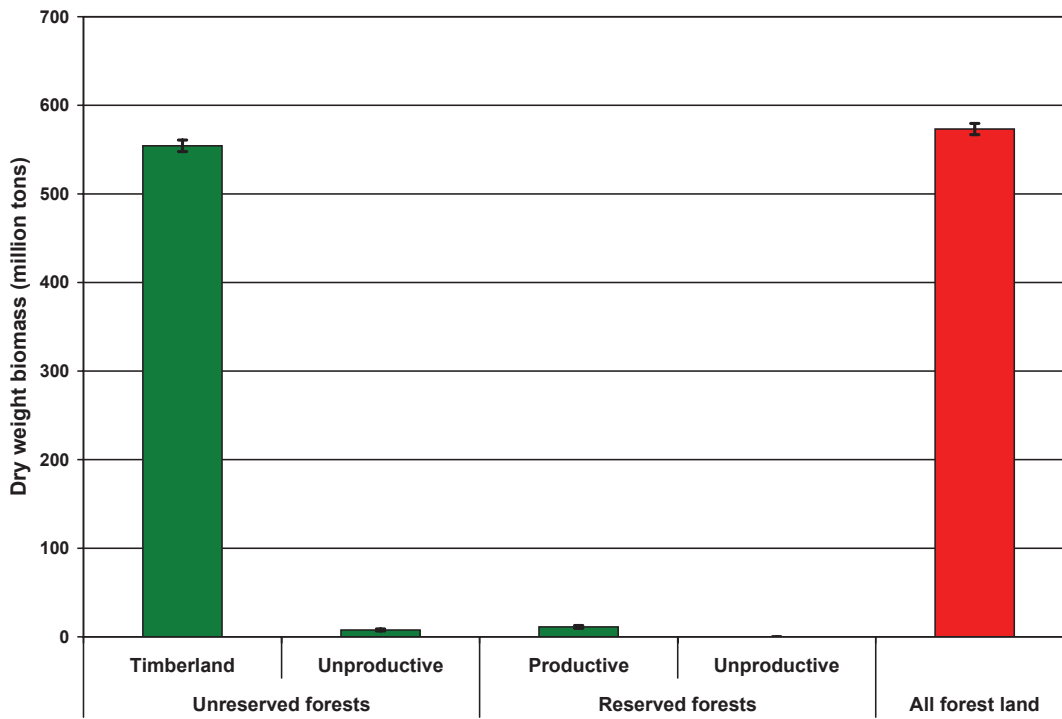


Figure 17.—Aboveground dry weight biomass of all live trees by forest land status and productivity, Missouri, 1999-2003.



GROWTH

Forest growth contributes to Missouri's ecological and economic health by increasing the forest biomass. Not only are forest structures maintained, but forest growth helps ease the loss of woody biomass due to old age and forest health problems, harvesting, and weather damage. We look at growth in terms of what the forest land can produce and what it has produced. Whether the growth rate is "good" or "bad" really depends upon the landowner's objectives. Certainly, growth is one measure of the health of a forested landscape.

All-Live Growth

Background:

All-live growth is a good measure of the productive capacity of Missouri's timberlands because it takes into account site quality, species composition, management history, and climate. We calculate growth as a net of the total growth of all live trees less mortality. We then divide by the number of years between inventories to come up with a net growth per year value. In this report, the

average annual net growth is based on the growth rate between 1989 and 1999-2003.

What We Found:

Missouri is a patchwork of low- and high-growth areas (Fig. 18). Even within the heart of the forested region in the southern part of the State, there are interspersed areas of variable growth.

What This Means:

Growth rates may differ for many reasons. In some cases, the sites vary in productivity. In other cases, growing space was released due to mortality or harvest, thus allowing other, sometimes younger, trees to use more resources. Regional differences in growth based on large-scale site productivity or climate differences are often obscured by site-specific variations in geology, weather, species mixture, and disturbance history. In Missouri, there was considerable mortality in the late 1980s (Lawrence et al. 2002, Spencer et al. 1992). Some of this mortality freed up growing space that, in turn, was taken by the remaining trees.

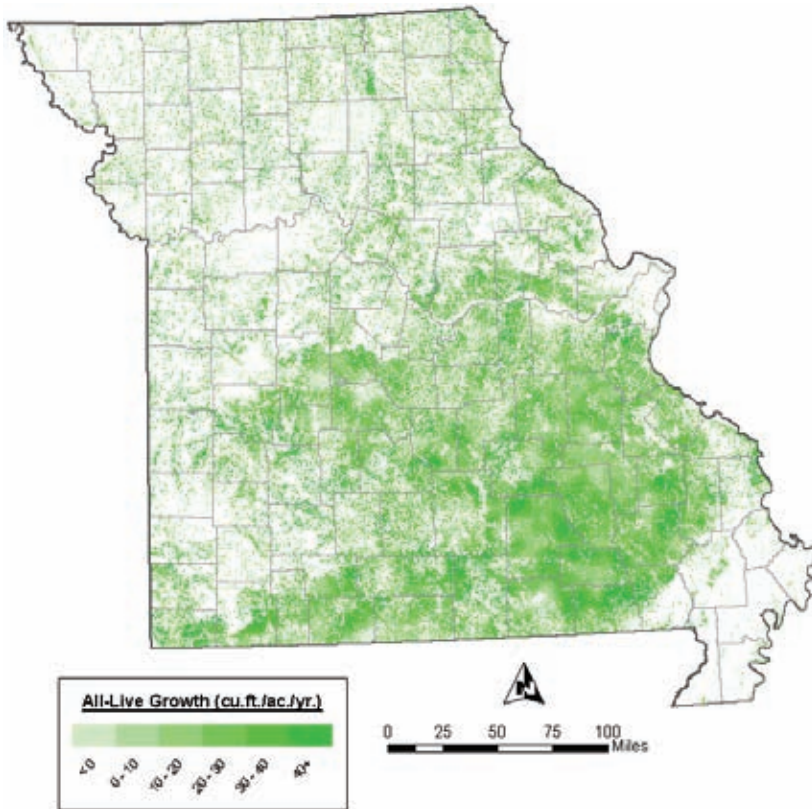


Figure 18.—All-live tree growth in Missouri, 1989 to 1999-2003. Light colors represent low growth; dark colors represent high growth.

Growing-Stock Growth

Background:

The growth of growing-stock volume provides an indicator of both forest health and the future availability of usable wood volume. We calculate growth as a net of the total growing-stock growth less mortality. We then divide by the number of years in the inventory period to come up with a net growth per year value. In this report, the average annual net growth is based on the growth rate between 1989 and 1999-2003.

What We Found:

The net growth of growing stock on Missouri’s timberland was 629.4 million cubic feet per year from 1989 to 1999-2003. Softwood growth was 44.1 million cubic feet per year; hardwood growth was 585.3 million cubic feet per year. Hardwood growth as a proportion of total growth was similar to the proportion of hardwood growing stock vs. total growing stock in the previous inventory. Hardwood growth was 93 percent of total growth; hardwood growing stock in 1989 was 90.4 percent of total growing stock. The largest net growing-

stock growth was in the other red oak species group, followed by select white oaks. Together the select oaks (white and red) had a net average increase of 175.4 million cubic feet per year. Some of the other species groups with high growth included other soft hardwoods (a net increase of 50.5 million cubic feet per year) and hickory (53.7 million cubic feet per year) (Fig. 19). The counties with the highest ratio of net growth of growing stock on timberland and total land area were generally located in the southeastern quarter of the State (Fig. 20).

What This Means:

Oak species make up a large proportion of the total volume, so it is not surprising that the oak categories show a high amount of growth. However, hickories and soft hardwoods also had high rates of growth. If the growth of non-oak species continues at this rate, any faltering of oak growth could result in a dramatic change in future species composition of Missouri’s forests. Later in this report, we will detail the regional and size-specific growth patterns of hickories and maples, two important competitors to oaks.

Features

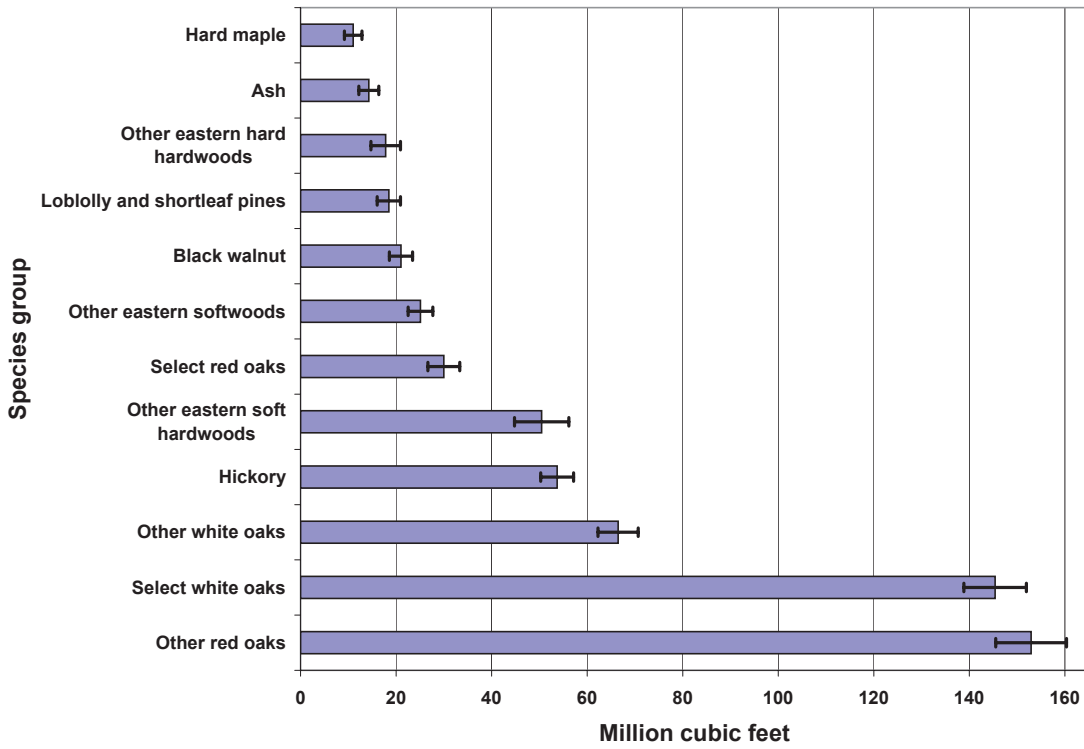


Figure 19.—Average annual net growth of growing-stock trees on timberland: top 12 species groups, Missouri, 1989 to 1999-2003.

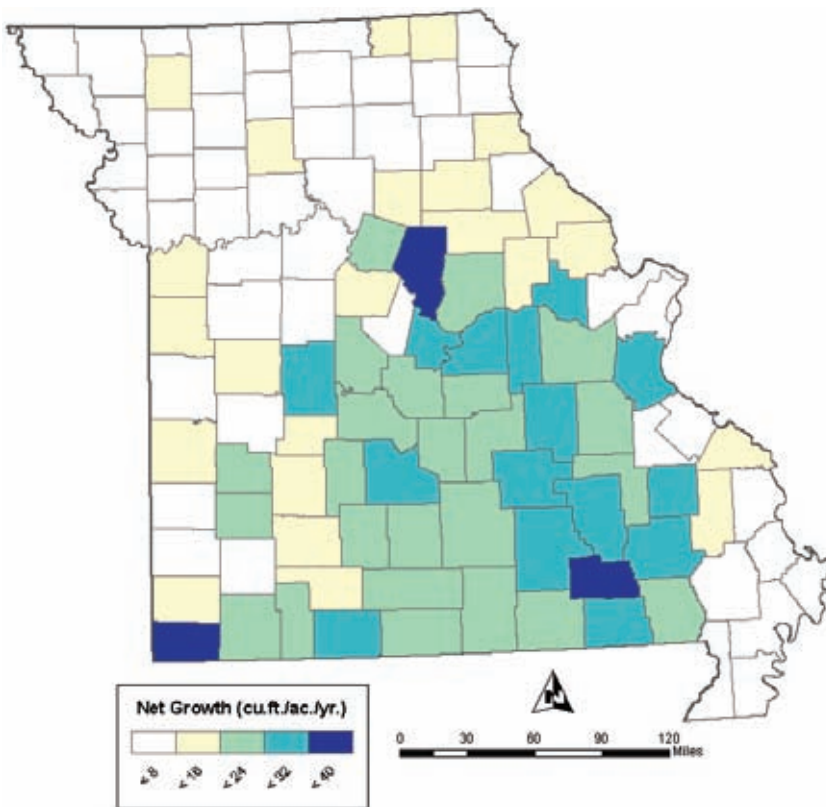


Figure 20.—Ratio of net growth of growing-stock per acre on timberland (cu. ft.) and the total area of land in each county (acres), 1989 to 1999-2003.

OAKS AND OTHER SPECIES ON THE MISSOURI LANDSCAPE

THE IMPORTANCE OF OAK

Oak trees are the centerpiece of Missouri’s forested resource, both ecologically and economically. Red and white oaks are the dominant resource for Missouri’s forest products industry. Although the majestic pine resource was once the principal source of Missouri’s forest wealth, oaks have been the most critical component of the State’s forests for so long that fluctuations in inventory can dramatically affect Missouri’s rural economy. Accelerated mortality could have disastrous consequences on the landscape. Given that so much rides on the health and continuity of the oak resource, we believe this genus merits our special attention.

Area

What We Found:

Oak/hickory forest types made up about three-fourths of the total hardwood forest land area in the 1999-2003 inventory (Fig. 21). The oak component has increased: the oak/pine, oak/hickory, and white oak forest type groups sampled in 1947 constituted 77.6 percent of the total timberland area, and the 1999-2003 oak/pine and oak/hickory groups made up 86.0 percent. In the 19th century, there were about 6 million acres of shortleaf pine in the State. Heavy harvesting between the 1880s and 1920s, subsequent management, and uncontrolled fires have resulted in about 1.5 million acres remaining, with the rest succeeding to a hardwood-dominated condition.

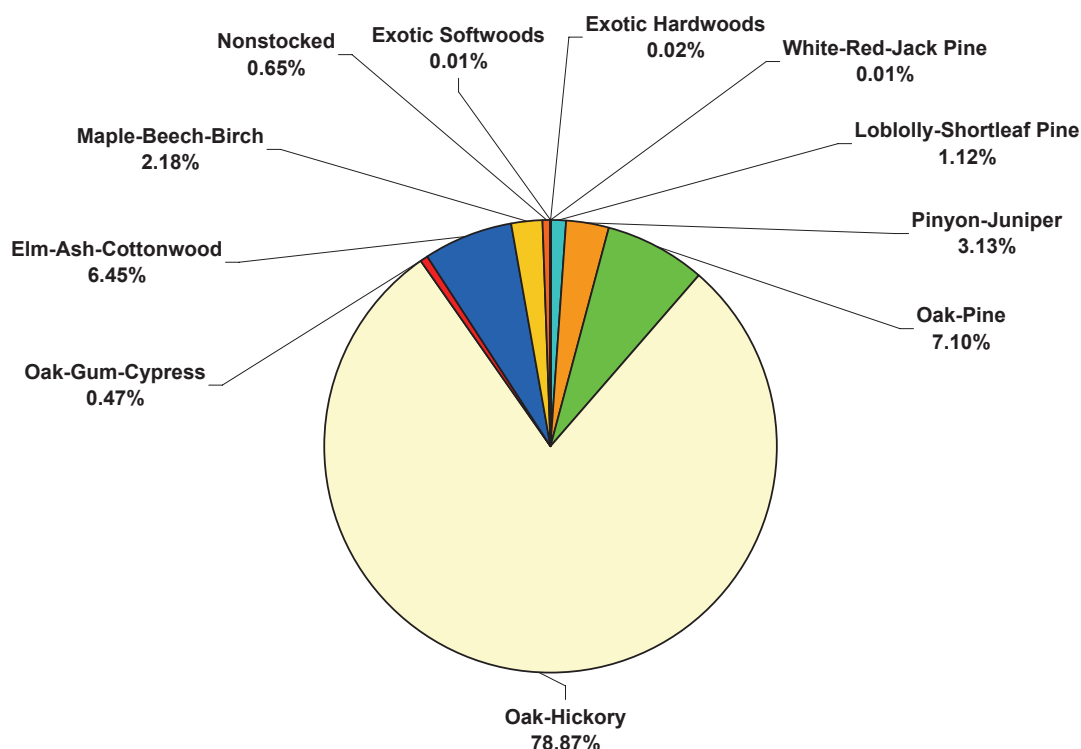


Figure 21.—Percentage of forest land area in Missouri by forest type group, 1999-2003.

What This Means:

Like all forests, Missouri's forests respond to disturbance. While the most prominent disturbances have been harvesting and land clearing, factors such as fire, ice storms, insects and diseases, and tornadoes have also shaped the forest structure and species mix we see today. Oaks were an important component of the forest even before the massive harvesting of pines in the late 19th and early 20th centuries. More than three-fourths of Missouri's forests were occupied by oak species in 1999-2003. With the reduction of the pine overstory, oaks have increased the proportion of their presence on the landscape. Recently, however, we have seen evidence that oaks may not occupy such a predominant position in the forests of the future.

Several cover type groups had less than 1 percent area in Missouri: exotic softwoods, exotic hardwoods, white/red/jack pine, and oak/gum/cypress.

Volume

Forest land volume can be thought of as an ecological "memory" of previous natural disturbances and human actions that we can use to assess the health of the landscape. Looking at total volume is helpful, but not all species are represented equally in Missouri's forests. We have seen the distribution of forest land area by forest type, but even then some individual species are in more than one type. For example, red maples might be in oak forest types as well as in maple/beech/birch forest types and elm/ash/cottonwood forest types. Therefore, we want to look at the species groups themselves to get a sense of their vigor and growth potential.

What We Found:

Just like in forest area, oaks dominate Missouri's landscape in terms of volume. In the 1999-2003 inventory, the net volume of all oaks was 69 percent of all hardwoods (11.1 billion cubic feet) while hardwood all-live volume was 92 percent of total all-live volume on timberland. The net volume of select oaks (red and white) made up 47 percent of all oak volume and 31.4 percent of all hardwood volume.



In 1999-2003, oak forests appeared to be denser than forests of non-oak species (Fig. 22). Sixty-nine percent of all-live volume of oak species was in the overstocked or fully stocked categories, while 63 percent of non-oaks were in these categories. In the absence of natural thinning disturbance or density management, at least a portion of these stands in the fully stocked category will move into the overstocked category.

What This Means:

The all-live volume species mix is dominated by oaks. The high volumes of oak species groups in the overstocked category seem to coincide with the higher incidence of oak mortality in Missouri in recent times (Lawrence et al. 2002). One thing to remember is that some conditions, such as drought, can change the amount of available growing space and push stands temporarily

Oaks and Other Species

into the overstocked category, increasing the probability of forest health problems and death.

Figure 23 displays the prominence of oaks in Missouri's forests. All-live volume of select red and white oaks was 47 percent of total oak volume. Oak volume was 69 percent of total hardwood volume, while hardwood all-live volume was 92 percent of total all-live volume on timberland.

Total net all-live volume of oaks on timberland increased by 24 percent between 1989 and 2003 in all inventory units. The increase in volume appears to be from existing trees putting on volume, rather than from new trees

growing into measurable size; the number of trees 5 inches and larger increased by only 2 percent, while the number of trees 1 inch and larger decreased by 15 percent between 1989 and 2003 (Fig. 24).

Figure 25 shows the distribution of timberland acreage by oak basal area classes where the total basal area is greater than 30 square feet per acre and the stand age is older than 30 years. The number of acres with high basal areas increased between the 1989 inventory and the 1999-2003 inventory. Although the total acreage did not substantially increase, the higher basal area classes accounted for an increasing proportion of the overall distribution.

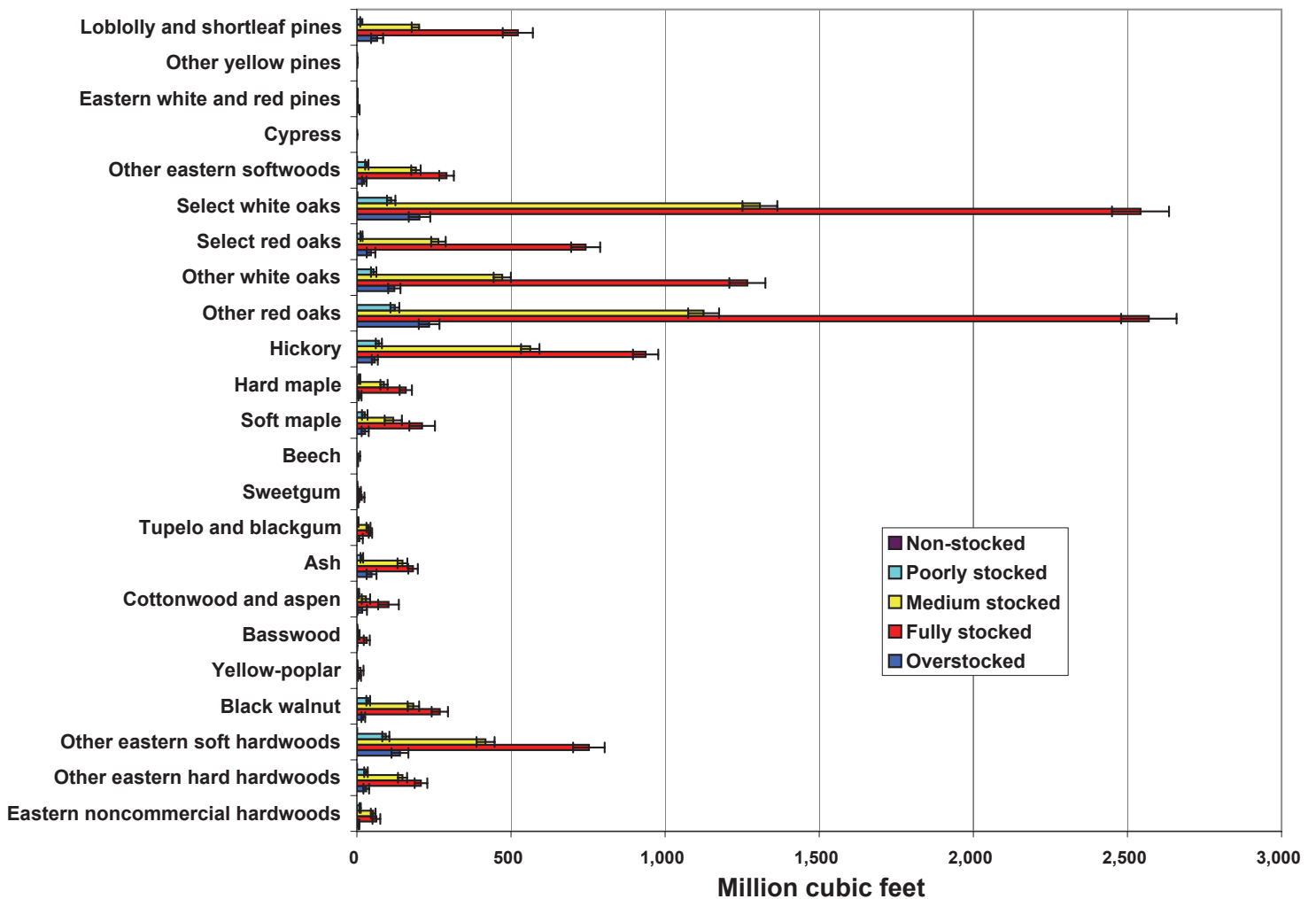


Figure 22.—All-live volume on forest land, in Missouri 1999-2003, by species group and all live stocking categories.

Oaks and Other Species

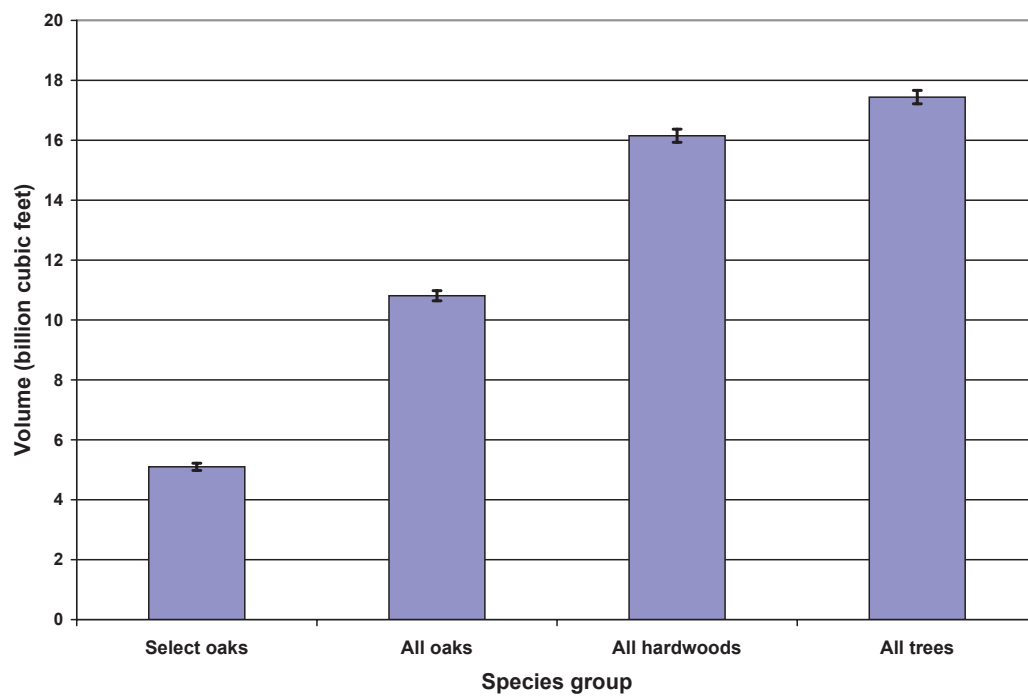


Figure 23.—All-live volume of selected hardwood species groups on timberland, Missouri, 1999-2003.

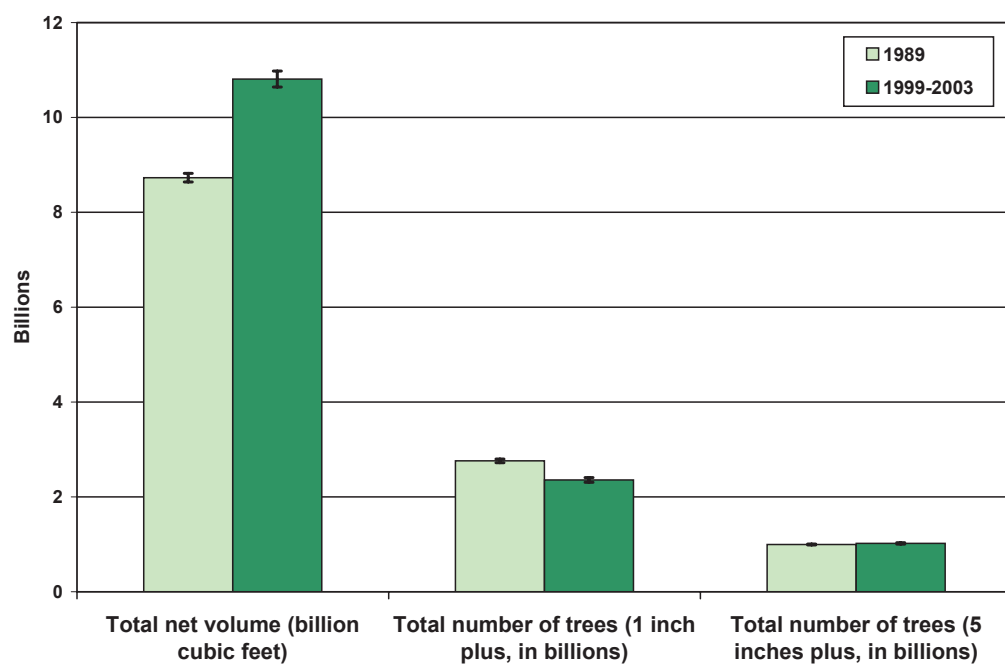


Figure 24.—Total net all-live volume and total number of trees 1 inch and larger and 5 inches and larger of all oak species on timberland in Missouri, by inventory year (1989 and 1999-2003).

Oaks and Other Species

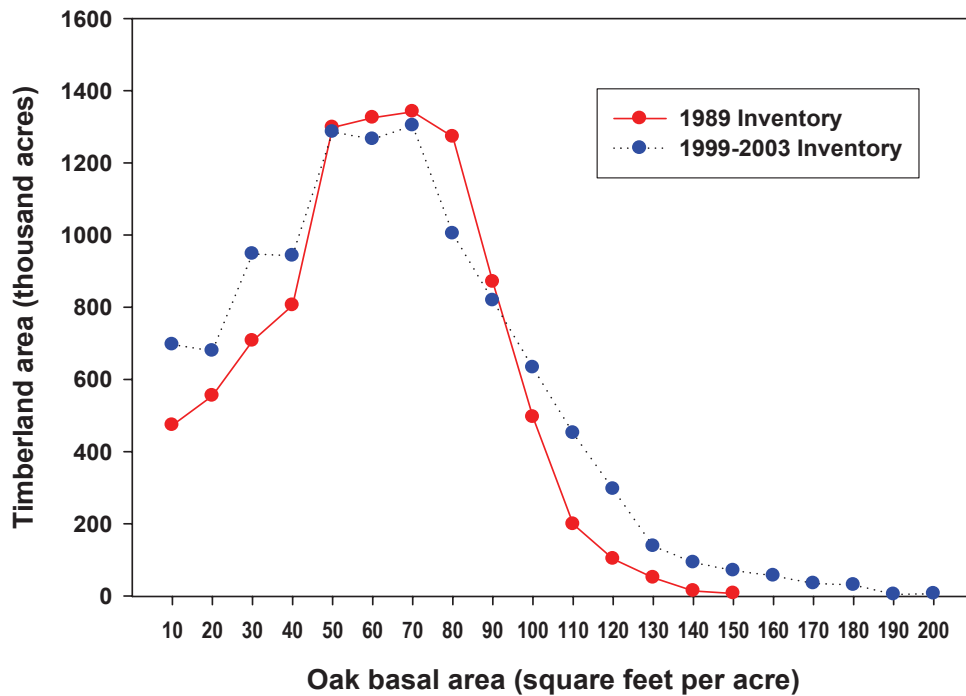


Figure 25.—Basal area of oaks on timberland where the total basal area is greater than 30 ft² ac⁻¹ and the stand age is older than 30 years.

The all-live volume and stocking data highlight the impact that high density has upon oak regeneration in Missouri's forests. The decline in the number of 1-inch-plus oak trees suggests that future forests will not have as predominant an oak component as today's forests. Studies have found that while oak regeneration in the Eastern United States has increased over the last 20 years, the proportion of total oak regeneration has declined (Moser et al., in press). Similar trends are being observed in Missouri, particularly in the eastern and northern parts of the State. These data suggest that as oaks in the overstory die, they may be replaced by other tree species.

Johnson et al. (2002) detailed the importance of accumulating oak regeneration in the understory and outlined the disturbances that encourage this accumulation. Two of the most common disturbances—harvesting and fire—promote two processes: (1) early growth becomes concentrated on the oak seedling root system as the aboveground growth gets killed off, and (2) less fire-resistant species are eliminated, so oaks have less competition for resources. Both types of disturbances have been declining in the eastern oak forests in general and in Missouri forests in particular. Missouri forest land owners must consider the role of disturbance if they wish to maintain and improve their oak resource.



MISSOURI'S OAK FORESTS ARE GETTING OLDER

The age of a forest can determine its growth, suitability for a particular species of wildlife, or potential for economic use. Forest age can help us figure out whether a past disturbance was caused by weather, insects, disease, or humans. It can also help us predict the forest's susceptibility and response to disturbance.

What We Found:

The mean age of Missouri's forests is slowly increasing, but we found no significant difference in mean age between the 1989 and 1999-2003 inventories. The latter inventory (1999-2003) was the first in which the mean ages of forest land in the three Ozark inventory units (Eastern Ozarks, Southwest Ozarks, and Northwest Ozarks) were all older than 50 years, although the increases were not statistically significant. Total volume increased by around 21 percent (Fig. 26). Non-oak volume increased by 15 percent, yet oak volume in stands

less than 60 years old increased by only 1 percent and oak volume in stands greater than 60 years old increased in volume by 35 percent. Oak forests 60 years and older are generally concentrated in the Eastern Ozarks, Northwest Ozarks, and Riverborder inventory units (Fig. 27).

What This Means:

Missouri's forests are getting older, but not uniformly across all species and forest types. The relationship between age and tree vigor, for example, depends upon the particular species, among other factors. What might be "old" for one species may be relatively "young" for another. Missouri's older oak forests seem to be concentrated in a few areas. These older forests complement the benefits for wildlife habitat that younger forests provide. The presence of a balanced, dispersed mix of tree ages should benefit all of Missouri's inhabitants. However, high concentrations of dense, older oak forests can also increase susceptibility to forest health problems (Lawrence et al. 2002).

Oaks and Other Species

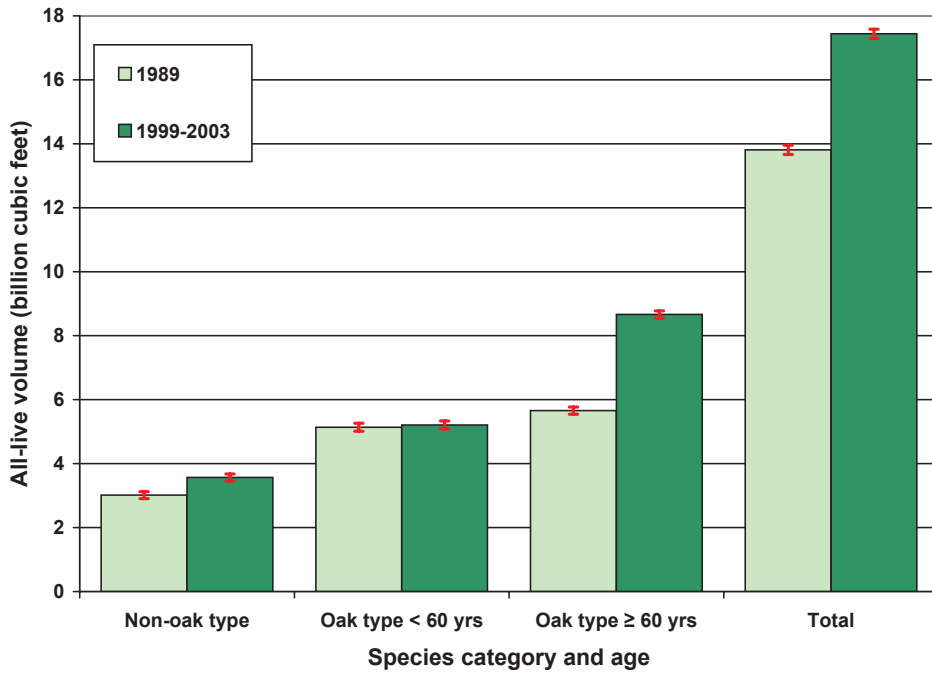


Figure 26.—All-live volume of oaks and non-oaks on timberland in Missouri by forest type, age category (for oak types), and inventory year.

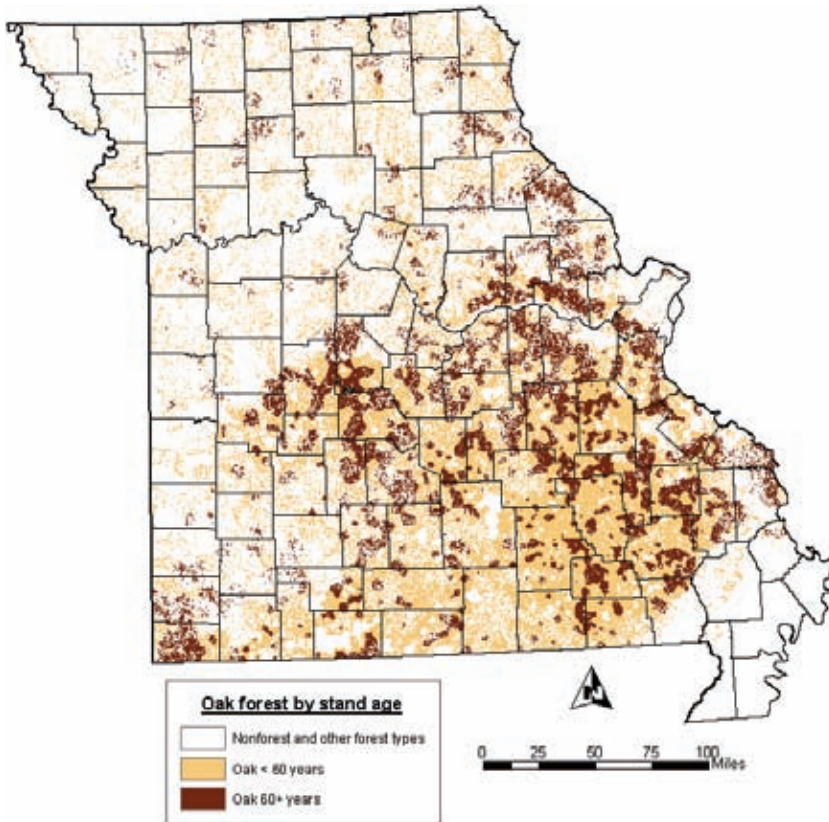


Figure 27.—Distribution of oaks younger than 60 years and 60 years and older and non-oak types on timberland in Missouri, 1999-2003.

Oaks and Other Species

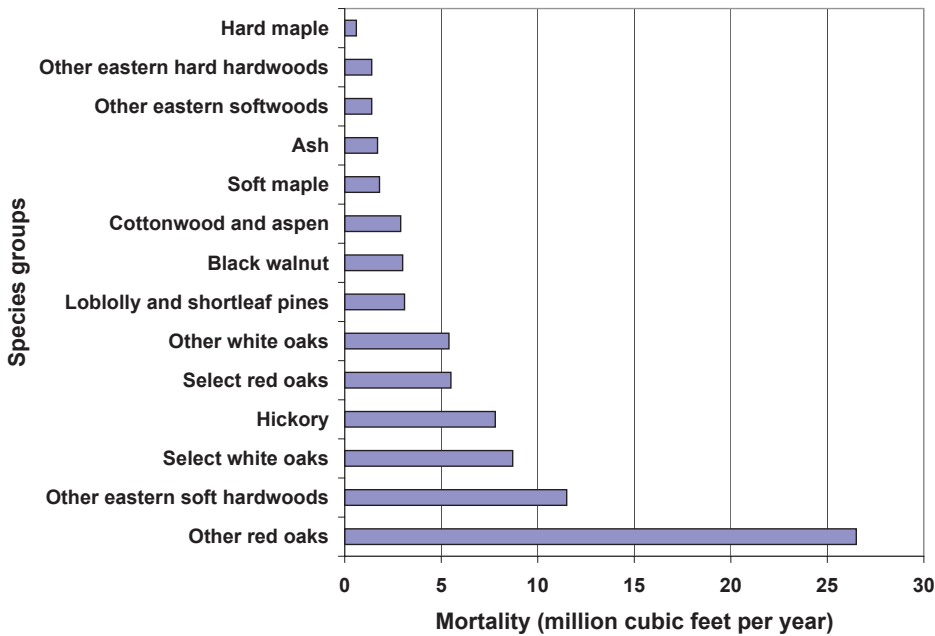


Figure 28.—Average annual net mortality of growing-stock trees on timberland: top 14 species groups, Missouri, 1989 to 1999-2003.

MORTALITY

Benjamin Franklin once said that “Nothing in life is certain except death and taxes.” Missouri trees do not have to worry about the latter, but mortality is a fact of a tree’s life. Mortality is a natural process in any living ecosystem and, while some people hate to see a dead tree, this forest “corpse” provides a valuable ecosystem function as wildlife habitat, substrate for young plants, or source of nutrients for the forest floor. Dramatic increases in mortality, however, sometimes indicate a fundamental problem due to age, climate, or insect or disease attack. Here we look at trends in mortality to get a sense of the overall health of the State’s forests.

What We Found:

Average annual mortality of all growing stock on timberland, 1989 through 1999-2003, was 81.8 million cubic feet per year. Almost 77.2 million cubic feet per year (94 percent of the total mortality) was from hardwoods, while the remaining 4.7 million cubic feet per year was from softwoods. Annual mortality of 15.9 million cubic feet per year (19.5 percent) occurred on public lands. For hardwoods alone, 13.8 million cubic feet per year of average annual mortality (17.8 percent) was on public lands; for softwoods, that figure was 2.2 million cubic feet per year (46.7 percent).

The species group with the highest average annual mortality was the other red oaks category, with 26.5 million cubic feet per year (34.3 percent) of all hardwood mortality (Fig. 28). This species group also had the highest average annual mortality on public lands, 5.7 million cubic feet per year or 21.5 percent of total mortality occurring on public lands. Other species groups with high mortality included other eastern soft hardwoods and select white oaks. Higher levels of mortality per acre of total land area were concentrated in eastern counties (Fig. 29).

What This Means:

The high levels of mortality volume in other red oaks probably reflect oak decline in certain regions (Lawrence et al. 2002), as well as the extensive presence of this species group in Missouri. The mortality of individual species, such as scarlet and black oaks, was high in certain areas, but mortality in other species in the other red oak group was lower. Given the gradually increasing age and density of Missouri’s forests, it would not be surprising to see locality-specific spikes in mortality in response to climate factors, like drought, and associated forest health problems.

Oaks and Other Species

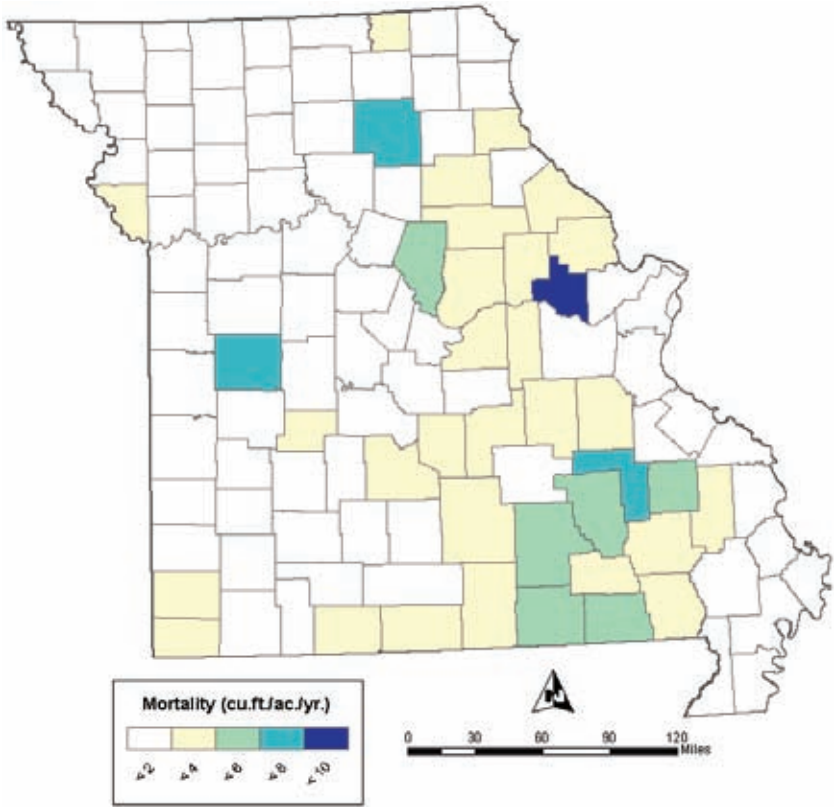


Figure 29.—Ratio of growing-stock mortality per acre on timberland (cubic feet divided by the total area of land in each county, in acres) 1989 to 1999-2003.

DIVERSITY

A forest composed of various tree species, tree sizes, and ages can provide a variety of habitats for wildlife and a range of recreation and aesthetic experiences. A diverse forest, while not completely free of forest health problems, is less likely to be devastated by an insect or disease that attacks a single species or a narrow group of species. Diverse forests may be more resilient in the face of severe weather disturbances or climate variations.

The Shannon Diversity Index measures a combination of the number of species and the evenness or distribution of those species (Magurran 2003). A forest with 10 species in which 90 percent of the area is occupied by one species will have a lower Shannon Index than a forest with 10 species in which each of the species occupies a roughly equal proportion of the forest area.

What We Found:

In figure 30, we can see pockets of high and low tree species diversity in Missouri forests⁵. Over time, the Shannon Index has held steady in some units and decreased in others (Fig. 31). In 2003, the Eastern Ozarks unit had the highest average Shannon value and the Prairie unit had the lowest. Although the number of individual species may not be declining, perhaps a higher proportion of the total basal area is represented by fewer species.

What This Means:

Climatic and site productivity factors and other natural disturbances, such as storms, can influence the number of species on a particular site. Diversity is most often influenced, however, by the competitive abilities of each tree, the collective associations of tree species (“who is next to whom”), and human attempts to direct a forest toward a particular structure or species mix. Forests with greater species, age, or structural diversity are more resilient in the face of a forest health problem that targets



a single species or age category. We have seen that Missouri’s forests are getting older; the increasing time since the last disturbance is one factor contributing to the decreased importance of early-successional pioneer species.

RECENT TRENDS IN OAK DECLINE

Background:

Oak/hickory forests constitute the vast majority of hardwood forest land acreage in the Eastern United States (Powell 1993) and in the Central Hardwood forest region. As mentioned earlier, oak/hickory forests made up almost three-fourths of the total Missouri forest land area in 1999-2003. Forest health problems that affect oak growth and survival could have a significant effect on Missouri’s forest ecosystem and economy.

⁵Actual diversity at a particular point on the map is an estimate based on the weighted average of the nearest FIA plots to the point and may not represent the true diversity at that point.

Oaks and Other Species

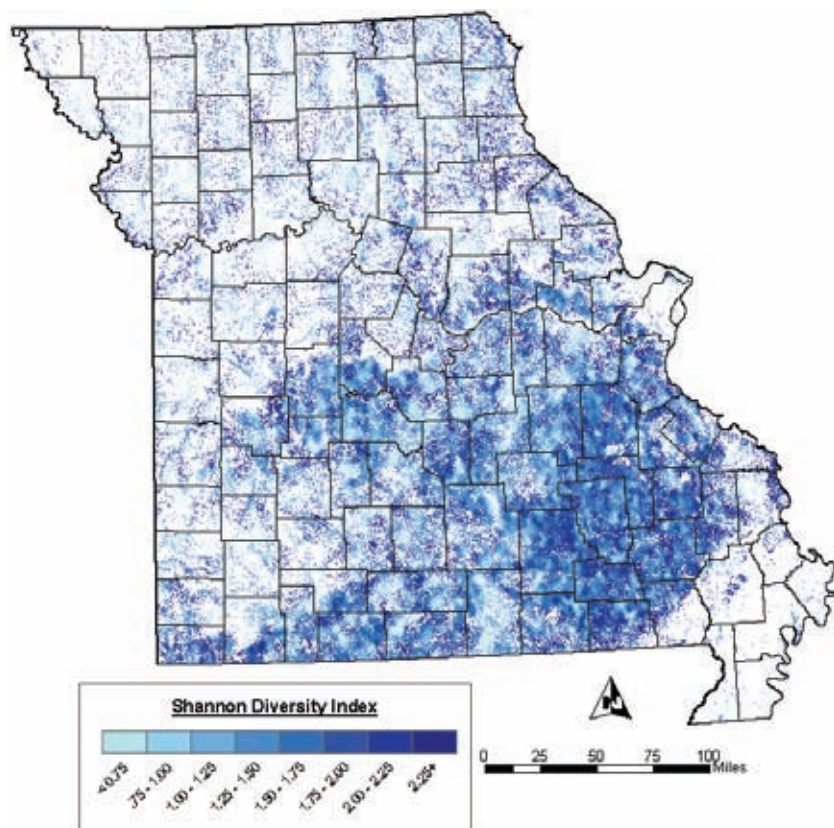


Figure 30.—Map of estimated tree species diversity (Shannon Diversity Index) of all live trees on timberland, Missouri, 1999-2003.

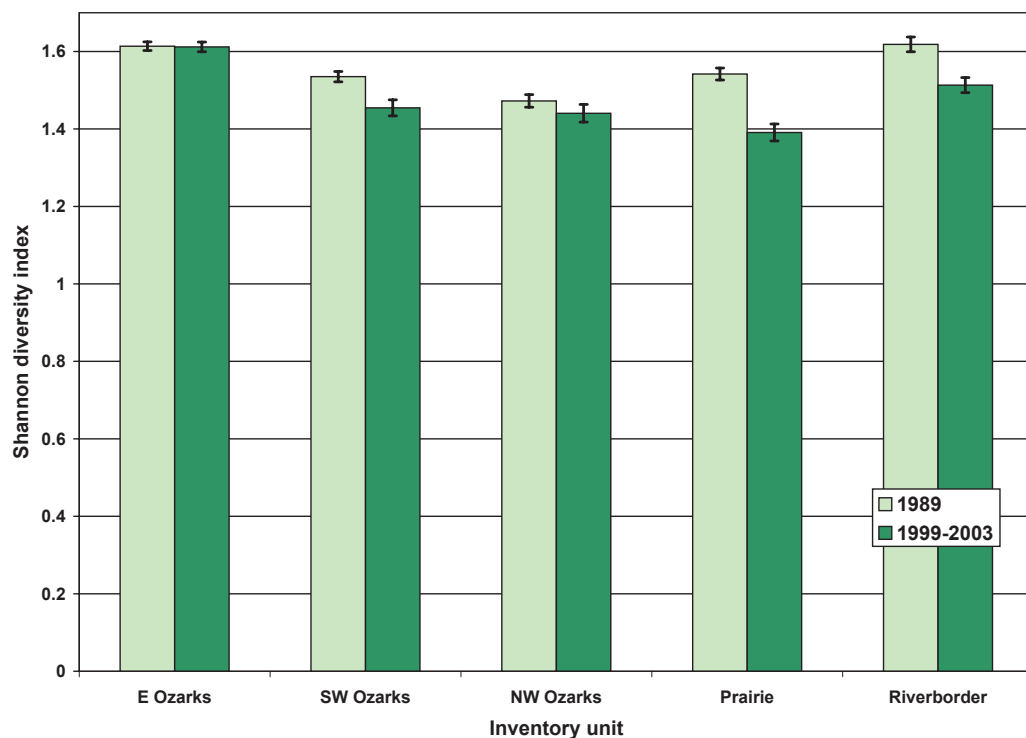


Figure 31.—Calculated Shannon Diversity Index for all live trees on timberland, Missouri, 1989 and 1999-2003, by inventory year and inventory unit.



One of these forest health problems, oak decline, is considered a “complex,” a group of pathogens and insects that together contribute to reduced growth, more quality defects, and increased mortality in tree species in the red oak group. The oak decline complex consists of the two-lined chestnut borer, the red oak borer, *Armillaria* fungus, and *Hypoxylon* canker, with additional damage caused by four other insects (Starkey et al. 1989). Although oak decline has been observed since the 19th

century, more recently it has been increasingly affecting the forests of the Ozark Plateau of Missouri and Arkansas. Evidence of crown dieback, growth reduction, and mortality in oak forests since the 1980s has far exceeded historic levels. The severe drought of the late 1990s, combined with the advancing age of the Ozark forests, has intensified the spread and severity of the effects (Lawrence et al. 2002).

Interim management guidelines were developed for forests susceptible to oak decline (Moser and Melick 2002). These recommendations were based on personal observations and comments from many field managers as well as other researchers. Underlying the guidelines were assumptions about the impact of five stand and site factors present in all susceptible forests. Moser and Melick (2002) suggested these five factors influenced the likelihood of attack by oak decline:

- Site (many ridgetops and south-west aspects have poor nutrient and/or water availability, stressing the oak trees on them)



Oaks and Other Species

- Age (stands older than 70 years are more prone to oak decline)
- Density (trees in stands with higher densities are more stressed than those in lower density stands)
- Susceptible species (scarlet and black oaks are the most prone to oak decline, particularly on poor sites)
- Lack of diversity (stands with high proportions of susceptible oaks are more prone to oak decline)

A forest health complex is a group of factors that together increase the likelihood of reduced tree vigor and death.

Nonetheless, we examined the five factors individually to see whether some individual influences shaped patterns of mortality in the forest.

What We Found:

Susceptible red oaks are increasing in size in Missouri, but not in numbers. Red oaks, such as scarlet, black, northern red, and southern red oaks, are particularly prominent in Missouri (Fig. 32). These species have been increasing in volume (Fig. 33). Much of the volume increase is due to growth of existing stems; the number of trees 5 inches in diameter and larger did not increase between 1989 and 1999-2003 and the number of trees 1 inch in diameter and larger declined between those inventories (Fig. 34).

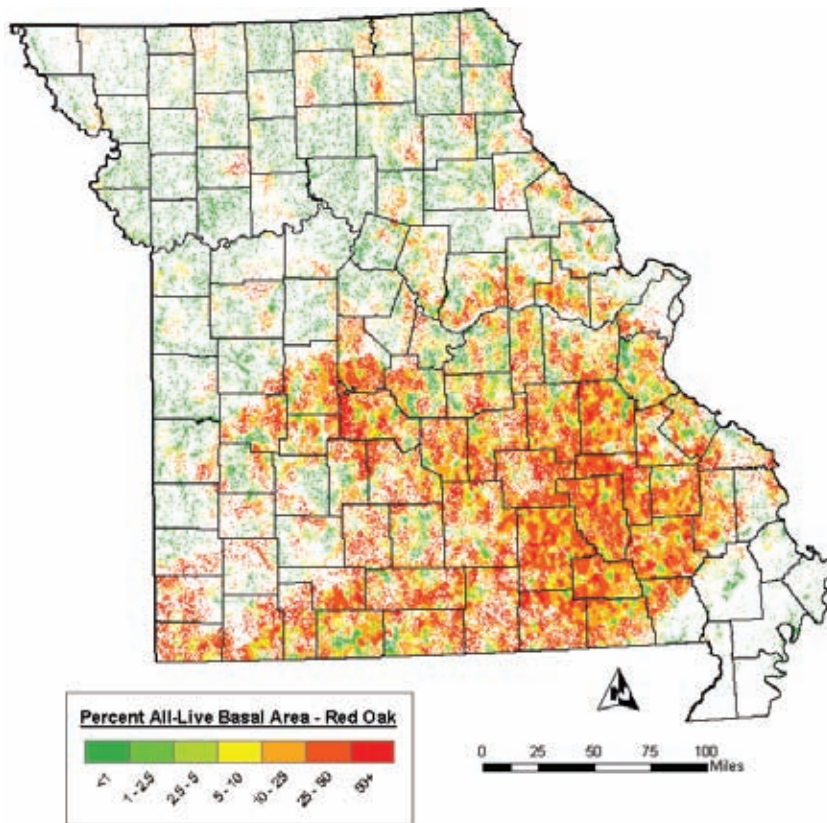


Figure 32.—Percent total live basal area of red oak species susceptible to oak decline in Missouri (1999-2003).

Oaks and Other Species

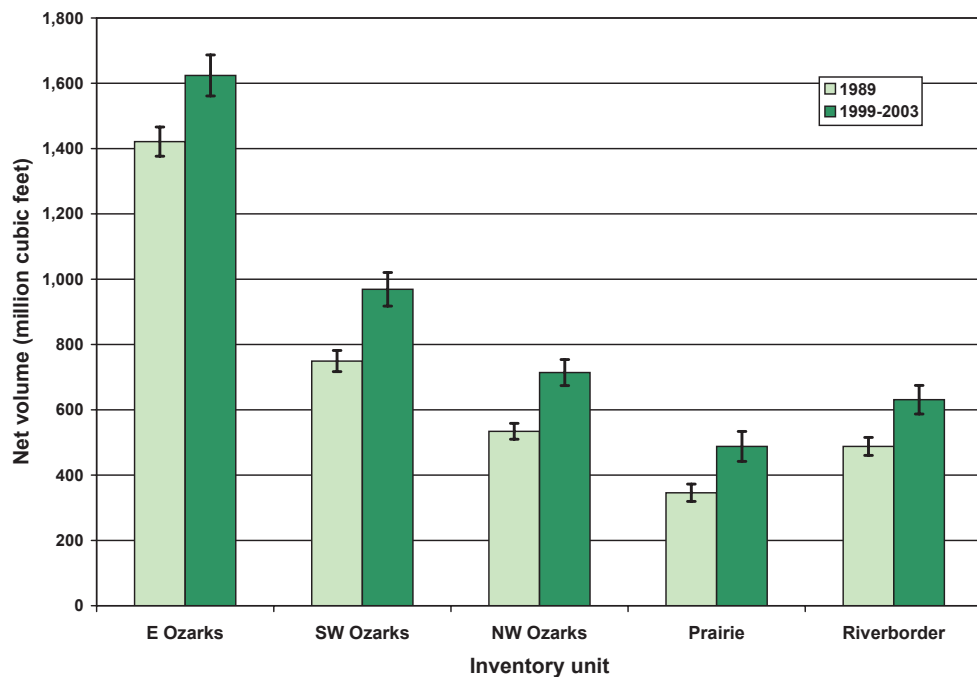


Figure 33.—Net all-live volume of major upland oak species considered susceptible to oak decline (scarlet oak, southern red oak, northern red oak, black oak), on timberland in Missouri, by inventory year and inventory unit.

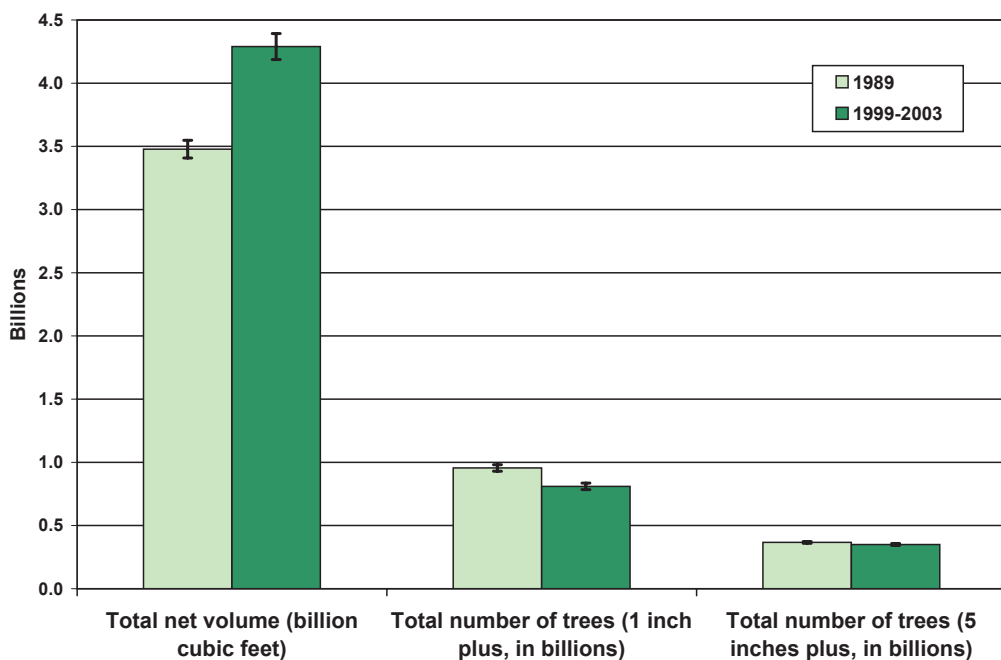


Figure 34.—Net all-live volume of major upland oak species considered susceptible to oak decline (scarlet oak, southern red oak, northern red oak, black oak), in billion cubic feet, and total number of trees, in billions, 1 inch and larger and 5 inches and larger, on timberland in Missouri, by inventory year (1989 and 1999-2003).

OAK DECLINE: DENSITY AND DIVERSITY

Looking at density and diversity (the latter represented by the oak basal area), we see immediately that the amount of oak mortality increased between the 1989 and 1999-2003 inventories (Fig. 35). Although the results are not significantly different, the 1989 inventory suggests less oak mortality when the total basal area category was very high but more oak mortality when the oak basal area category was high. In 1999-2003, the mortality increased progressively with each basal area category, whether we considered all trees or just oaks.

What This Means—Density and Diversity:

Physiological stress can increase the incidence of forest health problems and resulting tree mortality. Higher tree density, particularly in relation to a given amount of soil and water, increases tree stress. Although mortality seems to be increasing with increasing basal area, these differences are not statistically significant.

OAK DECLINE: ASPECT AND SITE

We looked at oak mortality in relation to aspect and to site quality. Although we found a dramatic increase in oak dry biomass mortality between inventories, within each inventory we found no significant difference between aspect or site-quality categories.

What This Means—Aspect and Site:

Anecdotal reports have suggested that current mortality was higher on ridgetops and south- and west-facing slopes. The FIA data do not definitively confirm that a particular aspect is more prone to oak decline. Site condition is a “basket” of factors, such as water, nutrients, and temperature. It could be that the 1999-2002 drought overwhelmed the influence of the other factors, stressing trees and causing increased mortality on “good” sites as well as “bad.” Or, like the other factors, the effects of the drought might not have influenced tree health during this last inventory cycle.

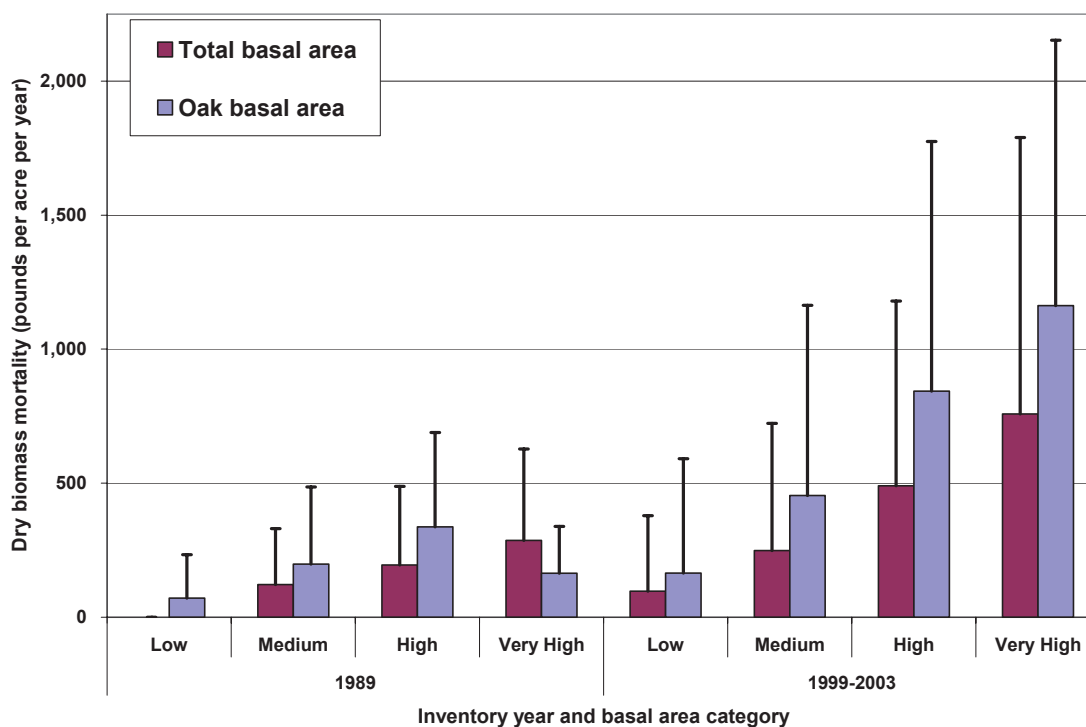


Figure 35.—Oak dry biomass mortality per acre on timberland in Missouri, by inventory year and total basal area category and oak basal area category of the previous inventory.

OAK DECLINE AND AGE

We looked at mortality for each inventory, calculated as an estimate of the biomass of trees that have died each year, since the previous inventory (1972 to 1989 and 1989 to 1999-2003). We compared mortality to the age at the beginning of the cycle. For example, we compared mortality in 1972-1989 to the plot age in 1972. We used age-class categories of Low (0-40 years), Medium (41-70 years), and Mature (71+ years). We found a definite pattern of higher dry biomass mortality with increasing age. However, the high degree of variation in each category means the differences are not significantly different (Fig. 36).

What This Means—Age:

Like the other factors, stand age seems to influence mortality. Although not all mortality is necessarily related to oak decline, the large increase in 1999-2003 vs. 1989 suggests something more at work besides the additional 10 years' time.

As we said, a disease complex is a basket of insect and disease factors that come together to kill a tree. So, too, are the factors that create the condition for this complex—a basket of site, stand, and age characteristics that together stress a forest and open it up to disease and insect attack. Although it is hard to demonstrate, this basket of factors seems to be greater than the sum of each factor individually; the factors seem to reinforce each other in predisposing the stand to attack.

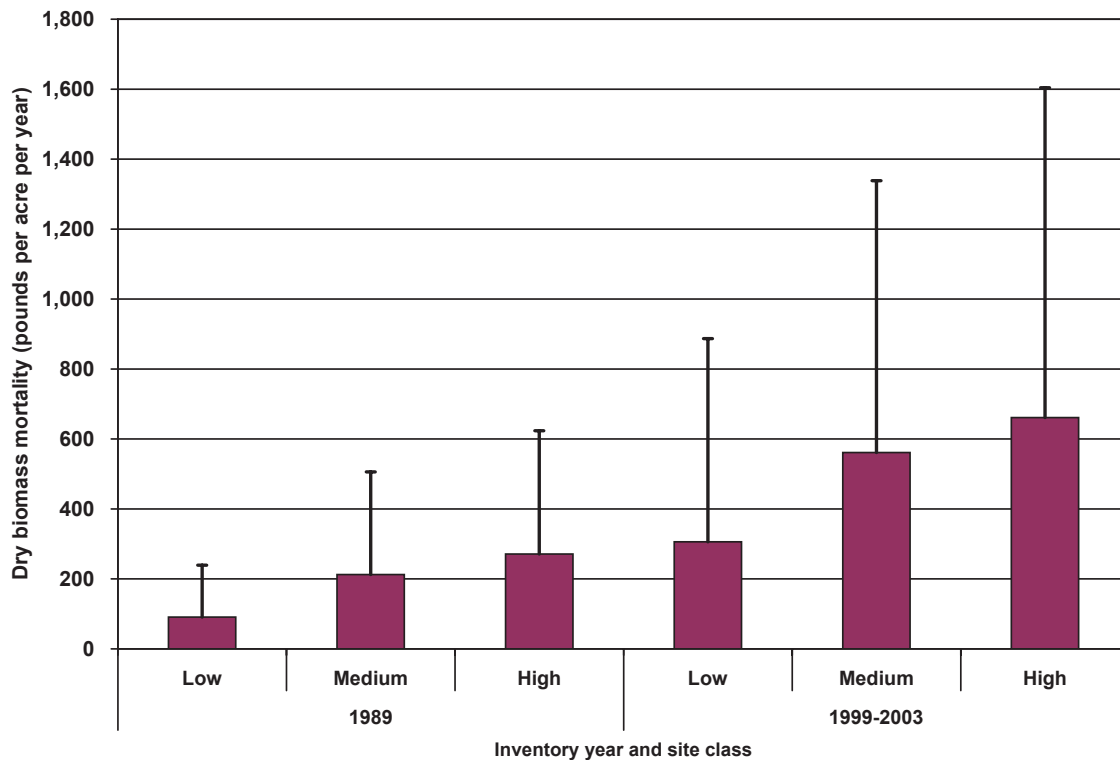


Figure 36.—Oak dry biomass mortality per acre on timberland in Missouri, by inventory year and stand-age category of the previous inventory.

THE OTHER TREES

Hickory Species

Background:

Hickories are common in Missouri's forests, although they are rarely dominant in older stands. Species such as shagbark hickory or mockernut hickory are found in uplands or bottomlands, while others, such as shellbark hickory, are generally found only in bottomlands. Seven species of hickory are found in the State: mockernut, shellbark, shagbark, bitternut, pignut, black, and pecan. Hickory trees produce a resilient wood that is valuable for tools requiring high impact strength, such as axe handles. Hickory nuts are an important source of food for wildlife.

What We Found:

Total net volume of hickories increased by 41 percent between 1989 and 1999-2003 (Fig. 37). The number of trees 1 inch and larger decreased by 6 percent between the two inventory periods. The number of trees 5 inches and larger increased by approximately 11 percent. The most pronounced increases in net volume of hickory species occurred in the Eastern Ozarks (28 percent) and Prairie (75 percent) inventory units (Fig. 38). Most of the smaller diameter classes had fewer trees in 1999-2003 than in 1989 (Fig. 39). The diameter classes 7 inches and larger had more trees in 1999-2003 than in 1989, probably because of ingrowth from the smaller diameter classes as well as land reclassified as forest. Figure 40 shows the change in number of hickory trees in each diameter class.

What This Means:

We are seeing a familiar theme: as Missouri's forests age, they gain more volume on existing trees, but not many new trees. The same pattern is evident with hickories: with the large increase in total volume combined with no or minimal increase in the number of trees, we may conclude that the jump in volume is due primarily to the growth of those hickory trees already present in the forest, rather than the establishment of new trees. Although the species rarely dominates forest canopies due to competition from oaks, anything that might cause a decline in oak numbers or vigor may result in an increase in the hickory presence in future Missouri forests.



Oaks and Other Species

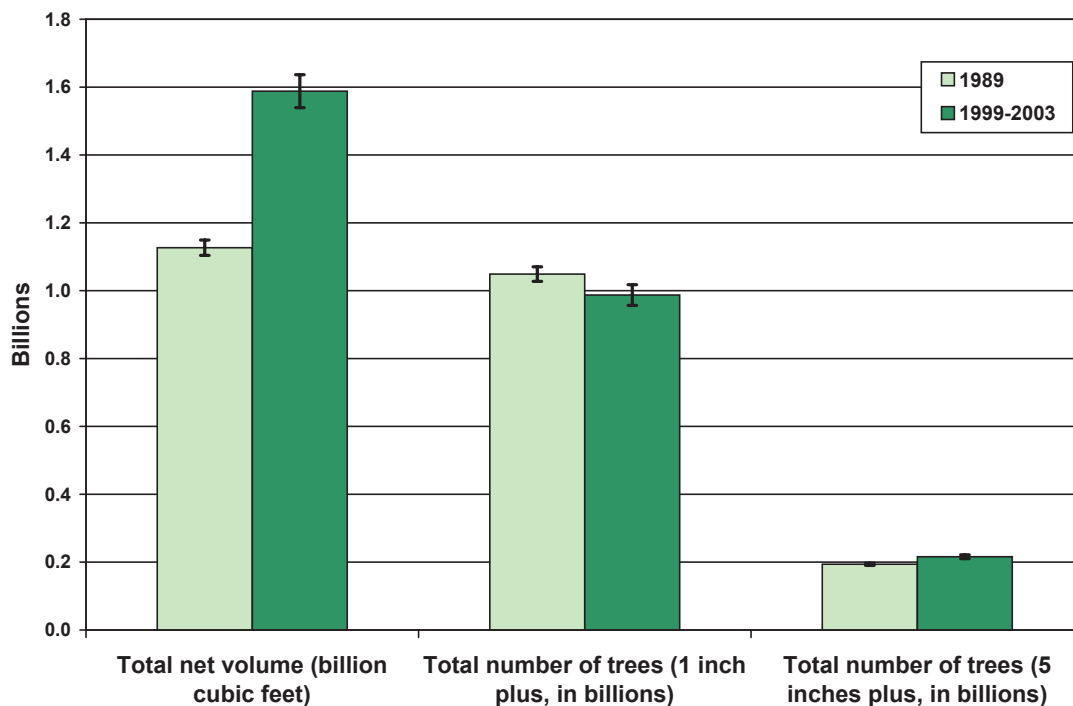


Figure 37.—Total net volume and total number of trees 1 inch and larger and 5 inches and larger of all hickory species on timberland in Missouri, 1989 and 1999-2003.

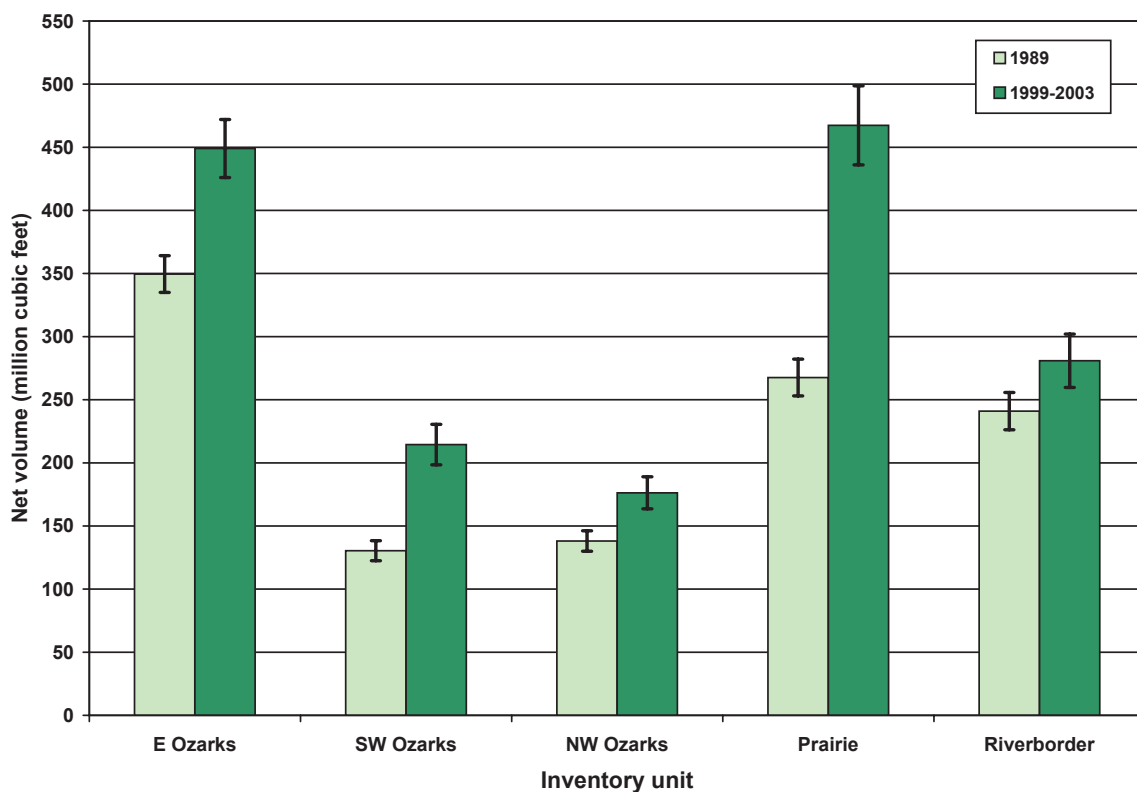


Figure 38.—Net volume of all-live hickories on timberland in Missouri, by inventory year and inventory unit.

Oaks and Other Species

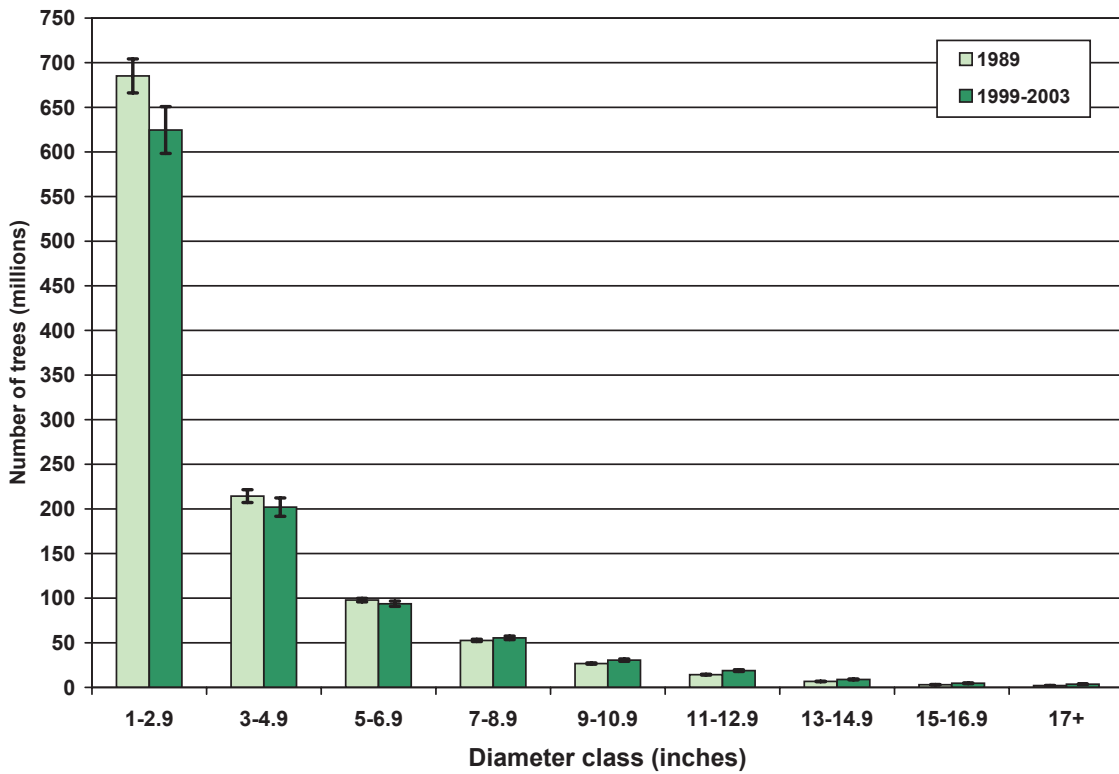


Figure 39.—Diameter distribution of hickory trees on timberland in Missouri, 1989 and 1999-2003.

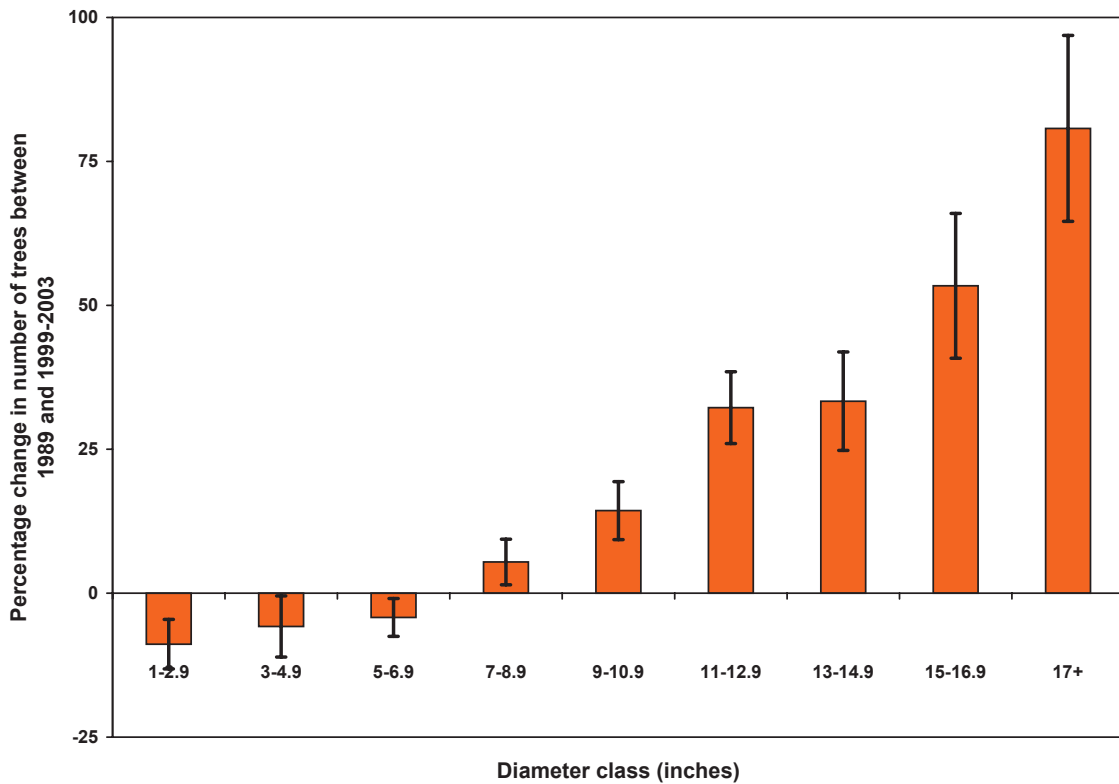


Figure 40.—Percentage change in number of hickory trees on timberland between 1989 and 1999-2003 inventories, by diameter class.



Sugar Maple and Other Maple Species

Background:

Maples are an increasing presence in Missouri's forests. Four species—sugar maple, red maple, silver maple, and boxelder—are found naturally in Missouri's forests. Sugar maple, also known as hard maple, is one of the most important hardwoods in the U.S. and a major species in Missouri. Good sugar maple logs are prized for furniture production and other fine wood uses, but this type of maple is mainly used for pallet and tie logs, pulpwood, and firewood in Missouri. Red maple has historically been found in swampy areas and very dry ridgetops, but lacking large-scale disturbance, particularly fire, it is expanding across the State's landscape. As late-successional species, maples can also indicate the amount of time since the last stand-initiating disturbance. Their shady canopies make it difficult for shade intolerant and mid-tolerant species, like many oaks, to regenerate and thrive in the understory. Given maple's economic impact and potential influence on other important tree species, we looked at some trends and characteristics of Missouri's maples.

What We Found:

Total net volume of all-live maple trees on timberland in Missouri almost doubled between 1989 and 1999-2003 (Fig. 41). The number of trees 1 inch and larger increased by 37 percent between the two inventory periods, and the number of trees 5 inches and larger increased by approximately 57 percent. The net volume of maple species increased across Missouri. The most pronounced increases occurred in the Prairie (112 percent) and Riverborder (87 percent) inventory units (Fig. 42).

The number of trees increased dramatically across all diameter classes, but particularly in the smaller diameter classes (Fig. 43). The 21- to 22.9-inch diameter class had the most spectacular increase although it started from a fairly small number of trees. What is more telling is the roughly 50- to 70- percent increase in the diameter classes under 12 inches, which indicates regeneration success and juvenile growth.

Figures 44 and 45 are graphs of basal area classes by inventory year for riparian-site maples (boxelder, red maple, and silver maple are primarily riparian species,

Oaks and Other Species

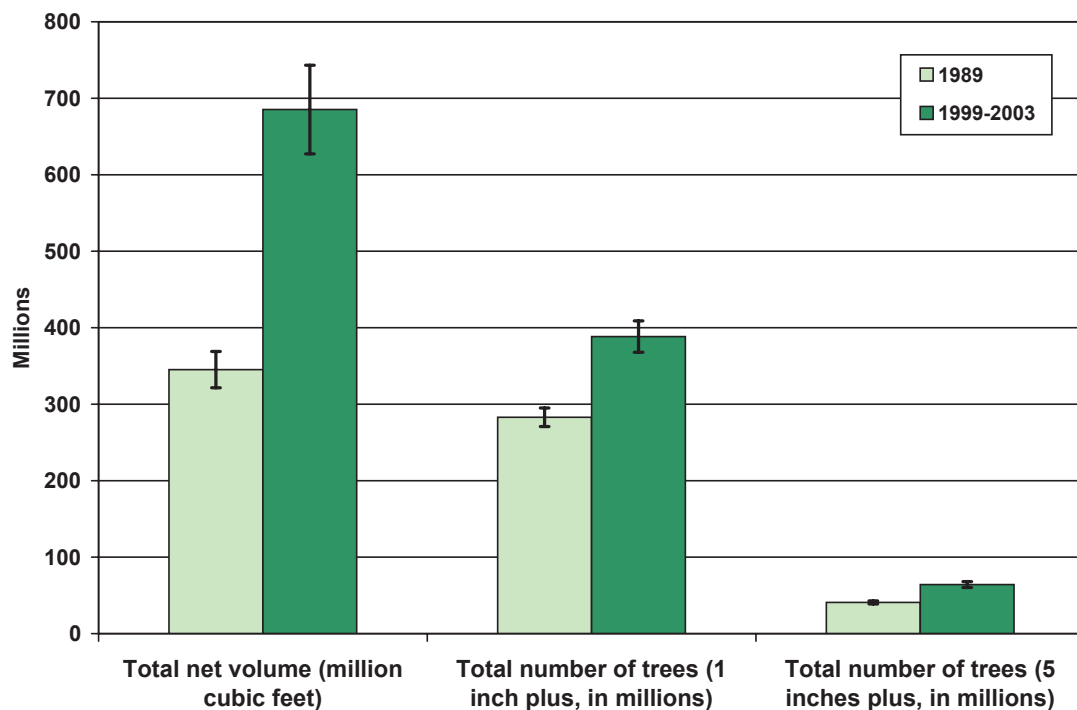


Figure 41.—Total net volume and total number of trees 1 inch and larger and 5 inches and larger of all maple species on timberland in Missouri, 1989 and 1999-2003.

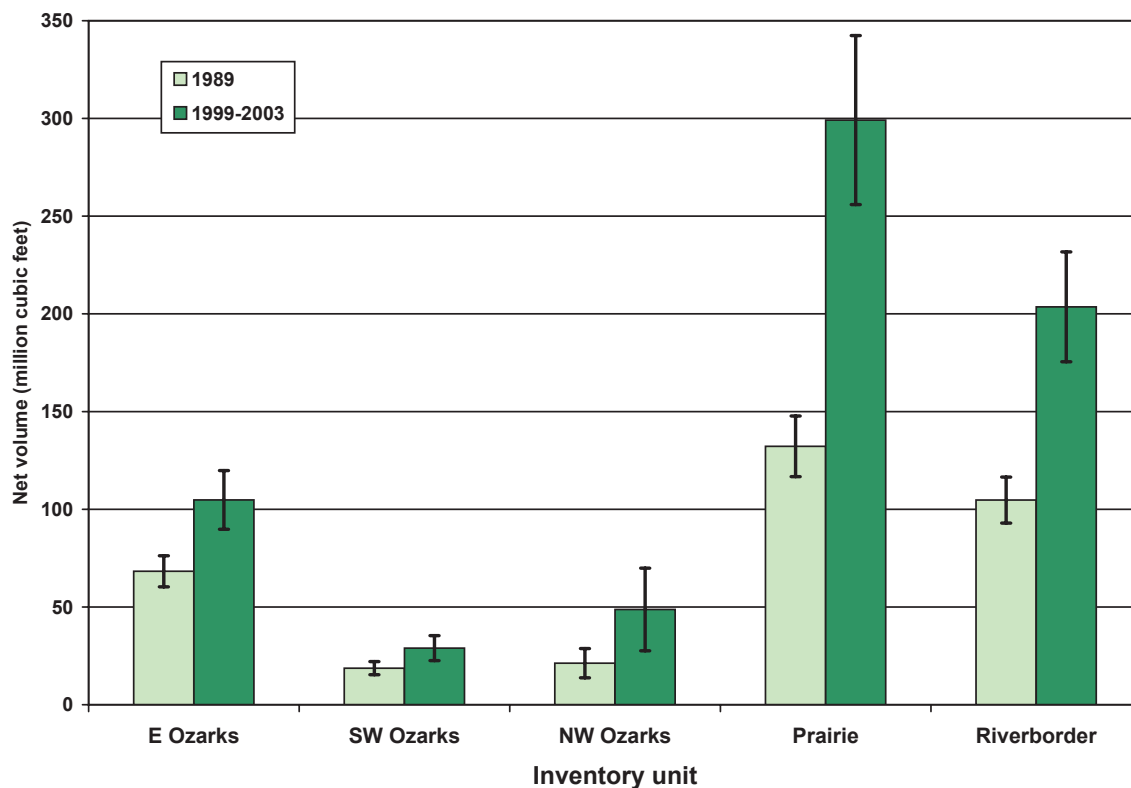


Figure 42.—Net volume of all-live maple trees on timberland in Missouri, by inventory unit, 1989 and 1999-2003.

Oaks and Other Species

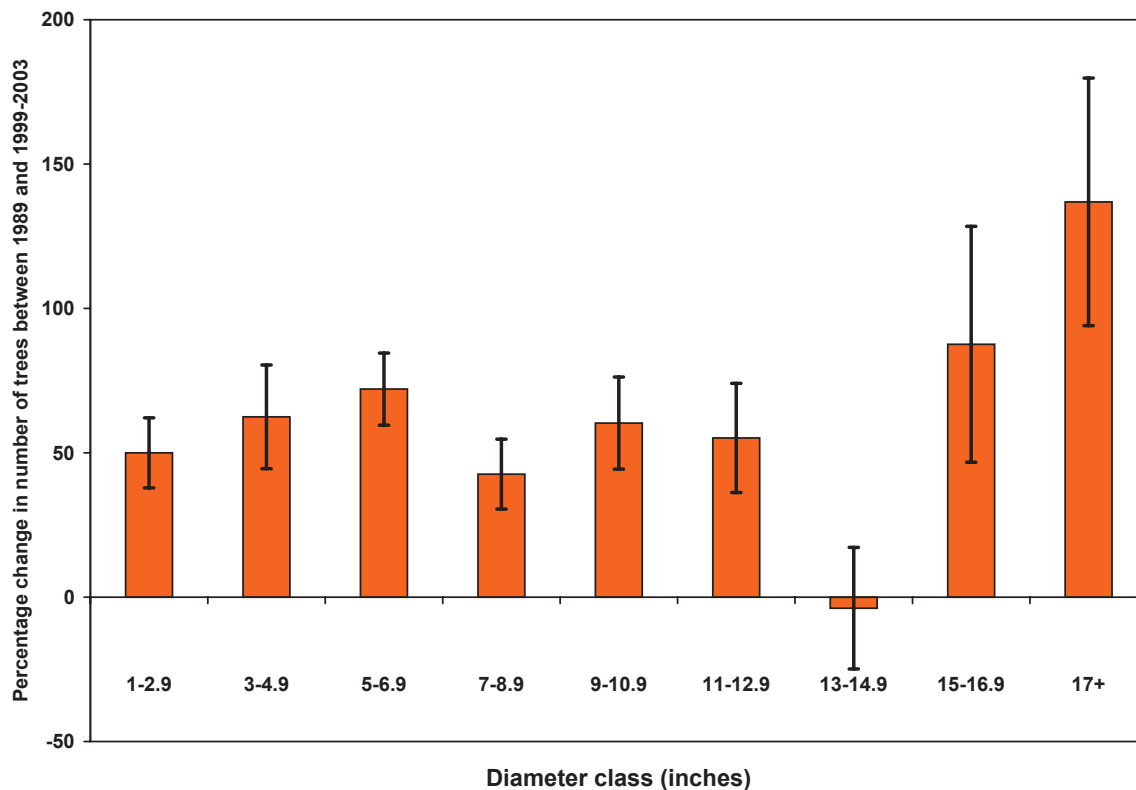


Figure 43.—Percentage change in number of all-live sugar maple trees on timberland between the 1989 and 1999-2003 inventories, by diameter class.

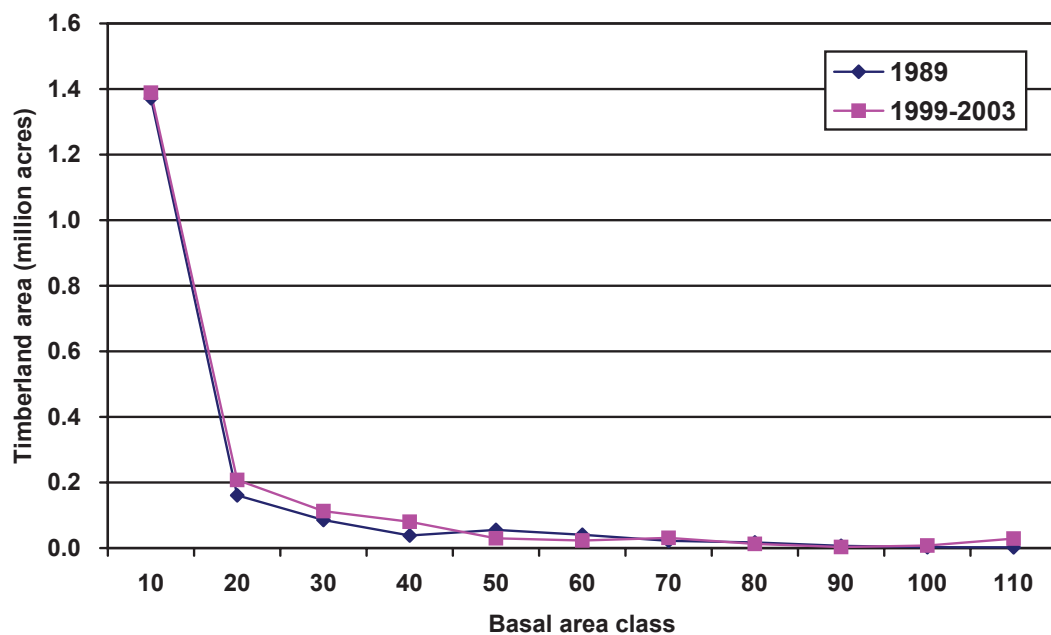


Figure 44.—Sum of timberland acres of stands with silver maple, red maple, and boxelder by basal area class; basal area class truncated at 110 ft² ac⁻¹.

Oaks and Other Species

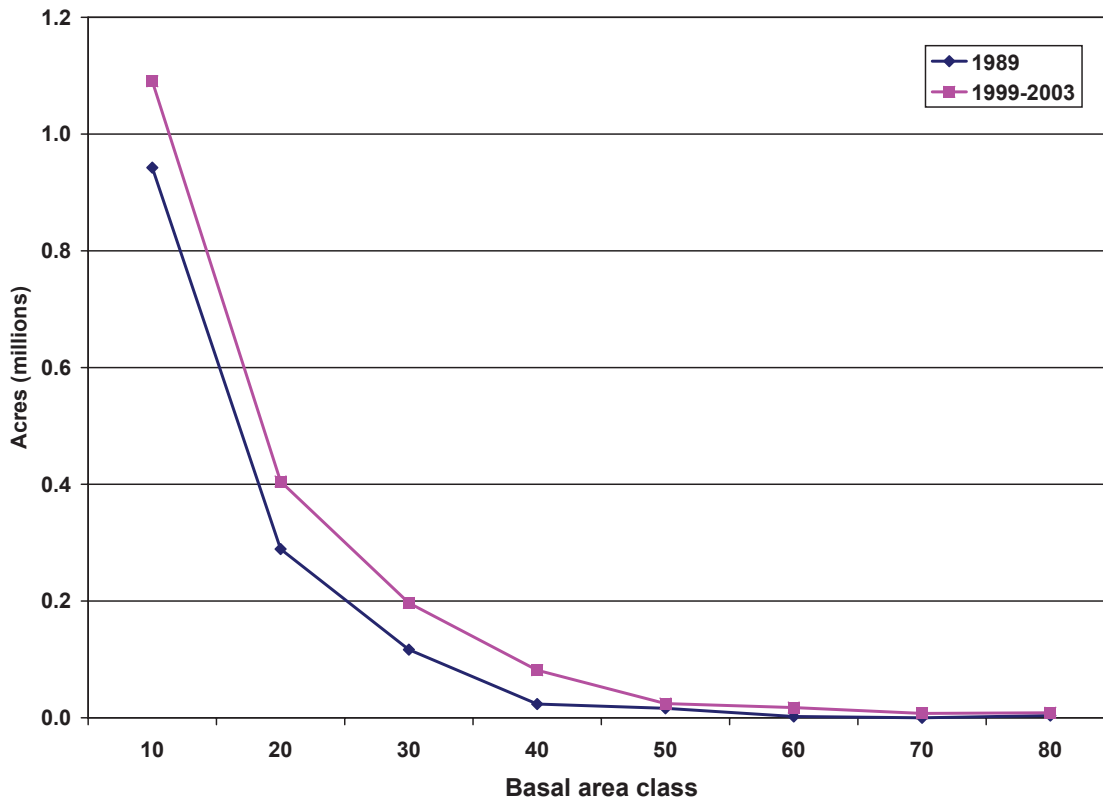


Figure 45.—Sum of timberland acres of stands with sugar maple by basal area class.

although all of them, particularly red maple, can be found across the landscape) and for sugar maple, respectively. Riparian maples have not increased between inventories; the 2003 curve is similar to the 1989 curve. Sugar maple, however, shows a pronounced increase, particularly in the lower basal area classes.

What This Means:

Maple species are becoming more important to Missouri's forests, and they are expanding rapidly with fewer disturbances, such as harvesting and fire. The presence of a vigorous understory suggests the future Missouri forested landscape will have many more maple species in the overstory than it does now. The major increase appears to be in maples on upland sites, particularly sugar maple. The chief impact of increased maple presence will be on the regeneration of less shade-tolerant competitors, such as oaks. As the midstory and the upper canopy gain more maples, less light is available on the forest floor, reducing oak germination and seedling survival.

Shortleaf Pine

Background:

At one time, southern Missouri had approximately 6 million acres of shortleaf pine-dominated forests. The wood was prized by the lumber industry, and huge mills were established to process the large amounts of virgin timber cut. In the late 19th century, the largest sawmill in the country was located in Grandin, Missouri, processing around 750 million board feet of pine lumber per year. After most of the pine timber was harvested, the industry moved on and the mills shut down. Although mature southern pines are much more resistant to fire than hardwoods, juvenile shortleaf pine still needs some respite from fire to grow into the overstory (although it has a limited capability of sprouting back after being top-killed). The former practice of frequently setting fires resulted in low pine reestablishment and caused the Ozarks to assume the largely hardwood character it has today.

What We Found:

All-live volume of the loblolly/shortleaf pine species group was 807 million cubic feet in 1999-2003, a slight increase over 1989 (Fig. 46). Unlike Missouri's hardwood forests, most of the pine volume was on public lands: 408 million cubic feet on Federal lands and 70 million cubic feet on State and local government lands. Not all of the pine volume was in pine forests. An estimated 310 million cubic feet was in the loblolly/shortleaf pine forest type group. Approximately 497 million cubic feet of the loblolly/shortleaf species group was in non-pine forest types, primarily oak/pine.

Total net all-live volume of shortleaf pine increased by almost 25 percent between 1989 and 2003 (Fig. 47), yet the number of all live trees 1 inch in diameter and larger decreased slightly. The number of all live trees 5 inches and larger increased slightly. The largest gain in total shortleaf pine volume was in the Eastern Ozarks, but the largest percent increase was in the Southwest Ozarks unit (Fig. 48). These units are the center of the original range of shortleaf pine in Missouri.

The number of shortleaf pine trees in diameter classes less than 9 inches markedly decreased between 1989 and 2003 (Fig. 49). Some of these trees have grown larger, but there appear to be fewer small trees coming along behind them.

What This Means:

The presence of shortleaf pine volume mainly in forests with a significant hardwood component suggests a management opportunity for those interested in increasing the proportion of pine on the landscape. They might then reduce the density of hardwoods in pine/hardwood stands and increase disturbances, such as periodic (not annual) fire, that inhibit the hardwood competition.

Fire can play an important role in the success or failure of pine establishment. Mature shortleaf pine is more



resistant to fire than hardwoods, but fire applied at the wrong time can reduce successful regeneration. Fire that occurs in the summer before seedfall can eliminate competing vegetation and expose mineral soil for the pine seeds. Although shortleaf pine can sprout back after being top-killed, repeated fires when this species is young will eliminate the juvenile age class. The total absence of fire, on the other hand, results in grass, shrub, and hardwood competition that will be too vigorous for the pine seedlings. Foresters need to balance these considerations to restore and maintain this species. In our data, the lack of ingrowth into the lower diameter classes suggests that shortleaf pine is not regenerating or not surviving in the face of hardwood competition.

Oaks and Other Species

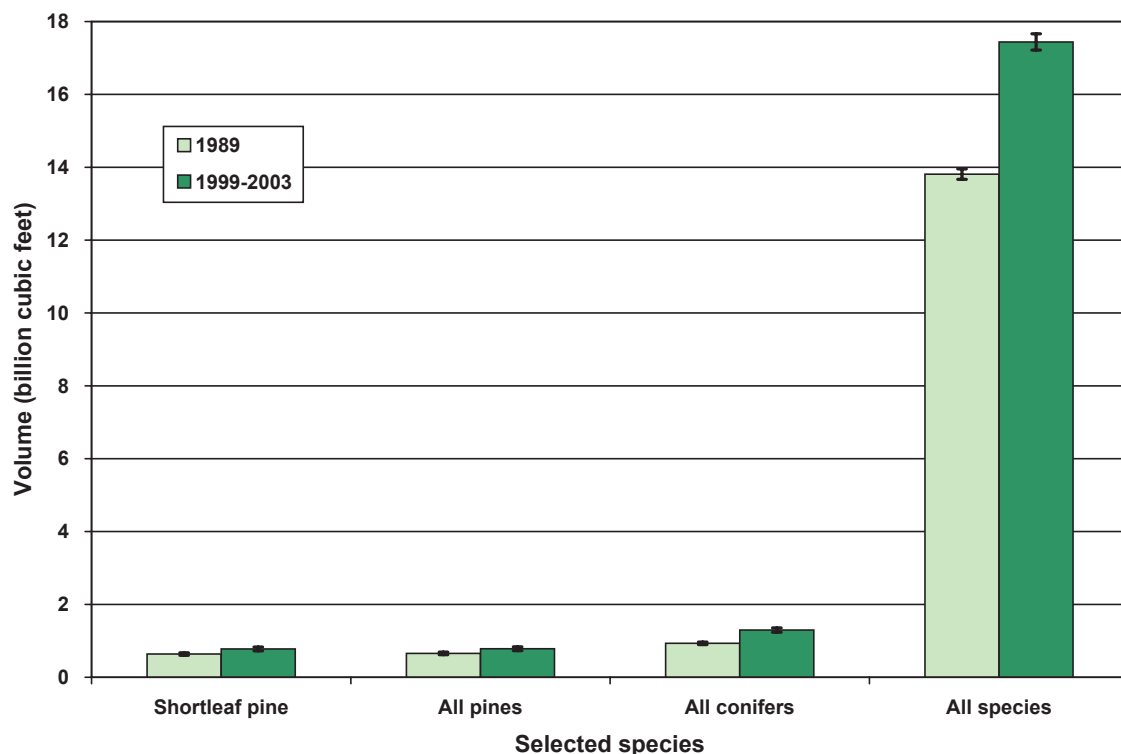


Figure 46.—All-live volume of selected softwood species groups on timberland, in billion cubic feet, Missouri, 1999-2003.

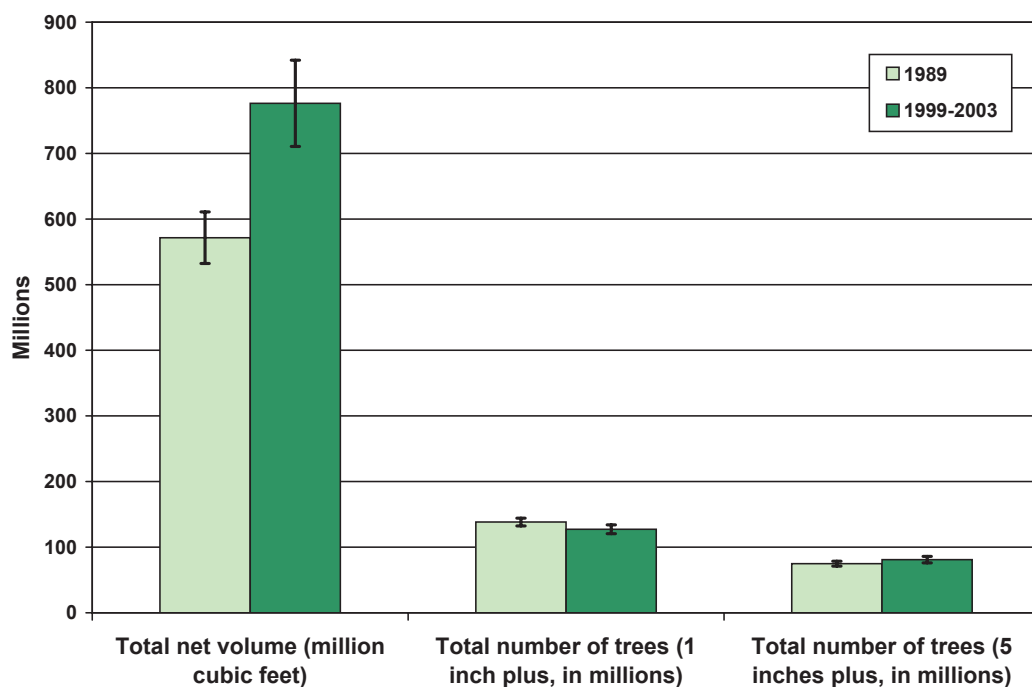


Figure 47.—Total net all-live volume and total number of trees 1 inch and larger and 5 inches and larger of shortleaf pine in Missouri, 1989 and 1999-2003.

Oaks and Other Species

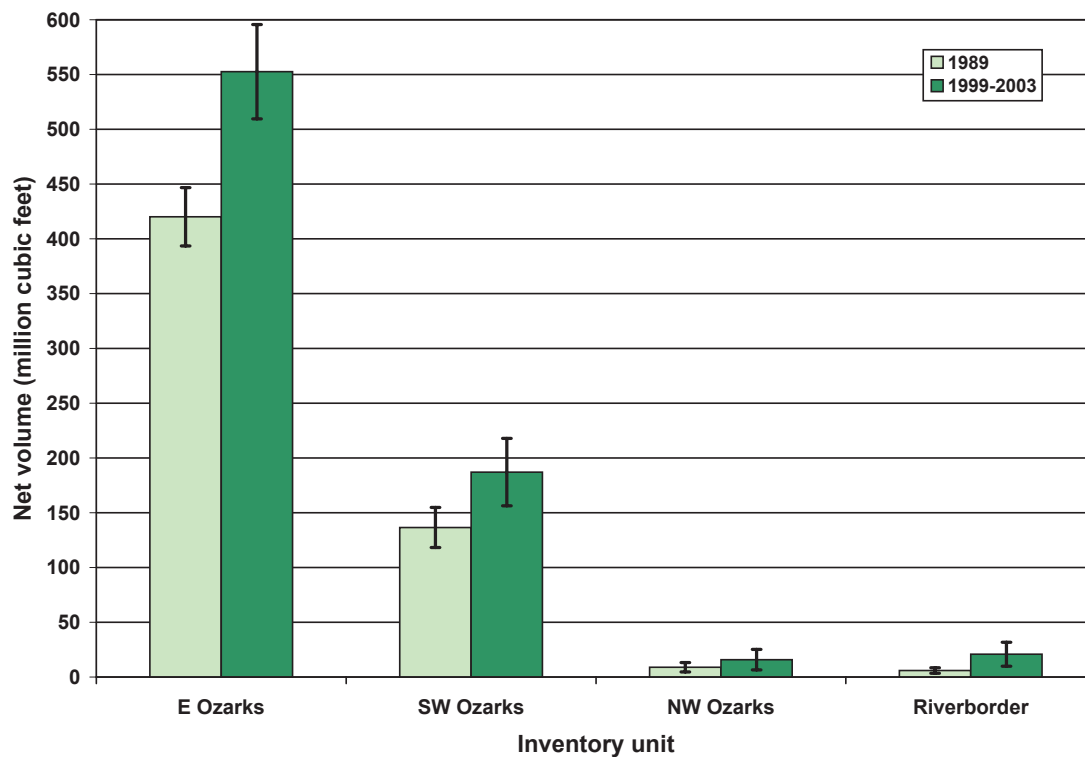


Figure 48.—Net volume of all shortleaf pines on timberland in Missouri, by inventory unit, 1989 and 1999-2003.

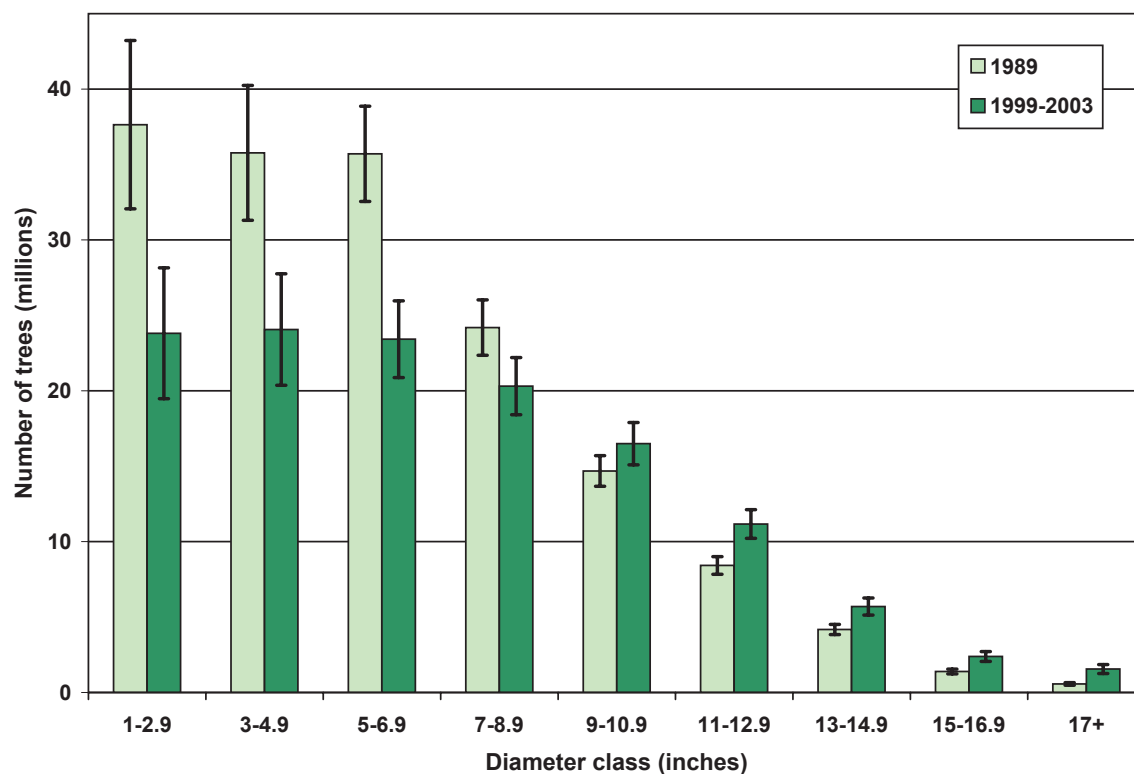


Figure 49.—Diameter distribution of shortleaf pine trees in Missouri, 1989 and 1999-2003.

Eastern Redcedar

Eastern redcedar is a coniferous species common to the Eastern United States. Historically limited to areas with infrequent fires, redcedar is a vigorous colonizer of open spaces, such as low-density woodlands and abandoned agricultural lands. Good seed crops occur every 2 or 3 years; seed dispersal depends heavily on birds and small mammals that eat and later pass out the seeds. On deeper soils, co-invaders, such as persimmon and sassafras, can quickly outcompete redcedar. On wooded sites, redcedar occurs with winged elm, blackjack oak, post oak, and white ash. If fire is suppressed, these species may be replaced by the more shade-tolerant white oak and sugar maple. Stands formed through invasion of old fields may start to break up at around 60 years of age as hardwoods or other competing species become established.

What We Found:

Eastern redcedar occurs throughout Missouri's forests, particularly in the central and southern regions (Fig. 50). Total all-live volume of this species doubled between 1989 and 2003. In addition, the number of trees 1 inch and larger and 5 inches and larger increased significantly between the two inventories (Fig. 51). The largest increases, in terms of absolute volume or percentage change, occurred in the Southwest Ozarks and Riverborder inventory units (Fig. 52).

What This Means:

Eastern redcedar is expanding throughout the Midwest (Schmidt and Piva 1996). The suppression of fire and the reduction in grazing on pastureland have resulted in an expansion of redcedar presence in Missouri never seen before now. While dense redcedar stands provide good wildlife cover, that density can reduce understory diversity and plant growth. The establishment of a redcedar stand will change the character of the forest landscape, encouraging some wildlife communities while limiting others. Dense eastern redcedar stands are highly susceptible to fire; an increase in such stands will increase the danger of wildfires unless adequate management and fire protection steps are taken.

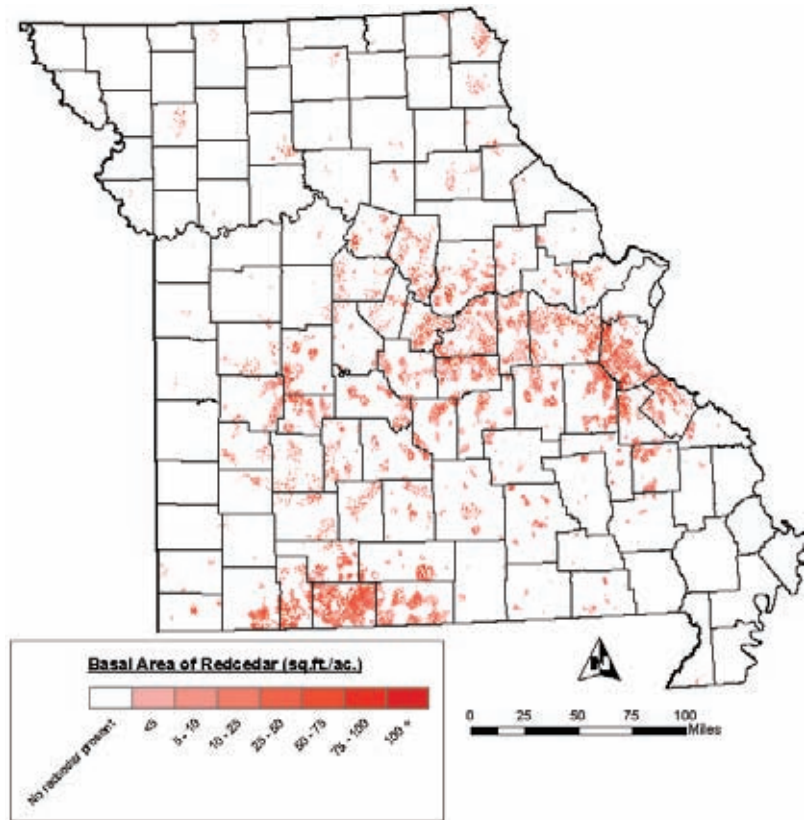


Figure 50.—Basal area of eastern redcedar, Missouri, 1999-2003.

Oaks and Other Species

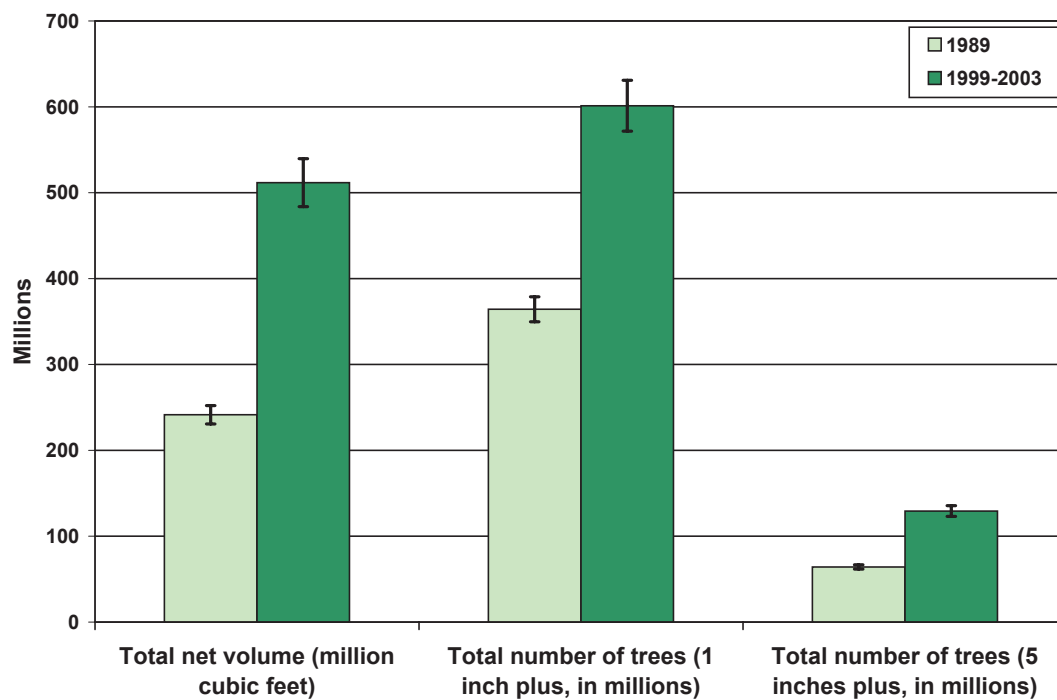


Figure 51.—Total net all-live volume and total number of trees 1 inch and larger and 5 inches and larger of eastern redcedar in Missouri, 1989 and 1999-2003.

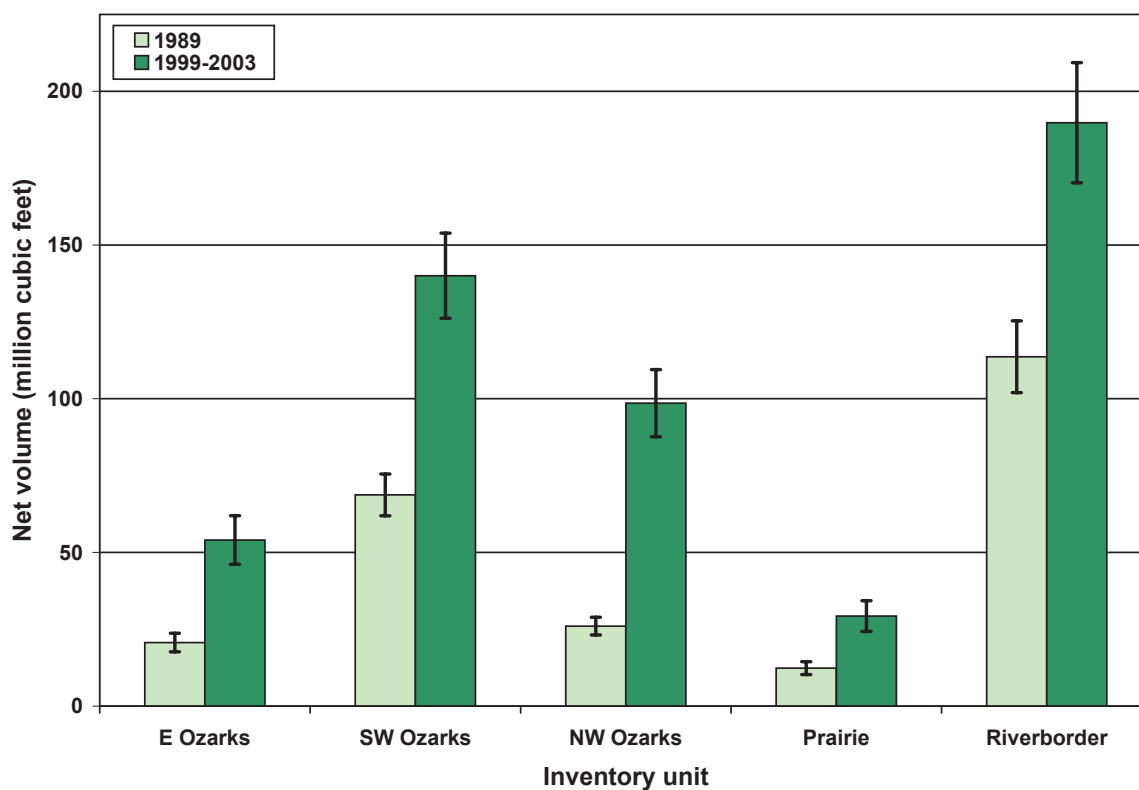


Figure 52.—Net volume of eastern redcedar on timberland in Missouri, by inventory unit, 1989 and 1999-2003.



Endangered Species Habitat—Indiana Bat

Background:

Oaks and hickories are components of Missouri's forest ecosystem that are particularly important to the Indiana bat (*Myotis sodalis*), an endangered species of bat native to most of the Eastern United States. Although this species prefers caves, it raises its young in roosts under live tree bark of selected species and under the bark or platy wood fragments on snags (dead trees). While many factors influence the population health of this species, the presence of roost trees is considered an important habitat characteristic (Clawson 2002, Humphrey 1975). Inventory data let us estimate the overall live tree basal area, cubic foot volume, and numbers of trees greater than 12 inches in diameter.

What We Found:

Figure 53 portrays the basal area distribution of all live trees for the six tree species (shellbark hickory, shagbark hickory, white oak, swamp white oak, post oak, and Delta post oak) that can provide roosting opportunities for the Indiana bat. Although many Missouri counties have potential Indiana bat habitat, our data suggest the suitable tree species are clumped in certain locations.

All-live volume of species suitable for Indiana bat roost trees increased from 1989

to 1999-2003 (Fig. 54). Although the net volume of the appropriate species increased substantially between inventories, the number of trees greater than 5 inches in diameter barely changed (Fig. 55). The average individual tree increased in size. This growth benefits female Indiana bats, which prefer larger trees for roost sites.

What This Means:

We deal with the volume and number of potential Indiana bat roost trees here and not the number of Indiana bats, so we cannot conclude whether tree volume or number is satisfactory. Although multiple factors influence bat habitat, there seem to be many potential roost trees of the appropriate species in Missouri. These trees apparently are getting larger and thus more suitable for habitat, but the small increase in number of trees between inventories suggests that Missouri might not maintain these numbers and volumes into the distant future.

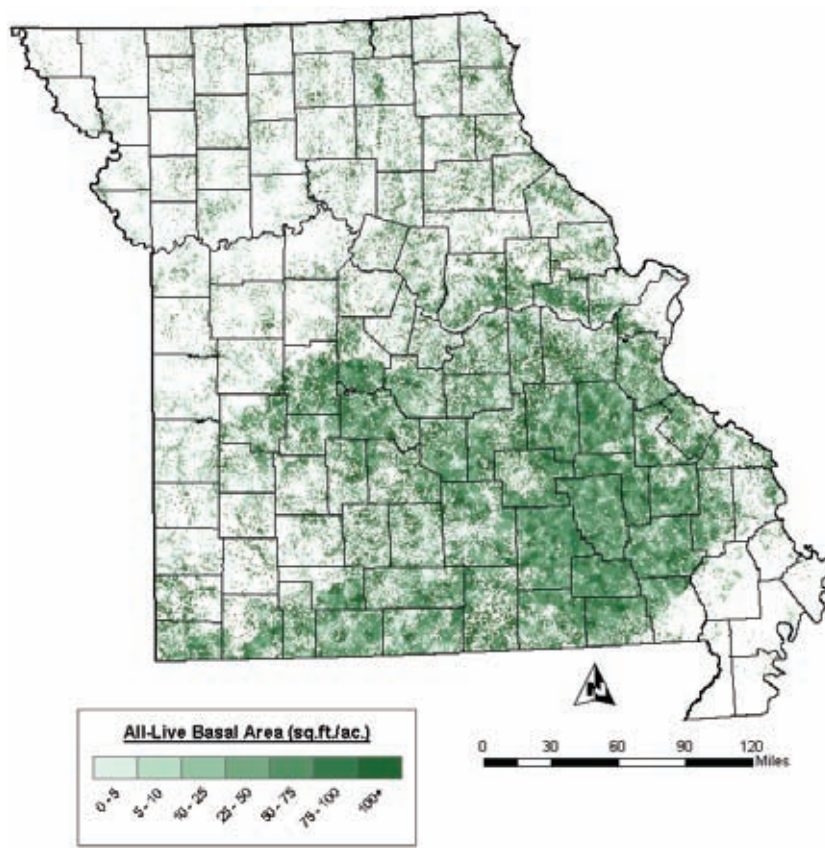


Figure 53.—Total all-live basal area of the six species considered suitable for Indiana bat roosts, Missouri, 1999-2003. Species are shellbark hickory, shagbark hickory, white oak, swamp white oak, post oak, and Delta post oak.

Oaks and Other Species

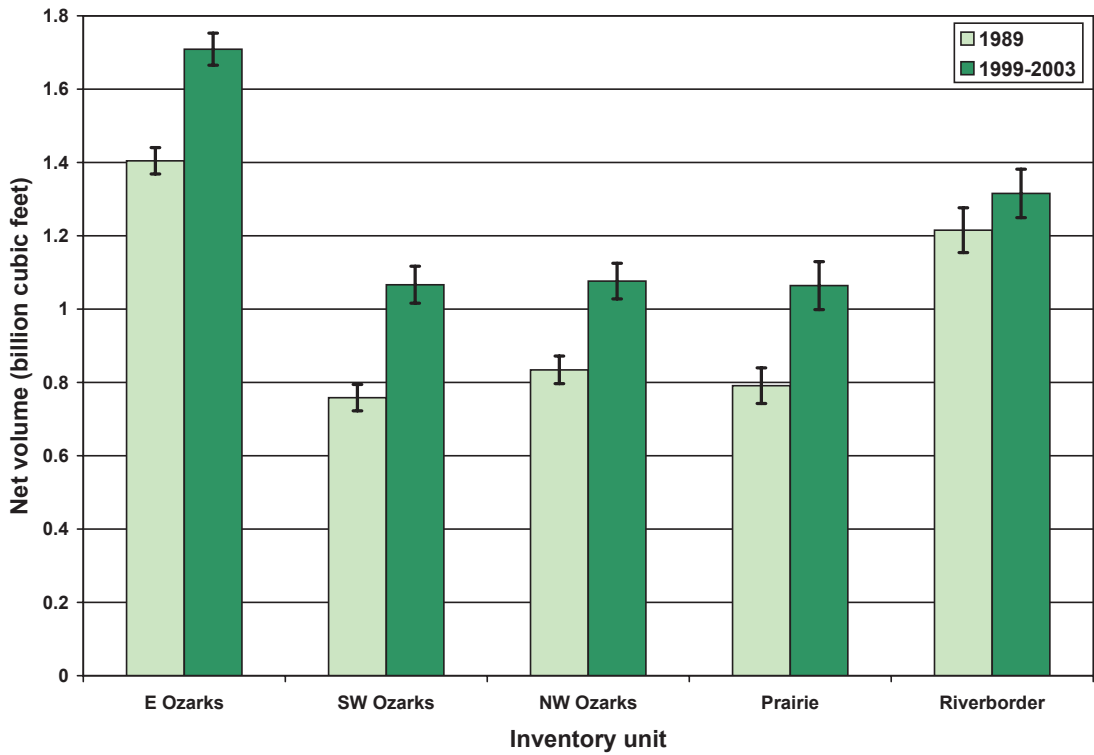


Figure 54.—Net all-live volume for trees 1 inch and larger of the six tree species considered most suitable for Indiana bat roosting in Missouri, 1989 and 1999-2003. Species are shellbark hickory, shagbark hickory, white oak, swamp white oak, post oak, and Delta post oak.

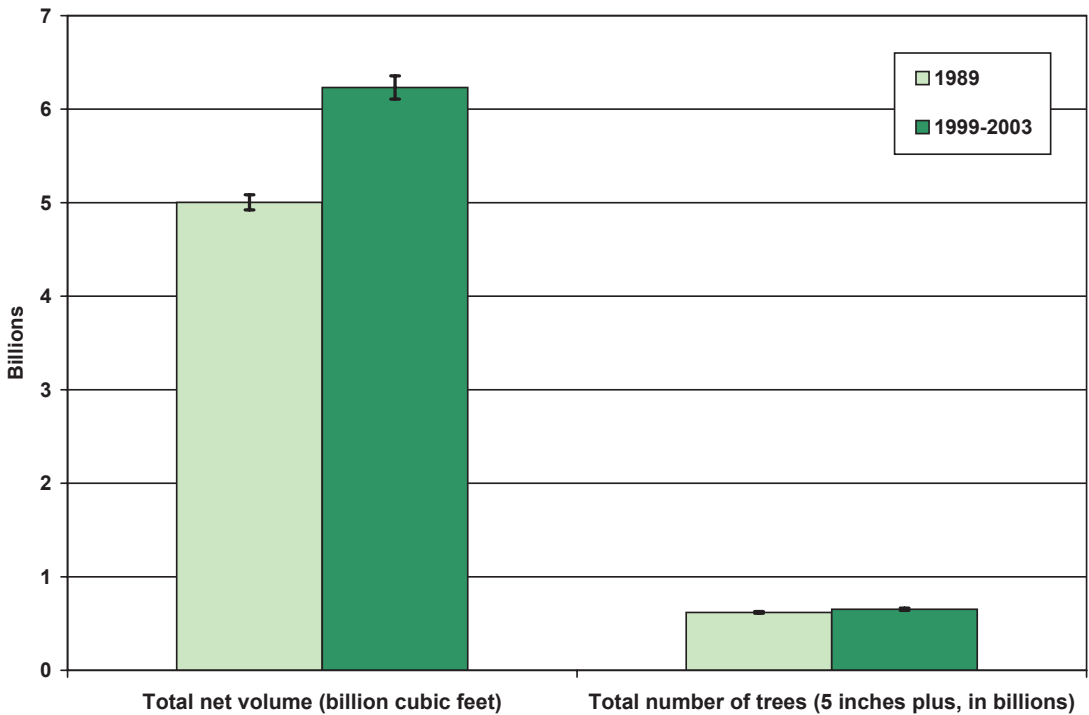


Figure 55.—Total net volume and total number of trees 5 inches and larger of species suitable for Indiana bat roosts, on timberland in Missouri, 1989 and 1999-2003. Species are shellbark hickory, shagbark hickory, white oak, swamp white oak, post oak, and Delta post oak.



FOREST PRODUCTS

SAWTIMBER VOLUME

Background:

Sawtimber volume is the volume of wood in the saw log portion of a tree (the section of a tree's bole between the stump and the saw log top, measured in board feet). Live sawtimber volume is used to determine the monetary value of wood volume in a tree or the amount of usable product that might be manufactured from that volume. When saw logs are sawn into pieces by sawmills, the pieces are converted to products such as lumber, veneer, and furniture stock.

What We Found:

In 1999-2003, the net volume of sawtimber on timberland was 46.5 billion board feet. Hardwoods constituted 91 percent of the volume (42.3 billion board feet) (Fig. 56). Of the hardwood sawtimber total, red and white oaks accounted for 73 percent (30.8 billion board feet). Trees 19 or more inches in diameter were 22.7 percent of the hardwood volume (9.6 billion board feet) and 5.5 percent of the softwood volume (227.5 million board feet). In 1989, the proportions were 16.8 percent and 3.6 percent, respectively (Spencer et al. 1992).

What This Means:

Oaks were roughly two-thirds of growing-stock volume and almost three-fourths of sawtimber volume, reflecting the value of the species and the emphasis placed on oak management in Missouri. Although larger size doesn't always mean older trees, we also note the higher proportion of the hardwood volume in large trees vs. the proportion of softwood volume in larger trees. Some of this disparity is due to the growth habits of fast-growing species such as cottonwood vs. slower growing species like eastern redcedar, but the data also suggest a higher proportion of the softwood stands are younger than in hardwood stands.

Products

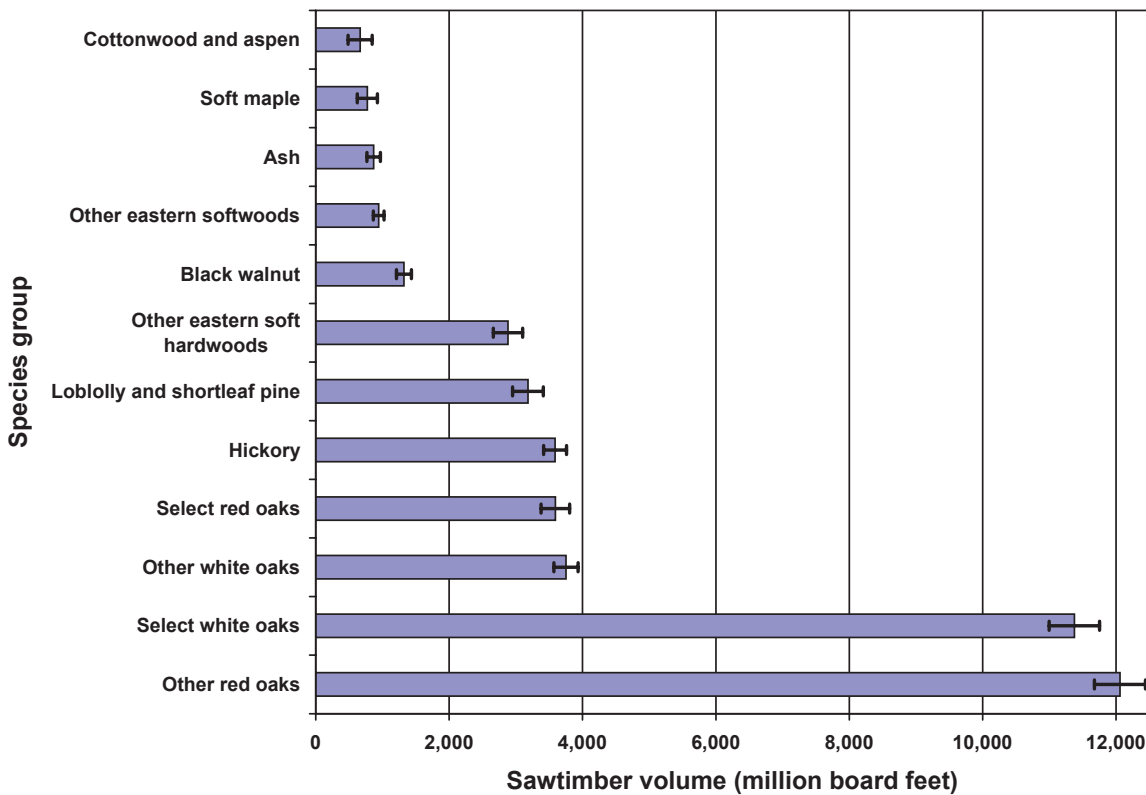


Figure 56.—Sawtimber volume of the 12 largest species groups, Missouri, 1999-2003.

Forest Inventory Removals

Background:

Forest Inventory and Analysis estimates the quantity of growing stock removed from timberland by human means (i.e., land clearing and management activities) from plot data, just like area, volume, and growth. We use these estimates to determine total wood consumption—an indicator of the contribution of Missouri’s forests to the State’s economy—and to gauge the sustainability of forest utilization in Missouri. To detect any patterns in growth and forest health, as well as to determine the sustainability of forest management practices, it is also useful to compare removals with growth and mortality. Examining trends in all-live volume allows us to monitor the underlying biological potential of Missouri’s forests.

What We Found:

Average annual removals of growing stock on timberland totaled 118.6 million cubic feet per year from 1989

to 1999-2003. Softwood removals were 11.5 million cubic feet per year or 9.7 percent of total removals. Hardwood removals were 107.1 million cubic feet per year. Removals from private property totaled 100.0 million cubic feet per year, 84.3 percent of all removals. Public land removals averaged 18.6 million cubic feet per year. The species group category other red oaks had the highest average annual removals at 40.2 million cubic feet per year (37.5 percent of the total average hardwood removals). The next highest species group was select white oaks at 30.4 million cubic feet per year (28.4 percent of total hardwood removals), followed by other white oaks at 10.1 million cubic feet per year (9.4 percent of the hardwood total).

From the data displayed in figure 57, it appears that the bulk of the removals occurred in the Southeast Ozarks unit, followed by the other two Ozarks units. The Prairie unit (the northern and far western portions of the State) did not have as much forested resources per acre, so it is

Products

not surprising that this unit did not have high volumes of removals per acre.

Select white oaks had the second largest amount of all-live volume in 1989 and the largest amount in 1999-2003 (Fig. 58a). The species group had the largest increase in volume of any of the 11 categories. The change in ranking reflects not only the growth of select white oaks, but also the higher mortality of the other red oaks species group (Fig. 58b). For all species groups, growth exceeded the sum of mortality and removals, in some cases substantially.

What This Means:

Throughout Missouri's history, the State's citizens have made use of its forested resources. As settlers moved into the region, they looked to forest land for resources they

needed to build their homes, towns, and industries. Removals reflected both the market's interest in particular species and the availability of these species in Missouri. Most products came from large-, and to some extent, medium-diameter stands, reflecting the focus of Missouri's markets on solid-wood end uses. While growth exceeded mortality and removals, the higher levels of mortality of other red oaks were reflected in the residual standing volume, particularly when compared to white oaks.

We have seen that oaks not only are highly valued species, but also represent most of the standing crop. As they dominate the forested landscape, it is no surprise that oaks also dominate removals. What we do not know is whether the industry, geared towards processing oak logs, will be able to adapt if the species mix changes.

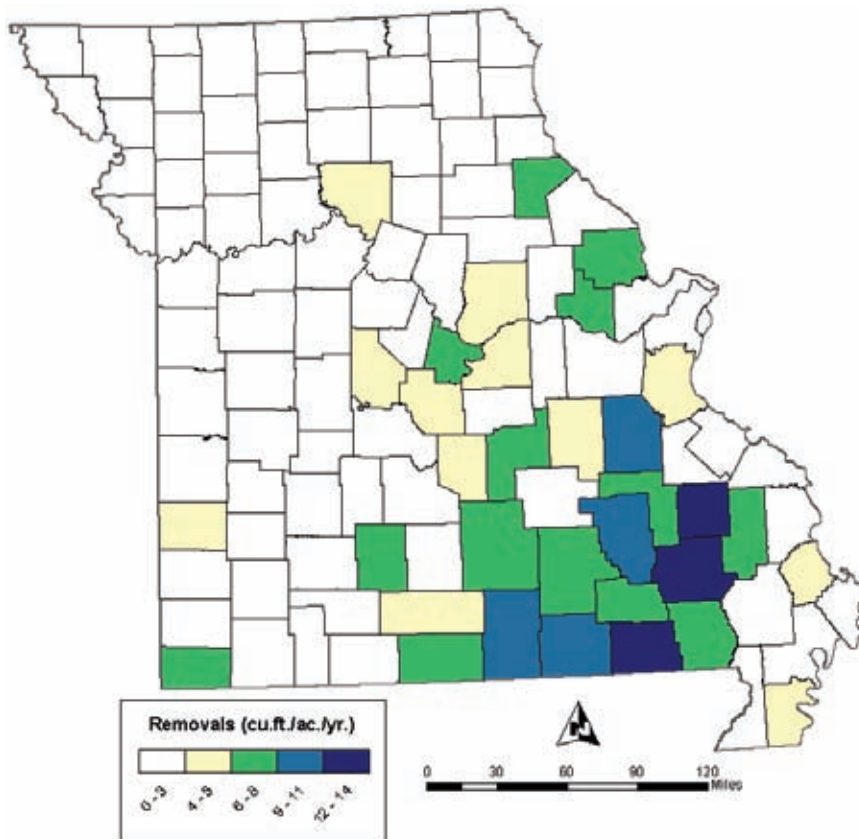


Figure 57.—The ratio of removals of growing stock on timberland, in cubic feet, divided by the total area of land in each county in Missouri, in acres 1989 to 1999-2003.

Products

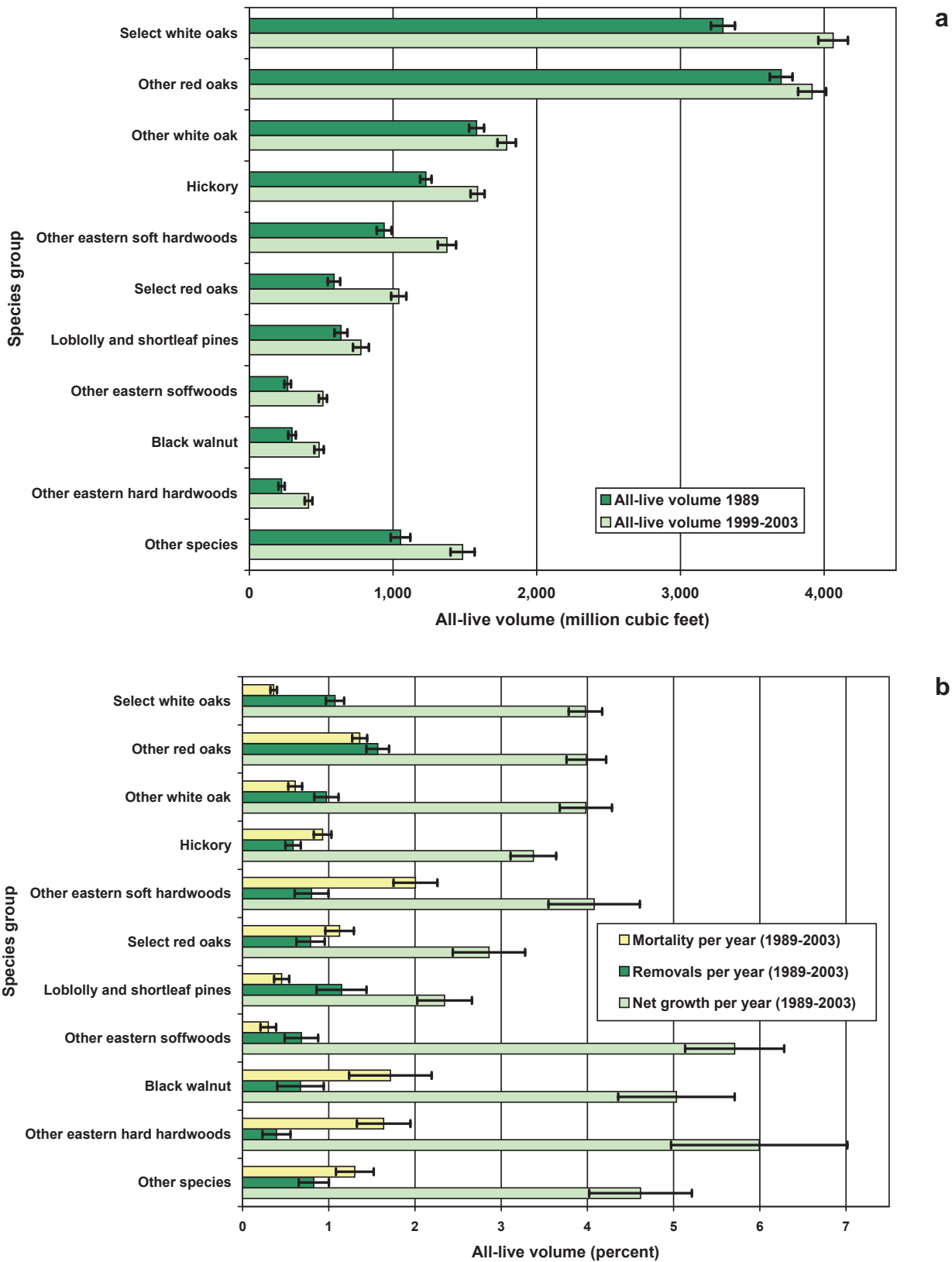


Figure 58.—a. All-live volume for the top 10 species groups in Missouri, 1989 and 1999-2003. b. Growth, removals, and mortality between 1989 and 1999-2003, expressed as a percentage of the 1999-2003 all-live volume, for the same species groups.



TIMBER PRODUCTS OUTPUT

Background:

Through the process of converting harvested trees into products such as lumber, veneer, or pulp, Missouri's forest resource provides income to both woodland owners and wood-processing mills. Removals, summarized in the previous section, include all removals of trees, not just harvesting for forest products. To better understand the effects of the primary wood use and manufacturing sector on the economy and its effects on the forests, it is important to monitor timber products output.

What We Found:

In 2003, Missouri's primary wood-using industry consisted of 371 sawmills, 8 cooperage mills, 8 post mills, 5 handle mills, 4 charcoal plants, 1 veneer mill, 1 pulp mill, and 6 mills producing other products. The total number of primary wood processors decreased by 36 mills from a survey conducted in 2000 (Treiman and Piva 2005). The primary wood-using mills in Missouri received more than 126 million cubic feet of industrial roundwood in 2003. More than 90 percent of the industrial roundwood processed in Missouri came from Missouri's forest land. Arkansas, Illinois, and Kentucky

contributed more than 80 percent of the total industrial roundwood imported into the State.

Industrial roundwood production for 2003 totaled 128.1 million cubic feet. The harvest of industrial roundwood from Missouri's forest land for saw logs accounted for more than 85 percent of the total industrial roundwood produced (Fig. 59). The Eastern Ozarks unit supplied 42 percent of the State's total industrial roundwood production (Fig. 60). Oaks were the most harvested species group, making up more than three-fourths of the total harvest. Other major species harvested for industrial roundwood were hickory, black walnut, shortleaf pine, and cottonwood (Fig. 61).

What This Means:

Most Missouri logs went to Missouri mills. While this means that the State's trees provide jobs for Missourians, it also means that the market for forest products is pretty much limited to in-state mills, which may restrict opportunities for Missouri's forest landowners to sell at the price they wish. Increasing opportunities to sell timber throughout the region as well as developing markets for non-oak timber would greatly benefit Missouri's forest landowners.

Products

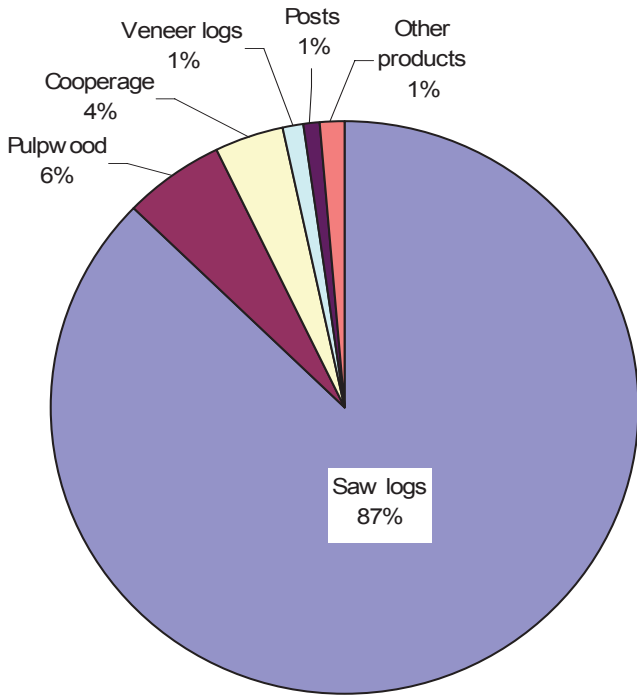


Figure 59.—Industrial roundwood production by product, Missouri, 2003.

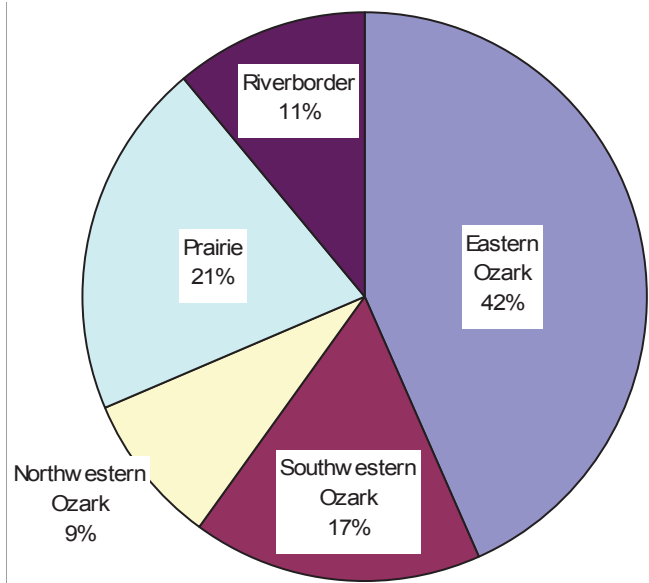


Figure 60.—Industrial roundwood production by Forest Survey Unit, Missouri, 2003.

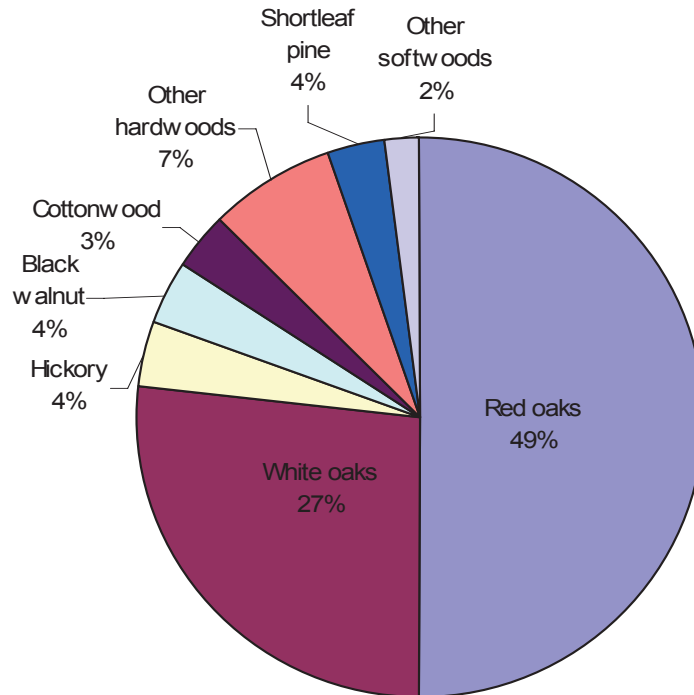


Figure 61.—Industrial roundwood production by species group, Missouri, 2003.

RESIDUES

Background:

Woody biomass from Missouri’s forests is not used completely; portions of the tree are left behind in the logging process. Decisions to leave wood behind depend on the mill’s needs and the logger’s consideration of potential value vs. the time it takes to process the wood on the site. For example, if a mill can process only railroad tie logs, then stems or large branches suitable for pulpwood might be left in the woods. Where there is a hardwood pulpwood market, such pieces might be harvested and taken to the mills.

What We Found:

In the process of harvesting industrial roundwood, 215.8 million cubic feet of wood material were removed from the forest land. Of this volume, 128.1 million cubic feet were used for industrial roundwood products and 87.7 million cubic feet were left on the ground as logging residues and slash. Growing-stock sources of industrial roundwood utilized 104.6 million cubic feet and left 25.1 million cubic feet of logging residues, while non-growing-stock sources utilized only 23.5 million cubic

feet and left 62.6 million cubic feet of logging slash on the ground.

There were 1.9 million green tons of mill residues produced at Missouri’s primary wood-using mills in 2003. Only 7 percent of the mill residues went unused (Fig. 62). Charcoal and miscellaneous products, such as livestock bedding and mulch, were the major uses of mill residue, consuming 33 and 29 percent, respectively, of the mill residues generated.

What This Means:

In the forest, harvesters of Missouri’s timber leave much woody material on the ground. Some of the underutilization may be the result of logger choice and might be reduced with more diverse markets or better training that allows the logger to recognize opportunity in every portion of the tree. In contrast, Missouri’s forest products industry appears to be quite efficient in utilizing mill residues. This efficiency could benefit landowners because purchasers of timber are able to pay more for stumpage knowing they will get more money for their product.

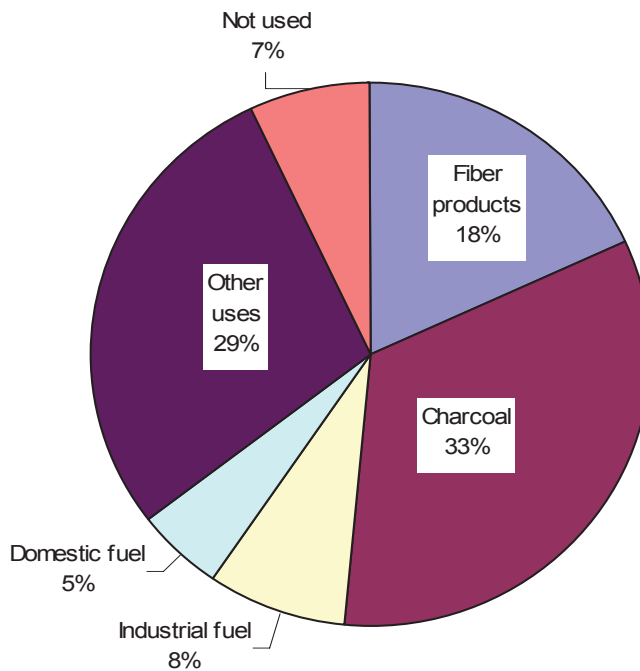


Figure 62.—Disposition of residues produced at primary wood-using mills, Missouri, 2003.

FOREST HEALTH

SOILS: THE FOUNDATION OF FOREST PRODUCTIVITY

Background:

Rich soils are the foundation of productive forest land. Inventory and assessment of the forest soil resource provides critical baseline information on forest health and productivity, especially in the face of continued natural and human disturbance.

What We Found:

The forests of Missouri are largely underlain by ultisols and alfisols of the Ozark Highlands (Fig. 63). Ultisols are identified by the presence of an illuvial clay horizon and base saturation less than 35 percent (USDA NRCS 2005). Both of these properties result from the movement of water through the soil profile, so these highly weathered soils with low native fertility are typically found in stable, older environments. Ultisols generally form under forests (Brady 1990). Alfisols are fertile soils generally possessing an illuvial clay horizon and a medium to high base saturation (USDA NRCS 2005). Most alfisols develop under deciduous forest (Brady 1990).

Soil samples were collected from 2001 to 2003, mostly in oak/hickory forests, so it is difficult to make meaningful comparisons with other forest types. Oak/pine forests are the only other forest type with more than two samples, and they tend to be found on higher quality soils than the oak/hickory forests. The mineral soils under these oak/pine forests appear to have a higher pH and greater amounts of carbon, nitrogen, and minerals summarized

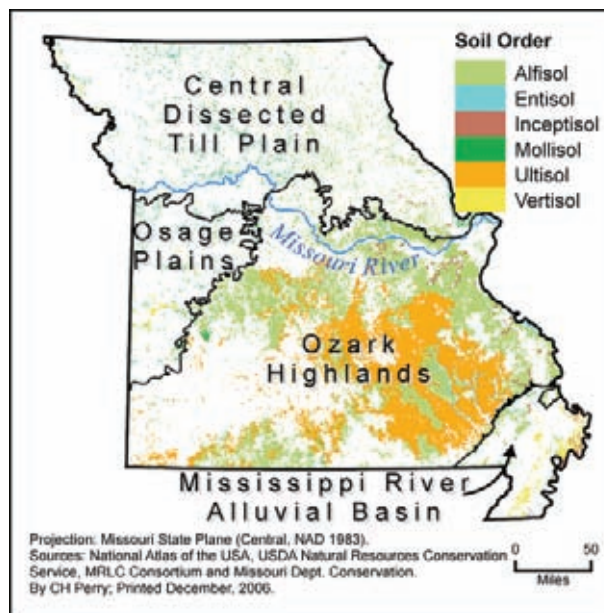


Figure 63.—Soil orders occurring on forest land and land type subsections of Missouri.

by effective cation exchange capacity (ECEC) than oak/hickory forests (Table 2). Curiously, the oak/pine forests appear to have lower levels of phosphorus, but it may not be a limiting nutrient in these landscapes. The oak/pine forests also appear to have lower levels of aluminum, an element that can be toxic in high quantities (Table 2). Soil quality index (SQI) is a new index designed to combine the distinct physical and chemical properties of the soil into a single, integrative assessment (Amacher and O’Neil, in prep). The primary forest soils of the Ozarks are generally of low quality, within both the State and region (Fig. 64). The Ozark forests also store less carbon in the soil than do the forest fragments in northern Missouri (Fig. 65).

Table 2.—Selected chemical properties of the mineral soil, Missouri, 2001-2003

Soil layer and forest type group	Number of samples	pH in H ₂ O	Carbon (percent)	Nitrogen (percent)	Phosphorus (mg/kg)	Aluminum (mg/kg)	ECEC (cmolc/kg)
Mineral (0-10 cm)							
Oak/hickory group	66	5.44	3.06	0.19	5.24	69.69	7.93
Oak/pine group	4	5.75	3.98	0.26	4.11	5.77	12.70
Mineral (10-20 cm)							
Oak/hickory group	63	5.24	1.20	0.09	4.96	105.10	5.90
Oak/pine group	4	5.79	2.24	0.17	3.04	5.38	9.46

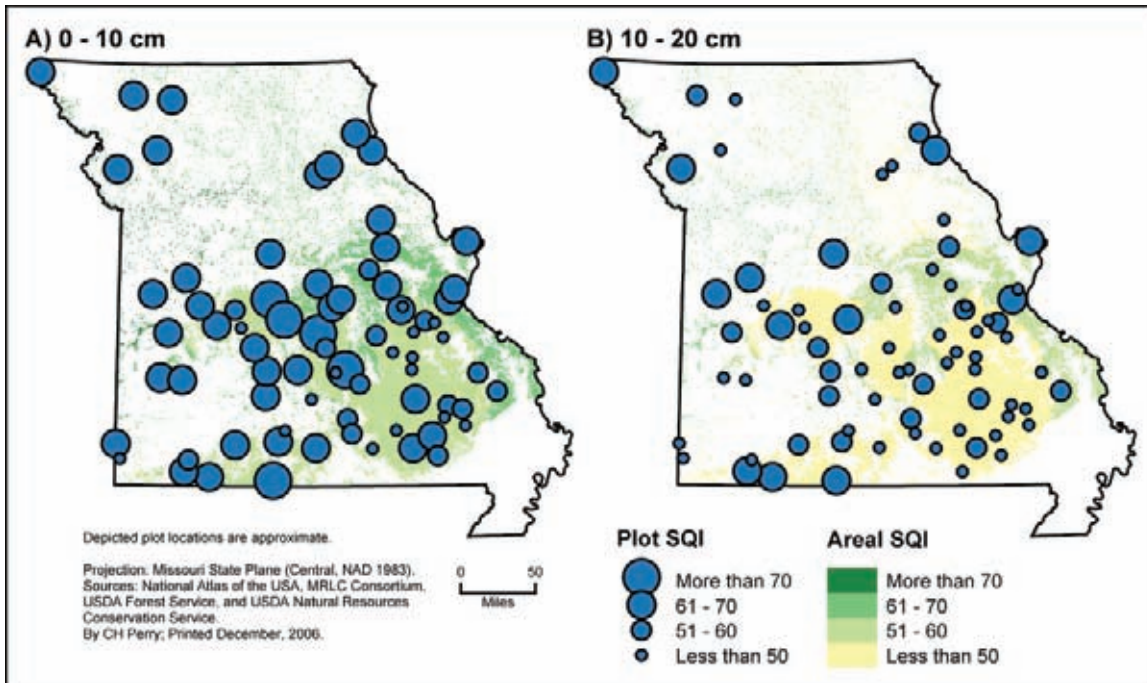


Figure 64.—Soil quality index values for plots and averaged across Major Land Resource Areas (MLRAs), Missouri, 2001-2003.

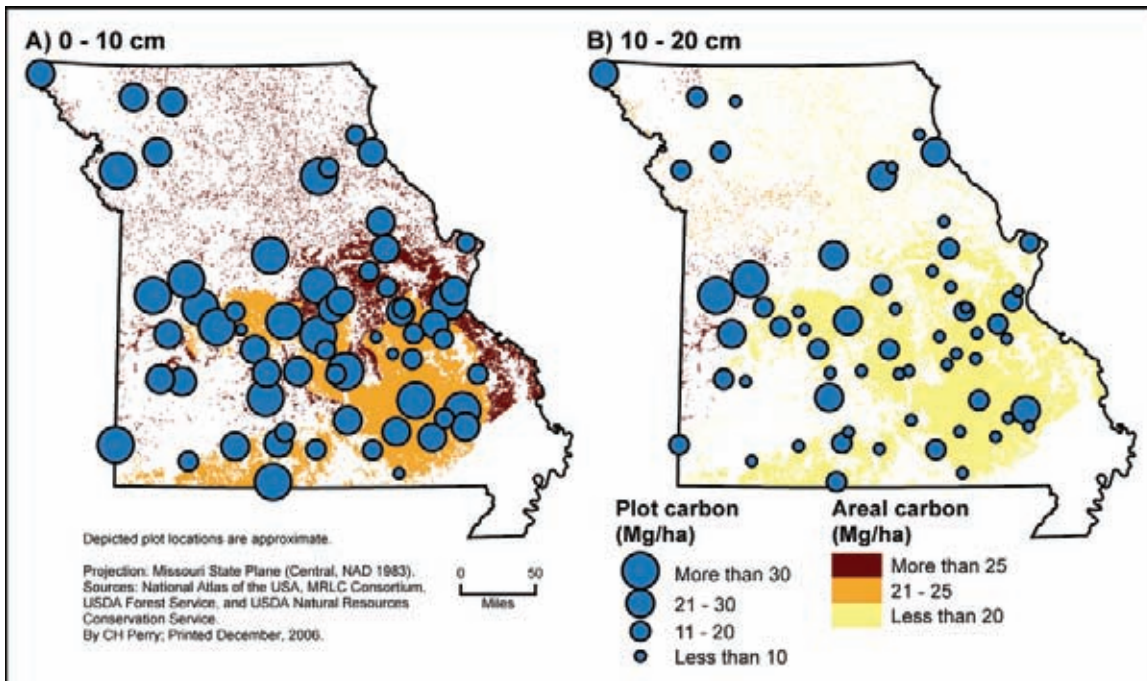


Figure 65.—Soil carbon sequestration observed on plots and averaged across Major Land Resource Areas (MLRAs), Missouri, 2001-2003.

The glacial geology of Missouri plays a profound role in the distribution of its forests and the quality of the underlying soils. The Central Dissected Till Plain was overrun by ice during the pre-Illinois glaciations; the Missouri River marks the approximate southern boundary of continental glaciation. The glaciers created a fertile soil that was largely converted to agriculture. The contiguous forest blocks in southern Missouri are concentrated in the Ozark Highland, a region that escaped glaciation. Without the glaciers, the landscapes were subjected longer to weathering and as a result tend to be less fertile. The quality of Missouri's forest soils is consistent with the historical conversion and use of the most productive landscapes for agriculture.

DOWN WOODY MATERIAL

Background:

Down woody material, in the form of fallen trees, branches, litterfall, and duff, fills a critical ecological niche in Missouri's forests. Down woody debris provides valuable wildlife habitat, largely determines forest fire behavior, and stores carbon for long periods.

What We Found:

The fuel loadings of down woody materials (fuel hour classes) were not exceedingly high in Missouri (Fig. 66). Missouri's loadings of 1-hour, 10-hour, and 100-hour fuels were not significantly different from those in nearby Indiana and Illinois. However, the loadings of the largest fuels (1,000+ hours) were significantly lower than in Indiana but higher than in Illinois. (Note that very few samples were collected for the down woody inventory in both Indiana and Illinois, hence the large standard errors for 1,000-hour fuels.) There was no apparent trend in total down woody fuel loadings (fine and coarse woody debris) among classes of live tree density in Missouri, although the highest fuel loadings often were associated with higher levels of standing tree density (Fig. 67). The size-class distribution of coarse woody debris appears to be heavily skewed (87 percent) toward pieces less than 8 inches in diameter (Fig. 68a). The

decay-class distribution of coarse woody debris appears to be dominated by moderate stages of decay across the State (Fig. 68b). The spatial distribution of coarse woody debris volume indicates the highest volumes of coarse woody debris were found in south-central Missouri (Fig. 69).

What This Means:

During the sampling of 2001–2003, Missouri's forests continued to show the effect of decades of oak decline. Although Missouri's coarse woody volumes were not abnormally high, they still may reflect recent years' mortality centered in the south-central forests of Missouri. On the other hand, the coarse woody debris represents a sizeable source of habitat for Missouri's wildlife, particularly for smaller fauna. Overall, the down woody materials in the State's forests do not pose a serious fire danger (except in times of drought).



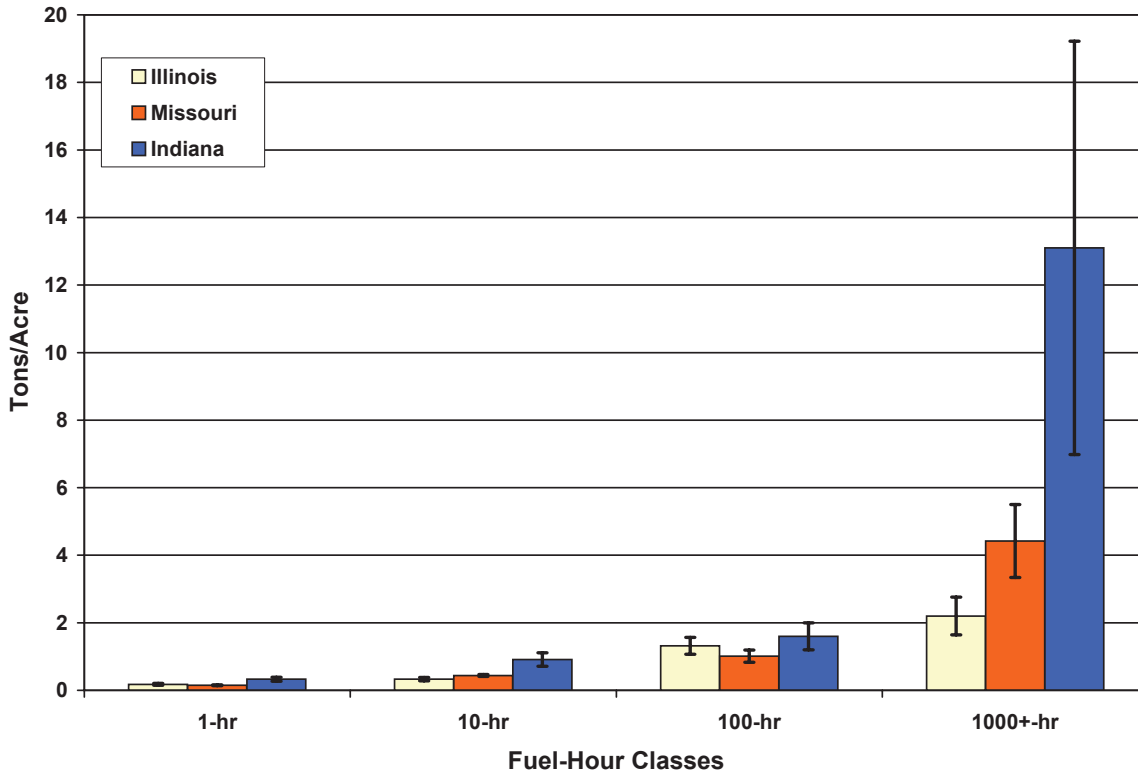


Figure 66.—Estimates of mean fuel loadings by fuel-hour class for Illinois, Missouri, and Indiana.

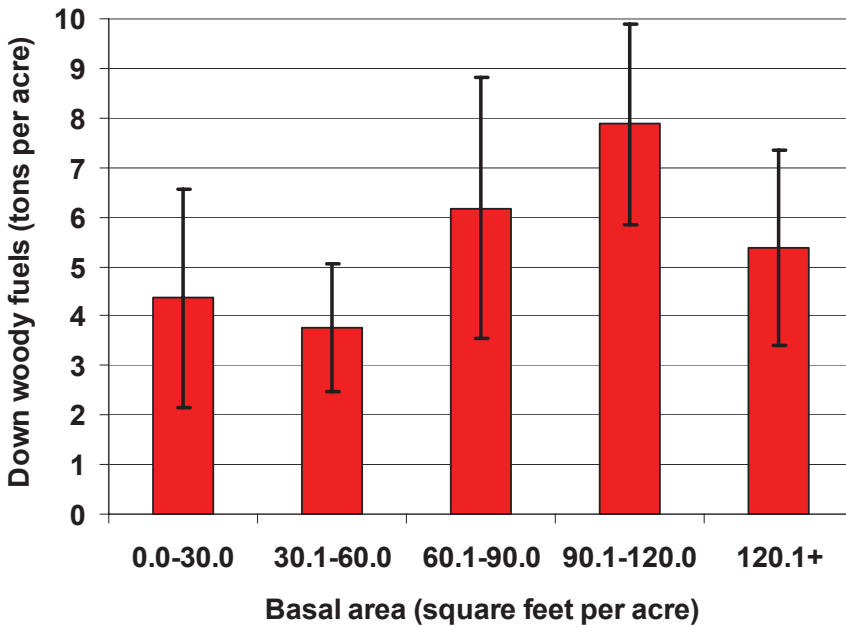


Figure 67.—Estimates of mean down woody fuels by stand density, Missouri, 2001-2003.

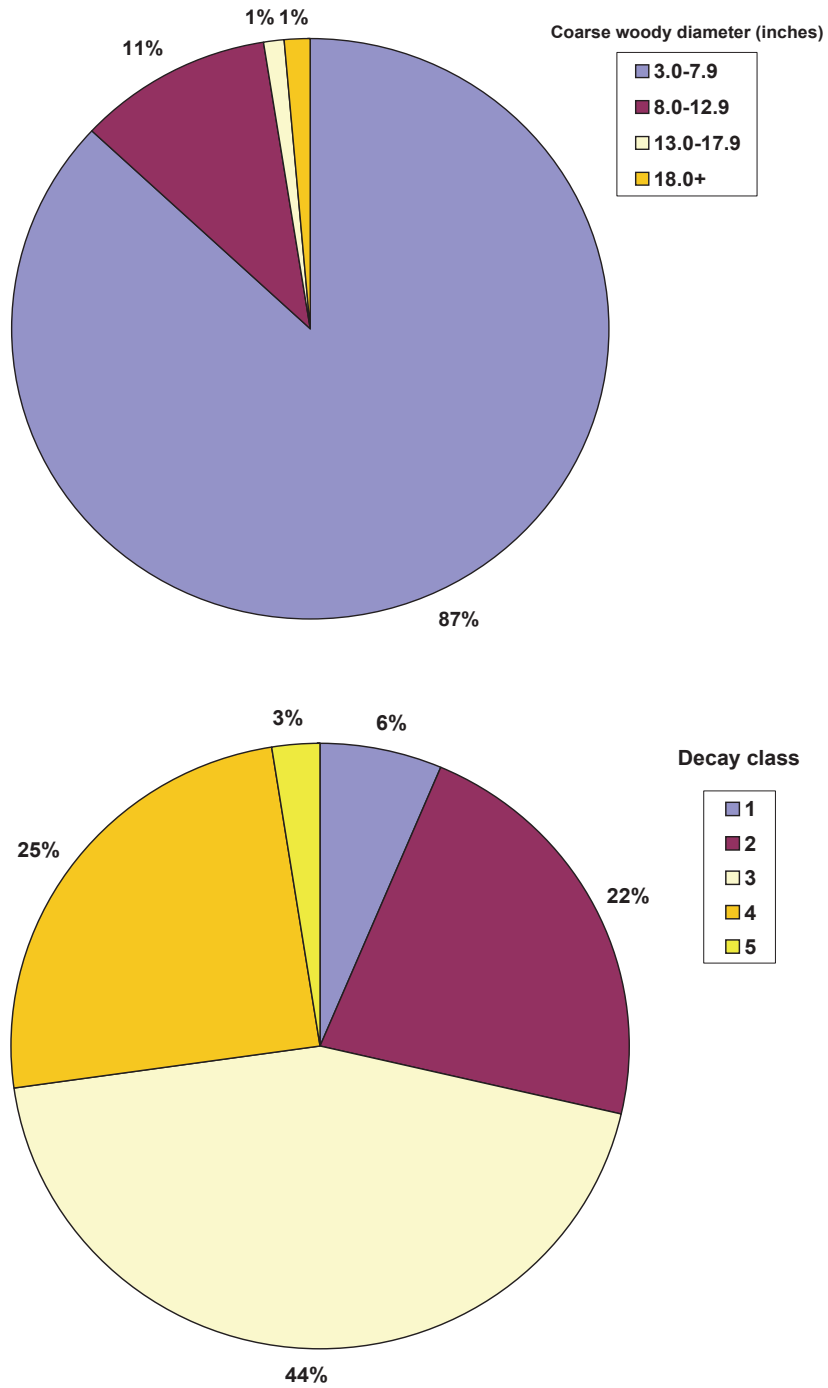


Figure 68.—Mean distribution of coarse woody debris (pieces per acre) by (a) size class and (b) decay class (1 = least decayed...5 = most decayed), Missouri, 2001-2003.

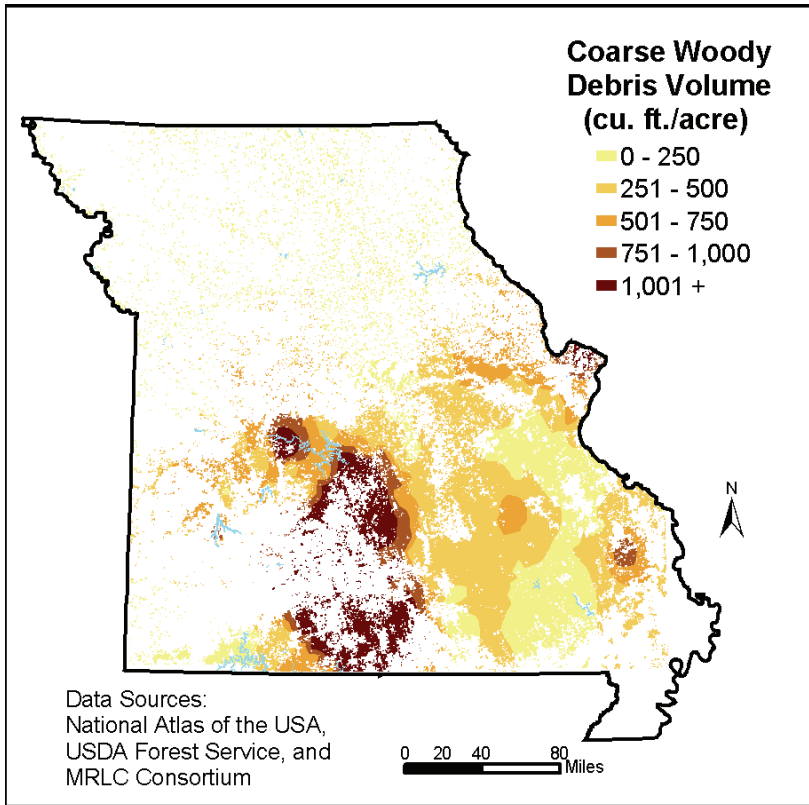


Figure 69.—Interpolated map of coarse woody debris volumes, Missouri, 2001-2003.

OZONE

Background:

The ozone layer we hear about in the news is made up of small concentrations of ozone in the stratosphere, an upper layer of Earth’s atmosphere. Ozone found in the troposphere, the lowest layer of the atmosphere, is usually caused by air pollution from car and truck engines and power plants. Although ozone is mainly produced in metropolitan areas, it is transported via prevailing winds and, therefore, may show elevated levels far from its source. Besides impacting human health, high levels of ozone can harm or even destroy agricultural crops and forest vegetation.

Ozone bioindicator data were first collected in Missouri in 2000, and the revised national ozone grid containing 41 plots was established in 2002. The most commonly sampled species in Missouri in rank order are common milkweed, black cherry, white ash, sassafras, dogbane, sweet gum, blackberry, and yellow poplar.

What We Found:

Ground level ozone exposures injured the foliage of sensitive understory and canopy tree species in Missouri between 2000 and 2002. The long-term productivity of ozone-sensitive species may be reduced by current peak hourly and seasonal ozone exposures (Table 3).

Missouri’s ozone exposures are among the highest in the North Central region. Bioindicator survey results were commensurate with these ozone exposures. All of the forests are subjected to elevated levels of ozone, but the

Table 3.—Bioindicator ozone injury information

Parameter	2000	2001	2002
Number of biosites	57	39	41
Percent of biosites with injury	33	33	21
Number of plants evaluated	2,912	2,678	4,242
Number of plants with injury	83	88	29
Average number of species per biosite	2.0	2.6	3.8

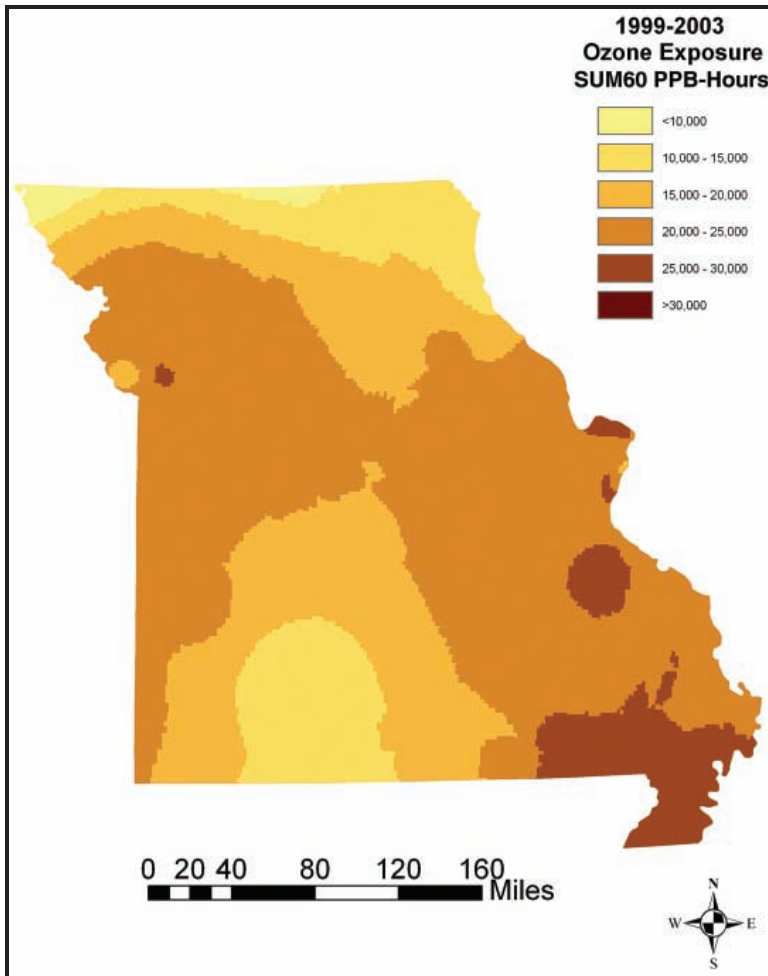


Figure 70.—Ozone concentrations in Missouri, 2003.

highest injury index scores, seasonal ozone exposures, and affected forest acreage are located in eastern Missouri (Fig. 70). The growth rates and biomass of seedlings and saplings of the species mentioned above have been reduced in controlled exposure studies at the ozone exposures observed in Missouri. Peak hourly ozone values more than 100 parts per billion and seasonal exposure exceeded thresholds suggested by the interagency Federal Land Managers Air Quality Group. Individual species within the forested landscape may have lower productivity, thus influencing overall competitiveness and forest composition.

Ozone damage is not equally distributed among the indicator species. Most of the injured plants were common milkweed. Injury was moderate to light on the other species. Yellow-poplar displayed ozone injury across

the State, but sweetgum and black cherry did not. These leaf injury surveys indicate that ozone injury occurred on 30 percent of the plots evaluated between 2000 and 2002. Most of the injury occurred during 2000 and 2001. About 2 percent of all evaluated plants had visible injuries over all survey years. Woody species had less injury than herbaceous understory species.

What This Means:

Missouri’s forests are exposed to ozone concentrations substantially above background levels. These ozone exposures are impacting ozone-sensitive native flora, particularly the common milkweed, an important source of food for monarch butterfly larvae. The potential effects of ozone stress should be less severe on the most common tree species, such as maples and oaks, because they are relatively tolerant of ozone. However, the current ozone

exposures, the confirming evidence of the foliar injury, and the overall injury scores do not bode well for growth and health in Missouri's forests, particularly for the ozone-sensitive bioindicator species.

UNDERSTORY VEGETATION: MORE THAN TREES

Background:

Understory vegetation is an important component of most forested ecosystems. By looking at diversity and abundance of vascular plant species, we may see indications of stresses such as pollution (e.g., ozone in the preceding section) or forest site degradation. Another indicator of disturbance is an increase in the amount of exotic species, many of which are early colonizers or pioneer species.

What We Found:

Understory vegetation sampling began in 2001, and 122 plots were sampled over the next 3 years. Virginia creeper was the most common understory vegetation species, found on 97 of the plots, followed by coralberry, eastern poison ivy, and white oak (Fig. 71).

What This Means:

Each plant community has its own history. Multiflora rose reflects the conversion of farmland to forest land. Eastern redcedar appears on land no longer disturbed by fire, cattle grazing, or other activities. Poison ivy is a common understory species on heavily disturbed sites throughout the Eastern United States. Because we have not yet completed a full 5-year cycle of sampling for understory vegetation, our conclusions are tentative. As we sample more plots, a more complete picture of Missouri's understory vegetation communities will emerge.



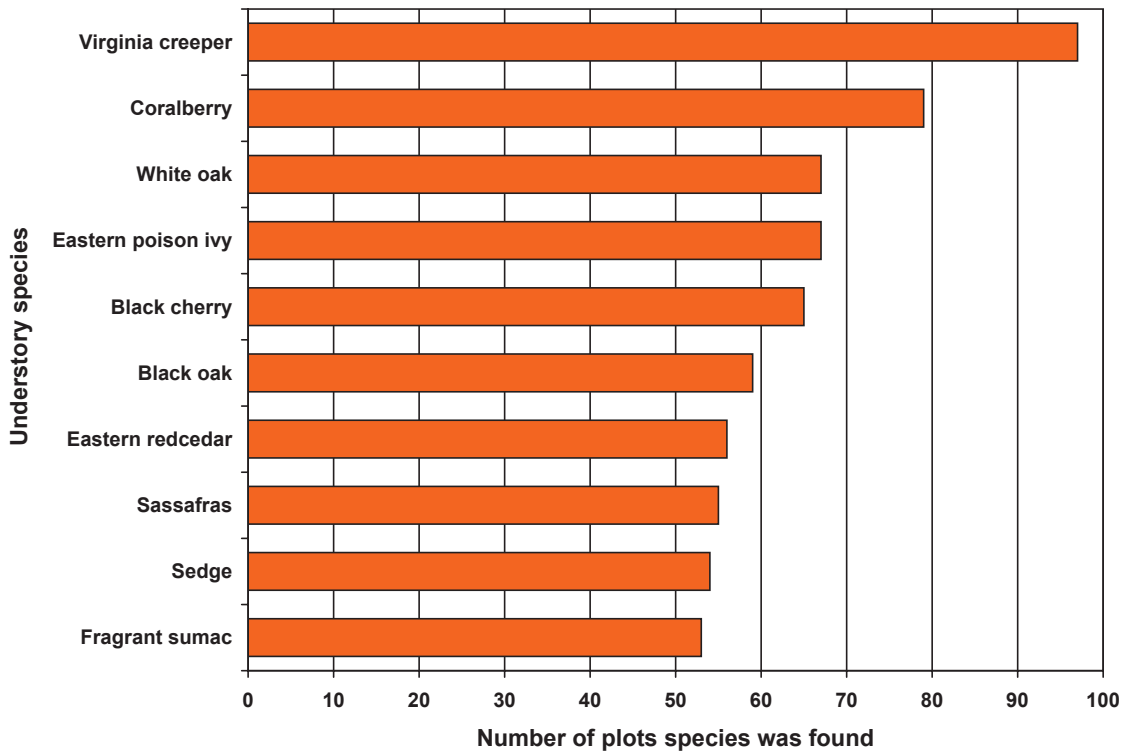


Figure 71.—Top 10 ground vegetation species sampled in Missouri, by number of plots out of a total of 122 phase 3 plots, 2001-2003.



NOT FROM HERE: NONNATIVE INVASIVE SPECIES IN MISSOURI

Invasive Plants

Background:

Thus far, our sampling has not detected a large number of exotic species. However, one prominent exotic species, multiflora rose, was the 19th most common ground vegetation species, found on 38 plots, including 11 plots in the 2003 panel (Fig. 72).

Emerald Ash Borer

Background:

In 2002, a previously undetected exotic beetle was discovered in southeastern Michigan and neighboring Ontario, Canada. Dubbed the emerald ash borer, this insect originated in Asia and probably came to North America in packing material. Here in the U.S., infested



ash trees usually die within 3 years, although death can occur in 1-2 years if the borer populations are at outbreak levels. Although ash rarely dominates the Missouri landscape, ash species are not uncommon in this State.

What We Found:

The proportion of ash in the overstory basal area is generally low (Fig. 73), although pockets of ash do exist, particularly near rivers. Total all-live volume of ash species increased by more than 100 million cubic feet between 1989 and 2003. There was also a significant increase in the number of trees 1 inch in diameter and greater and a much less substantial increase in the number of trees 5 inches in diameter and greater between the two inventories (Fig. 74). Trends in net all-live ash volume on timberland varied by inventory unit. Ash volume decreased slightly in the Eastern Ozarks unit and increased in the other four units, particularly the Prairie unit (Fig. 75).

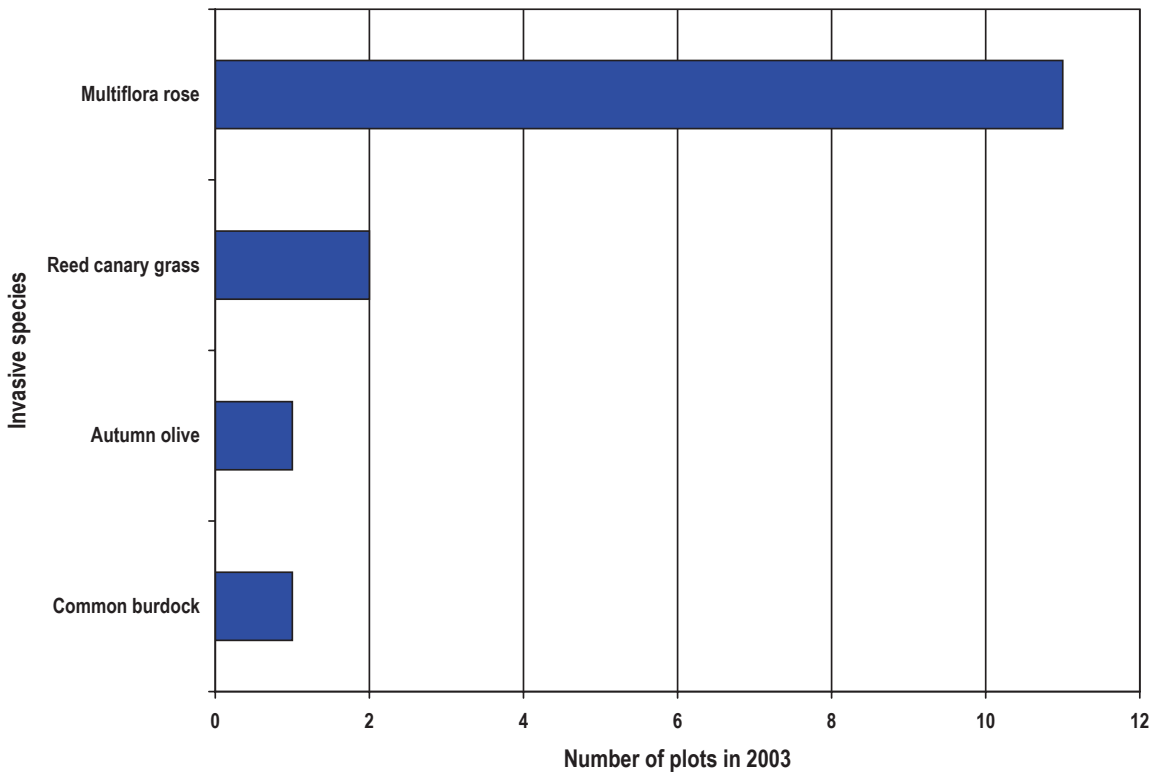


Figure 72.—Total number of plots in Missouri where nonnative invasive ground vegetation species were found, out of a total of 39 phase 3 plots, 2003.

What This Means:

Emerald ash borer is a serious forest health problem, killing almost all infested trees within a few years. Ash species are not as important a component of the forest landscape in Missouri as in other eastern States, but localized effects of emerald ash borer could be dramatic.

transportation—gypsy moths should arrive in Missouri by the middle of the 21st century.

Gypsy Moth

Background:

Since its accidental introduction into the United States around 1868, the gypsy moth has slowly spread south and west. The western edge of the generally infested area extends into southwestern Ohio, northeastern Indiana, and Wisconsin. Over the last century, the insect has caused much damage to northeastern forests, particularly those with high proportions of oaks. Where gypsy moth has become established, outbreaks occur intermittently every 5 to 15 years (Williams and Liebhold 1995). The expanding front of gypsy moth defoliation is less than 500 miles from Missouri, and at the current rate of spread—barring a leap-frog advance via inadvertent

Gypsy moth populations in North America can feed on more than 300 different shrub and tree species, which Liebhold et al. (1995) separated into three risk categories



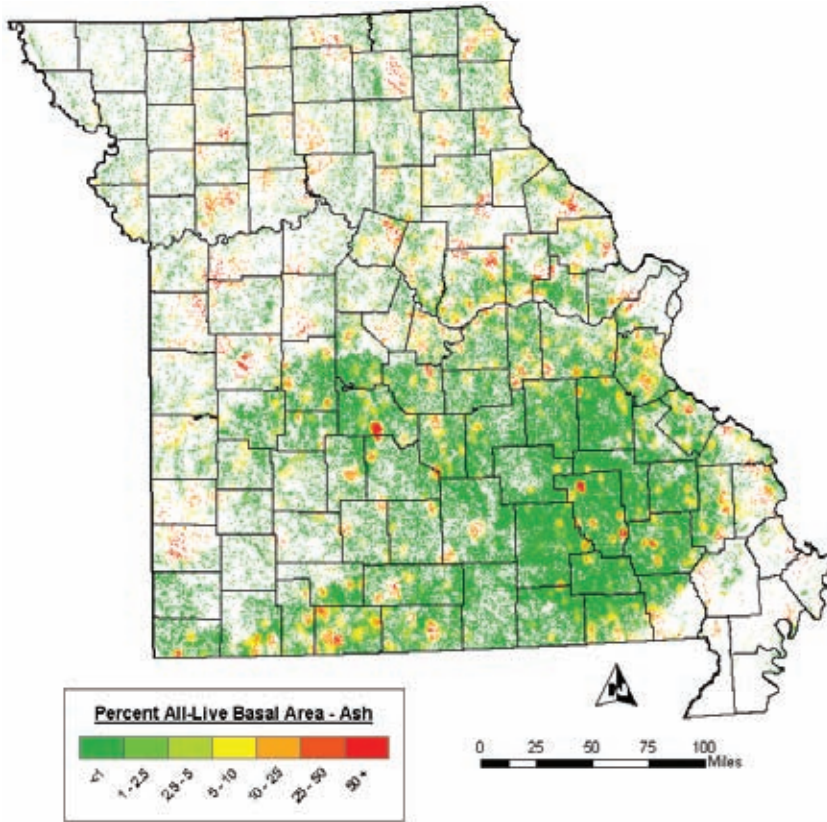


Figure 73.—Percentage of all-live basal area of ash species in Missouri, 1999-2003.

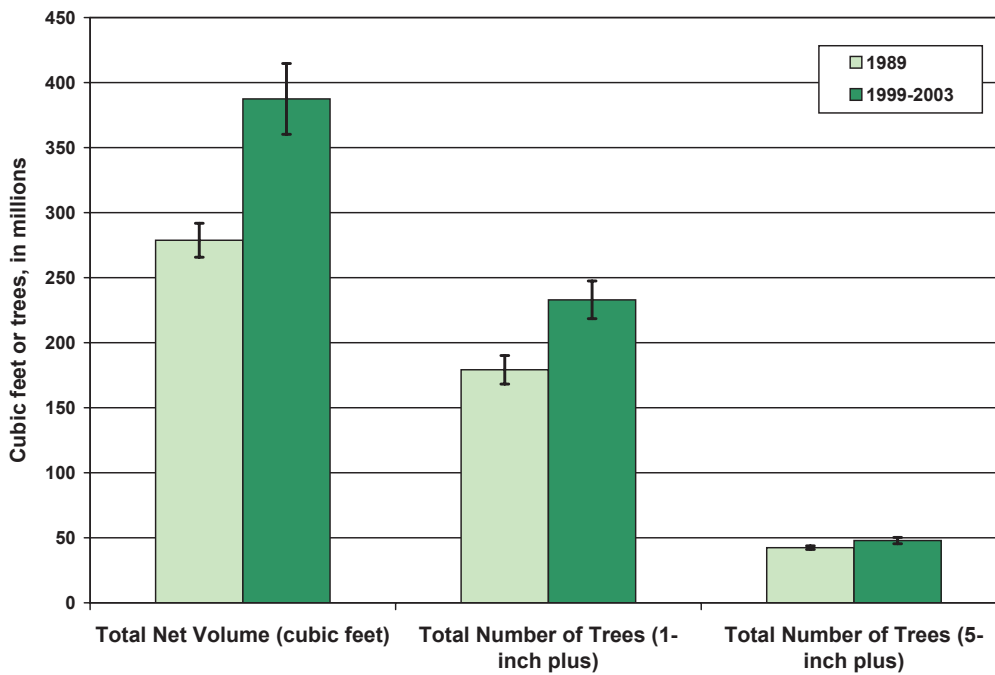


Figure 74.—Total net all-live volume and total number of trees 1 inch and larger and 5 inches and larger of ash species in Missouri, 1989 and 1999-2003.

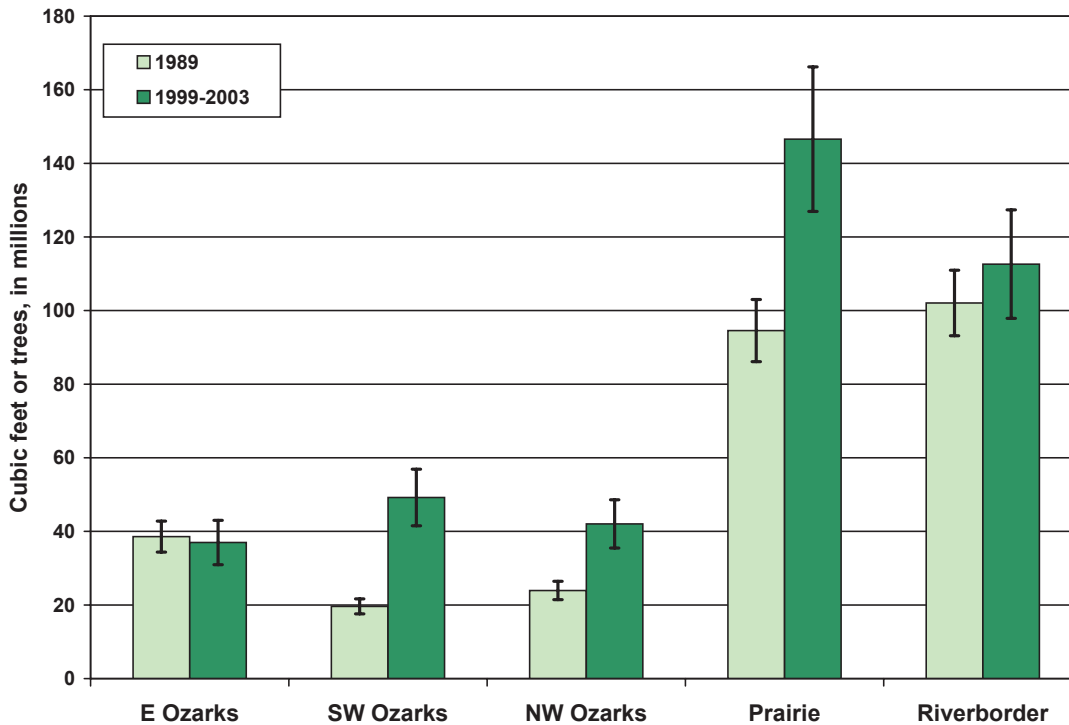


Figure 75.—Net all-live volume of ash species on timberland in Missouri, by inventory year and inventory unit.

of defoliation: susceptible, resistant, and immune. Susceptible species are those tree species preferred by the gypsy moth larvae. Many scientists have looked at forest stands and susceptibility to gypsy moth defoliation; the common factor in all of the models is basal area of susceptible species. The resistant category contains species the insect will defoliate only if there are no susceptible species to eat. Immune species are those which gypsy moths will not eat under any circumstances. Using this ranking system, Missouri tree species were assigned to one of the three categories of defoliation risk.

What We Found:

The first category, susceptible, contains 42 species common to the State, including most oak species. The 53 species in the second category, resistant, include shortleaf pine, elm and maple species, and cottonwood. Figure 76 displays the percentage of all-live-tree basal area on timberland of species considered (A) susceptible and (B) combined susceptible and resistant. The number of trees 1 inch and larger in diameter in both categories barely changed between 1989 and 2003. The number of

trees 5 inches and larger increased only slightly in most of Missouri, and actually declined in the Riverborder inventory unit.

What This Means:

Gypsy moth is coming to Missouri, and the State’s forests are at risk. Substantial all-live volume is in the susceptible class; if all these trees were to die, the effect on the landscape would be dramatic. The twin threats of greater susceptible volume and decreasing number of trees point to the potential for even greater devastation, especially for large trees. The rule of thumb is that a tree surviving two defoliations has a good chance of outliving a gypsy moth infestation. Larger, older (and often, slower growing) trees are less likely to survive. We have learned a lot about this insect and can implement practices to increase the survival chances of Missouri’s forests. Gottschalk (1993) outlined decision rules that can assist foresters in reducing gypsy moth’s impact on forest stands. Two methods are reducing the number of susceptible trees and increasing the vigor of those trees that remain on the landscape.

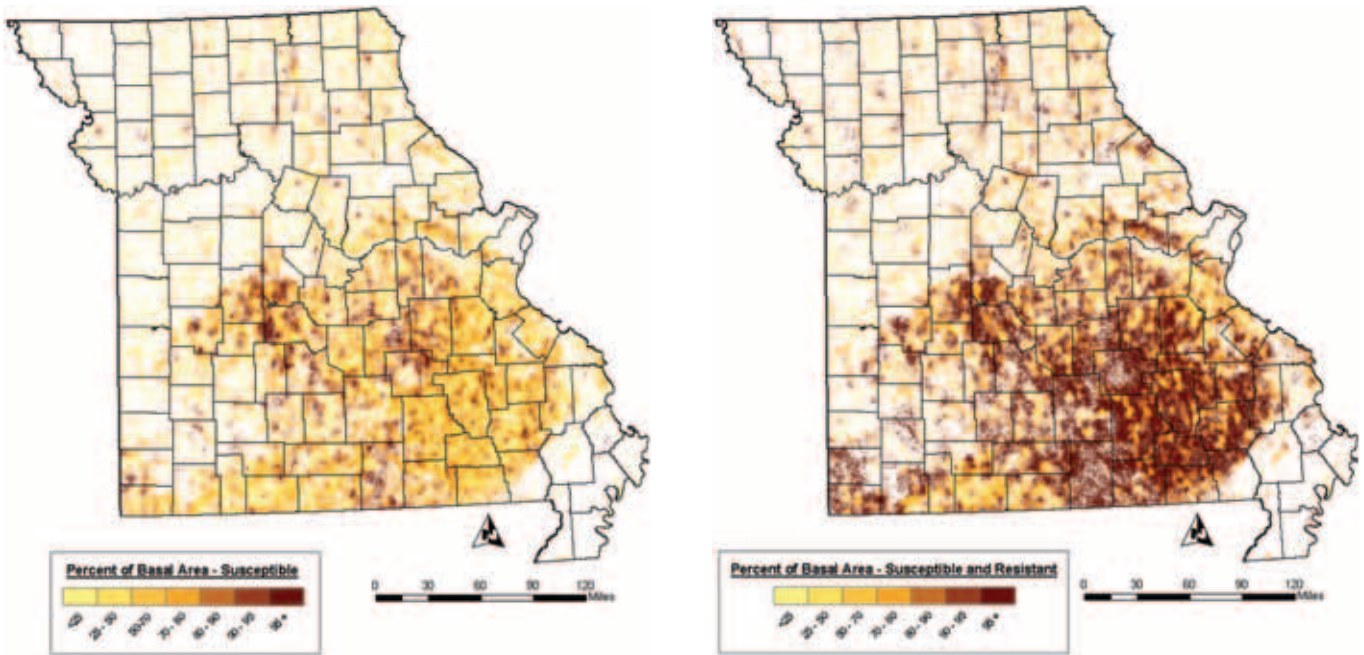


Figure 76.—Percentage of total all-live basal area of “susceptible” and the combined “susceptible” and “resistant” (to gypsy moth defoliation) categories in Missouri, 1999-2003.

DATA SOURCES AND TECHNIQUES

FOREST INVENTORY

The North Central Research Station's Forest Inventory and Analysis (NCFIA) program began fieldwork for the fifth inventory of Missouri's forest resources in 1999. This inventory launched the new annual inventory system in which one-fifth of the field plots (considered one panel) in the State are measured each year. In 2003, NCFIA completed measurement of the fifth and final panel of inventory plots in Missouri. Now that all panels have been measured, each will be remeasured approximately every 5 years. Previous inventories of Missouri occurred in 1947, 1959, 1972, and 1989 (Gansner 1965, Spencer and Essex 1976, Spencer et al. 1992, USDA 1948).

Data from new inventories are often compared with data from earlier inventories to determine trends in forest resources. However, for the comparisons to be valid, the procedures used in the two inventories must be similar. As a result of our ongoing efforts to improve the efficiency and reliability of the inventory, several changes in procedures and definitions have been made since the last Missouri inventory in 1989 (Spencer et al. 1992). Although these changes will have little effect on statewide estimates of forest area, timber volume, and tree biomass, they may significantly affect plot classification variables such as forest type and stand-size class. For estimating growth, removals, and mortality, the 1989 inventory (Spencer et al. 1992) was processed using estimation/summary routines for the 1999-2003 inventory. Although these changes allow limited comparison of inventory estimates among separate inventories in this report, it is inappropriate to directly compare all portions of the 1999-2003 data with those published for earlier inventories.

The 2003 Missouri forest inventory was done in three phases. During the first phase, FIA used a computer-assisted classification of satellite imagery to form two initial strata—forest and nonforest. Pixels within 60 m (2 pixel widths) of a forest/nonforest edge formed

two additional strata—forest/nonforest and nonforest/forest. Forest pixels within 60 m on the forest side of a forest/nonforest boundary were classified into a forest edge stratum. Pixels within 60 m of the boundary on the nonforest side were classified into a nonforest edge stratum. The estimated population total for a variable is the sum across all strata of the product of each stratum's estimated area and the variable's estimated mean per unit area for the stratum.

The second phase of the forest inventory consisted of the actual field measurements. Current FIA precision standards for annual inventories require a sampling intensity of one plot for approximately every 6,000 acres. FIA has divided the entire area of the United States into nonoverlapping hexagons, each of which contains 5,937 acres (McRoberts 1999). The total Federal base sample of plots was systematically divided into five interpenetrating, nonoverlapping subsamples or panels. The Mark Twain National Forest supported double intensity sampling on its lands. The Missouri Department of Conservation contributed the services of seven foresters to allow double intensity sampling in the Eastern Ozark and Riverborder inventory units. These units had a sampling intensity of one plot per approximately 3,000 acres. Each year the plots in a single panel are measured, and panels are selected on a 5-year, rotating basis (McRoberts 1999). For estimation purposes, the measurement of each panel of plots may be considered an independent systematic sample of all land in a State. Field crews measure vegetation on plots forested at the time of the last inventory and on plots currently classified as forest by trained photointerpreters using aerial photos or digital orthoquads.

NCFIA has two categories of field plot measurements—phase 2 field plots (standard FIA plots) and phase 3 plots (forest health plots) to optimize our ability to collect data when available for measurement. A suite of tree and site attributes are measured on phase 2 plots, and a full suite of forest health variables are measured on phase 3 plots. Both types of plots are uniformly distributed both geographically and temporally. The 1999–2003 annual

inventory results represent field measures on 4,632 phase 2 forested plots and 220 phase 3 plots.

The overall phase 2 plot layout consists of four subplots. The centers of subplots 2, 3, and 4 are located 120 feet from the center of subplot 1. The azimuths to subplots 2, 3, and 4 are 0, 120, and 240 degrees, respectively. Trees with a d.b.h. 5 inches and larger are measured on a 24-foot-radius (1/24 acre) circular subplot. All trees less than 5 inches d.b.h. are measured on a 6.8-foot-radius (1/300 acre) circular microplot located 12 feet east of the center of each of the four subplots. Forest conditions that occur on any of the four subplots are recorded. Factors that differentiate forest conditions are changes in forest type, stand-size class, land use, ownership, and density. For details on the sample protocols for phase 2 variables and all phase 3 indicators, please refer to <http://fia.fs.fed.us/library/fact-sheets/>.

TIMBER PRODUCTS INVENTORY

This study was a cooperative effort of the Missouri Department of Conservation (MDC) and the North Central Research Station (NCRS). Using questionnaires supplied by NCRS and designed to determine the size and composition of the State's primary wood-using industry, its use of roundwood (round sections cut from trees), and its generation and disposition of wood residues, MDC visited all known primary wood-using mills within the State. This allowed for a 100-percent response rate. Completed questionnaires were sent to NCRS for editing and processing.

As part of data editing and processing, all industrial roundwood volumes reported on the questionnaires were converted to standard units of measure using regional conversion factors. Timber removals by source of material and harvest residues generated during logging were estimated from standard product volumes using factors developed from logging utilization studies previously conducted by NCRS. Finalized data on Missouri's industrial roundwood receipts were loaded into a regional timber removals database where they were supplemented with data on out-of-State uses in Missouri roundwood

to provide a complete assessment of Missouri's timber product output.

NATIONAL WOODLAND LANDOWNER SURVEY

This survey of private woodland owners is conducted annually by the USDA Forest Service to increase our understanding of these owners—the critical link between forests and society. Every year, questionnaires are mailed to individuals and private groups who own the woodlands where FIA established forest inventory plots. Twenty percent of these ownerships (about 50,000) are contacted each year with more detailed questionnaires sent out in years that end in 2 or 7 to coincide with national census, inventory, and assessment programs. The target accuracies of the data are plus or minus 10 percent at the State level.

NLCD IMAGERY

Derived from Landsat Thematic Mapper satellite data (30-m pixel), the National Land Cover Data (NLCD) is a 21-class land cover classification scheme applied consistently across the United States by the U.S. Geological Survey (USGS) and the U.S. Environmental Protection Agency (EPA). The NLCD was developed from data acquired by the Multi-Resolution Land Characterization (MRLC) Consortium, a partnership of Federal agencies that produce or use land cover data. Partners include the USGS (National Mapping, Biological Resources, and Water Resources Divisions), EPA, the USDA Forest Service, and the National Oceanic and Atmospheric Administration.

MAPPING PROCEDURES

Maps in this report were constructed by either the categorical coloring of Missouri counties (based on the 1990 U.S. Census) according to forest attributes (such as forest land area) or the interpolation of forest attributes. Because the forest inventory is only a statistically based sample of forest at distinct points in Missouri, inferences must be made about the entirety of Missouri's forests. Interpolation of attributes between plot locations allows us to create forest attribute maps of the entire area of the State. Inverse Distance Weighting

(IDW), the interpolation method used in this report, assumes that things close to one another are more alike than those farther apart. For more information, see Johnston et al. (2001).

DATA SOURCES

Unless specifically cited, maps in this publication have the following data sources:

Political boundaries: ESRI™ Data and Maps, 2002

Forest/Nonforest cover: MRLC Consortium National Land Cover Database, 1992

Tree biological data: Forest Inventory and Analysis Database

Maps produced by:

Forest Inventory and Analysis (FIA)

Northern Research Station

USDA Forest Service

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TREE SPECIES IN MISSOURI, 1999-2003

eastern redcedar	<i>Juniperus virginiana</i>
shortleaf pine	<i>Pinus echinata</i>
eastern white pine	<i>Pinus strobus</i>
Scotch pine	<i>Pinus sylvestris</i>
baldcypress	<i>Taxodium distichum</i>
boxelder	<i>Acer negundo</i>
black maple	<i>Acer nigrum</i>
red maple	<i>Acer rubrum</i>
silver maple	<i>Acer saccharinum</i>
sugar maple	<i>Acer saccharum</i>
buckeye, horsechestnut spp.	<i>Aesculus spp.</i>
Ohio buckeye	<i>Aesculus glabra</i>
ailanthus	<i>Ailanthus altissima</i>
European alder	<i>Alnus glutinosa</i>
serviceberry spp.	<i>Amelanchier spp.</i>
pawpaw	<i>Asimina triloba</i>
river birch	<i>Betula nigra</i>
chittamwood, gum bumelia	<i>Sideroxylon lanuginosum</i>
American hornbeam, musclewood	<i>Carpinus caroliniana</i>
water hickory	<i>Carya aquatica</i>
bitternut hickory	<i>Carya cordiformis</i>
pignut hickory	<i>Carya glabra</i>
pecan	<i>Carya illinoensis</i>
shellbark hickory	<i>Carya laciniosa</i>
shagbark hickory	<i>Carya ovata</i>
black hickory	<i>Carya texana</i>
mockernut hickory	<i>Carya alba</i>
American chestnut	<i>Castanea dentata</i>
northern catalpa	<i>Catalpa speciosa</i>
sugarberry	<i>Celtis laevigata</i>
hackberry	<i>Celtis occidentalis</i>
eastern redbud	<i>Cercis canadensis</i>
flowering dogwood	<i>Cornus florida</i>
hawthorn spp.	<i>Crataegus spp.</i>
cockspur hawthorn	<i>Crataegus crus-galli</i>
downy hawthorn	<i>Crataegus mollis</i>
common persimmon	<i>Diospyros virginiana</i>
American beech	<i>Fagus grandifolia</i>
white ash	<i>Fraxinus americana</i>

Tree species in Missouri, 1999-2003—continued

green ash	<i>Fraxinus pennsylvanica</i>
blue ash	<i>Fraxinus quadrangulata</i>
waterlocust	<i>Gleditsia aquatica</i>
honeylocust	<i>Gleditsia triacanthos</i>
Kentucky coffeetree	<i>Gymnocladus dioicus</i>
butternut	<i>Juglans cinerea</i>
black walnut	<i>Juglans nigra</i>
sweetgum	<i>Liquidambar styraciflua</i>
yellow-poplar	<i>Liriodendron tulipifera</i>
Osage-orange	<i>Maclura pomifera</i>
cucumbertree	<i>Magnolia acuminata</i>
apple spp.	<i>Malus spp.</i>
mulberry spp.	<i>Morus spp.</i>
white mulberry	<i>Morus alba</i>
red mulberry	<i>Morus rubra</i>
water tupelo	<i>Nyssa aquatica</i>
blackgum	<i>Nyssa sylvatica</i>
swamp tupelo	<i>Nyssa biflora</i>
eastern hophornbeam	<i>Ostrya virginiana</i>
American sycamore	<i>Platanus occidentalis</i>
eastern cottonwood	<i>Populus deltoides</i>
bigtooth aspen	<i>Populus grandidentata</i>
swamp cottonwood	<i>Populus heterophylla</i>
cherry and plum spp.	<i>Prunus spp.</i>
black cherry	<i>Prunus serotina</i>
chokecherry	<i>Prunus virginiana</i>
American plum	<i>Prunus americana</i>
white oak	<i>Quercus alba</i>
swamp white oak	<i>Quercus bicolor</i>
scarlet oak	<i>Quercus coccinea</i>
northern pin oak	<i>Quercus ellipsoidalis</i>
southern red oak	<i>Quercus falcata</i>
cherrybark oak	<i>Quercus pagoda</i>
shingle oak	<i>Quercus imbricaria</i>
overcup oak	<i>Quercus lyrata</i>
bur oak	<i>Quercus macrocarpa</i>
blackjack oak	<i>Quercus marilandica</i>
swamp chestnut oak	<i>Quercus michauxii</i>
chinkapin oak	<i>Quercus muehlenbergii</i>

Tree species in Missouri, 1999-2003—continued

pin oak	<i>Quercus palustris</i>
willow oak	<i>Quercus phellos</i>
chestnut oak	<i>Quercus prinus</i>
northern red oak	<i>Quercus rubra</i>
Shumard oak	<i>Quercus shumardii</i>
post oak	<i>Quercus stellata</i>
black oak	<i>Quercus velutina</i>
black locust	<i>Robinia pseudoacacia</i>
willow spp.	<i>Salix spp.</i>
peachleaf willow	<i>Salix amygdaloides</i>
black willow	<i>Salix nigra</i>
sassafras	<i>Sassafras albidum</i>
American basswood	<i>Tilia americana</i>
white basswood	<i>Tilia heterophylla</i>
elm spp.	<i>Ulmus spp.</i>
winged elm	<i>Ulmus alata</i>
American elm	<i>Ulmus americana</i>
Siberian elm	<i>Ulmus pumila</i>
slippery elm	<i>Ulmus rubra</i>
rock elm	<i>Ulmus thomasii</i>
smoketree	<i>Cotinus obovatus</i>

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The first completed annual inventory of Missouri's forests reports more than 14.6 million acres of forest land. Softwood forests make up 4 percent of the total forest land area; oak/hickory forest types make up about three-fourths of the total hardwood forest land area. Missouri's forests have continued to increase in volume, with all-live tree volume on forest land in Missouri an estimated 18 billion cubic feet compared to 9 billion cubic feet in 1972. All-live tree biomass on forest land in Missouri amounted to 573 million dry tons in 1999-2003. Almost 9 percent was in small trees, 74 percent was in growing-stock trees, and 17 percent was in non-growing-stock trees. Softwood growth was 44.1 million cubic feet per year and hardwood growth was 585.3 million cubic feet per year. Oak species constitute roughly three-fourths of the volume and three-fourths of the harvest. Total net all-live volume of oaks on timberland increased by 24 percent between 1989 and 2003. More than 82 percent of Missouri's forest land is held by private landowners.

KEY WORDS: forest area, forest health, completed annual inventory, Missouri

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