Michigan's Forests

2004

Resource Bulletin
NRS-34

USDA United States Department of Agriculture
Forest Service
Northern Research Station

Acknowledgments

We thank members of the field crew for their hard work and dedication while collecting the information that is the basis for this report.

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Andrew Bird
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Benjamin Williams
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Kevin Yazzie
Craig Yost
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Special thanks go to Gary Brand, Patrick Miles, John Vissage, Ron Piva, Mark Majewsky, Charles Paulson, Beth Schulz, Gretchen Smith, John Coulston, Barry Wilson, and Edward Schools, who also contributed to this report.

Cover photo: Lookout from Brockway Mountain in Keweenaw County, Michigan. Photo by Scott A. Pugh, U.S. Forest Service.

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Manuscript received for publication
August 2008

Published by:
USDA Forest Service
Northern Research Station
11 Campus Blvd, Suite 200
Newtown Square, PA 19073-3294
June 2009

For additional copies:
USDA Forest Service
Publications Distribution
359 Main Road
Delaware, OH 43015-8640
Fax: 740-368-0152

Visit our website:
www.nrs.fs.fed.us

Foreword

Michigan is a state like no other in the Nation with two peninsulas and a large latitudinal gradient. From the warmer agriculture and urban areas in the south to the colder wooded lands in the north, the State offers unique ecosystems, land uses, and one of the most diverse forests in the United States.

Nearly all of the forest land in Michigan was cut and/or burned during European settlement (Dickmann and Leefers 2003). The bulk of the lumber boom and most of the fires occurred in the late 1800s and early 1900s. By 1920, the lumber boom had ended and secondary succession was in full swing with the recovery of the forests. Since then, these forests have been maturing. Today, Michigan has more forest land than any other state in the Northeast or Midwest. And, Michigan's State Forests and a number of large private ownerships are certified as practicing sustainable forestry through the Forest Stewardship Council (FSC) and the Sustainable Forestry Initiative (SFI). The U.S. National Forests are managed under the National Forest Management Act and National Environmental Protection Act. There also are numerous assistance programs to help small forest-land owners. Nonetheless, there are a number of factors that could threaten forests in coming years. Some of these include invasive pests, fragmentation and parcelization, multiple land-use pressures, and climate change.

The status and trends of forest resources can indicate whether Michigan's forests are being managed in a healthy manner. The U.S. Forest Service, through its Forest Inventory and Analysis (FIA) program and in partnership with the Michigan Department of Natural Resources, Forest, Mineral, and Fire Management Division, inventoried the State's forest resources in 1935, 1955, 1966, 1980, and 1993. In 2000, Michigan's periodic inventory was replaced with an annual inventory in which a portion of the field plots are measured each year. A full inventory is completed every 5 years. The first annual inventory of Michigan (10,355 forested plots) was completed in 2004 and covers the period

2000-04. Also new in this 2004 inventory was the addition of a number of forest health indicators. Part of the new Phase 3 inventory, these include tree crown, down woody material, soil, and vegetation diversity and structure.

In this report we describe and highlight the current status and trends observed within Michigan's forests. We invite you to read and consider this report knowing that it will stimulate additional discussion, analysis, and education about one of Michigan's greatest treasures.

Contents

Highlights

Forest Features

- Among the 50 States, Michigan ranks 22nd in land area but 10th in forest-land area.
- Forest land accounts for 19.3 million acres or 53 percent of land in Michigan; 97 percent or 18.7 million acres is timberland.
- Nearly 1.2 million acres are classified as timberland plantations.
- Sugar maple/beech/yellow birch is the predominate forest type (22 percent of timberland). Aspen (13 percent) is the second most abundant forest type. Northern white-cedar (7 percent) and red pine (5 percent) are the most abundant softwood forest types.
- Just over three-quarters of the timberland in Michigan is fully or medium stocked. This level of stocking is conducive to maintaining forest health, quality timber products, and efficient timber production. Only 14 percent of timberland is poorly stocked or nonstocked.
- Overall, the forests continue to mature and shifts in the composition of Michigan's forests are evident, in part due to succession. The number of sawtimber trees has increased considerably. Shade-tolerant species like eastern white pine are increasing in number and volume while intolerant and short-lived species like jack pine and paper birch are declining.
- There are 13.4 billion trees on timberland, 65 percent of which are hardwoods. The number of trees increased from 1980 to 2004 (675 to 716 trees per acre). The number of saplings and sawtimber trees increased by 16 and 55 percent, respectively, while the number of poletimber trees remained the same.
- There are 27,303 million cubic feet (ft^3) of growing stock on timberland or about 1,457 ft^3 per acre. Total growing stock on timberland has increased significantly in each inventory since 1955 but this increase has slowed over time. From 1955 to 1966, the increase was nearly 4 percent per year. Since 1980, the increase has been just under 2 percent per year.

- Prominent species like sugar maple, red maple, northern white-cedar, red pine, northern red oak, and eastern white pine gained significantly in growing-stock volume from 1980 to 2004. Similarly, the number of sawtimber trees also increased for most of these species.
- The volume of jack pine and paper birch has declined since 1980.
- Although the volume of quaking aspen, balsam poplar, and balsam fir growing stock has declined since 1980, the number of saplings has increased considerably for these species.
- Since the first inventory by FIA in 1935, volume has been increasing. This has contributed to substantial gains in carbon sequestration. Biomass, measured as live aboveground tree biomass on forest land, is estimated at 793.7 million dry tons (average of 41.1 dry tons per acre).
- There are 78.9 billion board feet of sawtimber on timberland. Like growing-stock volume, sawtimber volume has increased over time.
- The average annual net growth of growing stock on timberland was 786.8 million ft^3 from 1993 to 2004. This is about 2.9 percent of growing-stock volume on timberland in 2004.
- All prominent species in Michigan have moderate to high percentages of average annual net growth to volume.
- The average annual mortality of growing stock on timberland was 224.5 million ft^3 from 1993 to 2004. This is about 0.8 percent of growing-stock volume on timberland in 2004. This is a relatively low percentage.
- Balsam fir and American elm have relatively high percentages of average annual mortality to volume. Jack pine, paper birch, bigtooth aspen, balsam poplar, black spruce, and white spruce have moderate mortality-to-volume percentages.

- Average annual removals of growing stock on timberland totaled 291.2 million ft^3 from 1993 to 2004. This is about 1.1 percent of growing-stock volume on timberland in 2004. This is a relatively low percentage.
- All prominent species in Michigan have low to moderate percentages of average annual removals to volume. Jack pine had the highest rate among the prominent species at 2.9 percent.
- The ratio of net growth to removals from 1993 to 2004 was 2.7, indicating that volume is increasing at a moderate to high rate as compared to other states. Since 1955, the overall net growth to removals ratio has remained almost constant.

Forests in Flux

- Of Michigan's forest land, 62 percent or 11.9 million acres are owned by families, individuals, private corporations, and other private groups. The remaining 38 percent (7.4 million acres) is managed by Federal, State, and local government agencies.
- Although most family forest owners did not report having a management plan for their land over the next 5 years, 19 percent (1.7 million acres) of the family forest land is owned by people who plan to sell or pass on their forest land during the next 5 years.
- Fifty-two percent of the family forest land is owned by people who have commercially harvested trees. Only 18 percent of this land is owned by people who reported having a written forest-management plan.
- A large amount of former forest-industry land has been sold to real estate investment trusts and timber management organizations. Changing patterns of ownership can influence the structure and use of forest land.
- All but 3 percent of forest land in 1993 remained forest land in 2004. Diversions from forest land were offset by reversions to forest land that resulted in no net change from 1993 to 2004.

- Although the forest-land base has remained relatively stable at the state level, there has been substantial change by county. This change has been more pronounced in the southern and northern Lower Peninsula.
- The northern Lower Peninsula contains most of the forest land but a considerable amount is classified as edge. Forest land in the southern Lower Peninsula contains little interior forest and consists almost entirely of edge or small, isolated patches. Conversely, the Upper Peninsula contains much more interior forest but much of the landscape is dissected by roads.

Forest Health

- Fuel loadings of down woody materials are not exceedingly high in Michigan relative to other states. In most parts of the State, potential fire danger is not as severe as in some other states. While down woody debris has significant value for wildlife habitat and as a carbon sink, fuel types and loading in some areas may warrant treatments to reduce the risk of wildfire.
- Nonnative insects and diseases such as the emerald ash borer, gypsy moth, larch casebearer, oak wilt, and beech bark disease have caused considerable damage to forest resources. Nonnative species have not evolved with our forest ecosystems and may have no biological control agents.
- Widespread defoliation caused by the native forest tent caterpillar, which began a four-year outbreak in 2000, reached peak defoliation in 2001. The most notable impact from this insect is on aesthetics.
- Jack pine budworm, eastern larch beetle, spruce budworm, large aspen tortrix, red-headed pine sawfly, red oak and black ash decline, and environmental elements like drought and late frost also caused considerable damage.
- A significant portion of the jack pine resource is mature or will be mature in the next decade. Seventy percent of jack pine volume is in stands more than 45 years old. Damage from forest pests and diseases increases and the economic value of jack pine decreases sharply beyond stand ages of 60 years.

- Sixty-five percent of the plots sampled for nonnative species (125) had at least one identifiable nonnative species. Higher percentages of nonnative to total species were evident in the Lower Peninsula. Likewise, the percentage of nonnative-species ground cover to total ground cover was higher in the Lower Peninsula.
- The forests of northern Michigan are at low risk of ozone-induced, visible foliar injury. Ozone-sensitive species in southern Michigan are at low to moderate risk of injury.

Forest Products

- The economic benefits of Michigan's forests are enormous as more than $12 billion and 150,000 jobs contribute to Michigan's economy annually through forest-based industries, recreation, and tourism (Michigan Dep. Nat. Resour. 2007a).
- Michigan's paper and wood products industries employ more than 19,000 workers with an output of about $4.4 billion annually (U.S. Census Bur. 2002).
- Most industrial roundwood production in Michigan is pulpwood (61 percent). Saw logs and veneer logs account for 35 and 2 percent of production, respectively.
- The top three hardwood species groups harvested were aspen, hard maple, and soft maple (51 percent of total production); red pine, jack pine, and spruce were the top three softwood species groups harvested (21 percent).
- Michigan is processing most of its own wood resources. Since the late 1980s, the amount of wood processed in the State has remained fairly constant while the number of small and medium-size mills has been declining.

Background

Covered Road, Houghton County, Michigan, 2007. Photo by Scott A. Pugh, U.S. Forest Service.

Before You Begin

What is a tree?

Trees are perennial woody plants with central stems and distinct crowns. In general, the Forest Inventory and Analysis (FIA) program defines a tree as any perennial woody plant species that can attain a height of 15 feet at maturity. The problem is deciding which species should be classified as shrubs and which should be classified as trees. A complete list of the tree species measured during this inventory is included in the Appendix. Throughout this report, the size of a tree is expressed in diameter at breast height (d.b.h.), in inches. This is the diameter, outside bark, at a point 4.5 feet above ground.

What is a forest?

The area of forest land often determines the allocation of funding for certain State and Federal programs. FIA defines forest land as land that is at least 10-percent stocked with trees of any size or formerly having had such tree cover and not currently developed for nonforest use. In general, the minimum area for classification must be at least 1 acre in size and 120 feet in width. There are more specific area criteria for defining forest land near streams, rights-of-way, and shelterbelt strips (North Cent. Res. Stn. 2003).

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

FIA defines three types of forest land:

- Timberland—forest land that is producing or is capable of producing crops of industrial wood and is not withdrawn from timber utilization by statute or administrative regulation. These areas are capable of producing in excess of 20 ft^3/acre/year of industrial wood in natural stands. Currently, inaccessible and inoperable areas are included.
- Reserved forest land—forest land that is withdrawn from timber utilization through statute, administrative regulation, or designation without regard to productive status, e.g., some state parks, national parks and lakeshores, and Federal wilderness areas.
- Other forest land—forest land that is not capable of growing 20 ft^3/acre/year and is not restricted from harvesting, e.g., some northern white-cedar in low, wet areas or some jack pine on very low-fertility sites.

Timberland accounts for 97 percent of the forest land in Michigan. Two percent is reserved and 1 percent is other forest land.

Prior to the 2004 inventory, FIA measured trees only on timberland plots, so we could not report volumes on all forest land. As a result, trend analyses for tree measurements were limited to timberland. Since 1999, the new annual inventory design allows us to report volumes on all forest land. As remeasurement proceeds, we will be able to report trends for all forest land, including growth, removals, and mortality.

How do we estimate a tree's volume?

FIA expresses volume in cubic and board feet (International 1/4-inch rule). In Michigan, wood often is measured in cords (a stack of wood 8 feet long by 4 feet wide and 4 feet high). A cord of wood consists of about 79 ft^3 of solid wood and 49 ft^3 of bark and air. When converting from cubic to board feet, there are 4 to 8 board feet per cubic foot because there are losses from cutting rectangular boards from round logs, e.g., squaring the log and saw kerf.

To estimate volume, FIA uses several hundred cut trees with detailed diameter measurements along their lengths (Hahn 1984). Statistical models were applied to this data by species group. Using these models, FIA produces volume estimates for individual trees based on species, diameter, and site index. The latter is an expression of the quality of a site to grow specific trees.

FIA reports sawtimber volume in board feet using the International 1/4-inch rule. To convert from the International to the Scribner rule, see Smith (1991).

How much does a tree weigh?

The U.S. Forest Service's Forest Products Laboratory developed estimates of specific gravity for a number of tree species (For. Prod. Lab. 1999). These specific gravities are applied to estimates of tree volume to estimate the biomass of merchantable trees (weight of the bole). Regression models are used to estimate the biomass of stumps (Raile 1982), limbs, and bark (Hahn 1984). Currently, FIA does not report the biomass of roots or foliage.

FIA can report biomass as green or oven-dry weight. Green weight is the weight of a freshly cut tree. Oven-dry weight is the weight of a tree with no moisture content. On average, 1.9 tons of green biomass equals 1 ton of oven-dry biomass.

How do you analyze FIA data?

Definitions, methods, location, ownership, precision, scale, and temporal trends are important factors to consider when analyzing FIA data. Estimates are derived from sample plots throughout a state. Larger areas of interest will contain more plots and thus produce more reliable estimates. For example, there usually are sufficient plots within a county with which to provide reliable estimates for general categories of interest like all forest land. There may not be enough plots associated with specific delineations like a single forest type. It also is important to consider the degree to which a variable can be measured precisely.

For instance, a stand variable like age is not as precise as forest type and a tree variable like crown dieback is not as precise as diameter.

Location and ownership also are important considerations when analyzing the status and trends of forests. Forest resources vary by region and ownership group. For instance, some forest types are more plentiful in specific regions and ownership groups, e.g., northern red oak in northern Lower Peninsula and red pine on public land.

Definitions and procedures have changed between inventories. Besides determining definition and procedural changes, it is important to investigate multiple variables over time. As an example, when analyzing changes in stand size, one also should look at changes in number of trees by size class. In another example, changes in forest-type acreages should be supported by changes in the associated tree species.

In the past, FIA inventories were completed every 10 to 20 years. It took decades with few temporal observations to identify trends. With the new annual inventory, some trends will be easier to identify because a subset of observations (20 percent) are made every year. It still is necessary to look over long time periods because many trends like succession can be difficult to discern in short timespans.

Comparing data from different inventories: apples to oranges?

Michigan has been inventoried five times by FIA in the last century: 1935 (Lake States For. Exp. Stn. 1936), 1955 (Findell et al. 1960), 1966 (Chase et al. 1970), 1980 (Raile and Smith 1983, Spencer 1983), 1993 (Leatherberry and Spencer 1996, Schmidt et al. 1997).

To improve the consistency, efficiency, and reliability of the inventory, a number of major changes occurred between the 1993 and 2004 inventories. For example, some land-use classes are considered forest in this 2004 inventory but they were nonforest in the 1993 inventory (see page 105). Also, the minimum stocking (relative density of trees) percentage for forest land changed from 16.7 in the 1993 inventory to 10 percent in the 2004 inventory. These changes had virtually no effect on forest and timberland estimates.

There were greater changes in stocking, forest-type, and stand-size estimates. Methods for calculating stocking were improved in the 2004 inventory. Forest type and stand size are determined from stocking, and more precise definitions of forest type were developed for the 2004 inventory. For additional information on stocking, see "National Algorithms for Determining Stocking Class, Stand Size Class, and Forest Type for Forest Inventory and Analysis Plots" at http://www.fia.fs.fed.us/library/field-guides-methods-proc/.

A major change between the two inventories was the change in plot design. For the sake of consistency, a new, national plot design was implemented by all five regional FIA units in

1999 (see page 175). Prior to this new plot design, fixed and variable-radius subplots were used in the 1980 and 1993 inventories. The new design uses fixed-radius subplots exclusively. Both designs have strong points but they often produce different classifications for individual plot characteristics. Unpublished FIA research comparing these plot designs showed no noticeable difference in volume and tree-count estimates.

Unlike other inventories, the 1993 inventory included modeled plots, that is, many plots were measured in 1980 and projected forward using the STEMS85 growth model (Belcher et al. 1982, Holdaway and Brand 1986). This was done to save money by reducing the number of undisturbed plots visited in the field. Disturbance was determined by comparing aerial photographs of the plots and looking for reductions in canopy cover. The idea was that parameters for the STEMS85 growth model could be fine tuned using the measured, undisturbed plots and then applied to the remaining unmeasured, undisturbed plots. Unfortunately, the use of modeled plots introduced errors, so the practice was discontinued.

In Michigan, 59 percent (6,045 of 10,224 plots) of the timberland plots were modeled for the 1993 inventory. This generally resulted in an overestimation of volume and biomass (Table 1). Pokharel and Froese (2008) found that Forest Vegetation Simulator models like STEMS85 have structural weaknesses resulting in substantial overestimation of diameter increment. This translates to an overestimation of volume and biomass. Estimates of number of trees also varied. There was virtually no effect on estimates of acreage. Removing all modeled plots and making estimates only with measured or nonmodeled plots also presents a problem. The sample is much smaller and it may have bias. By looking at the 2004 and more recent estimates (2005 and 2006) based solely on nonmodeled plots, it appears that better 1993 estimates would be between the all-plot (modeled and nonmodeled) and nonmodeled-plot estimates. Modeled data from the 1993 inventory are not presented in other sections of this report. Area estimates of forest and timberland were not based on modeled data. Only measured plots were used in the estimates of average annual growth, mortality, and removals from 1993 to 2004. Most of the detailed comparisons in this report are between the 1980 and 2004 inventories. This works well for identifying most important trends.

Table 1.—Acreage, volume, biomass, and number of trees on timberland for all plots (modeled and nonmodeled) versus only nonmodeled plots, Michigan, 1993.

	Timberland	Live volume	Growing-stock volume	Sawtimber volume	Live biomass	Live trees	Growing-stock trees
	thousand acres	million ft^3	million ft^3	million board feet	thousand dry tons	million trees	million trees
All plots (modeled and nonmodeled)	18,616	29,304	26,661	71,025	811,753	11,409	3,142
Nonmodeled plots	18,381	23,790	21,105	52,623	682,603	12,751	2,737
Percent difference	1.3	23.2	26.3	35.0	18.9	-10.5	15.0

Figure 1 shows how results vary by method and definition as well as some of the distinct effects of modeling in 1993. Timberland is shown by stand size over time but there are three variations for the 1993 inventory. As mentioned previously, stocking calculations changed in 2004. In turn, stand-size classifications changed. Classifications also differed between the 1980 and 1993 inventories.

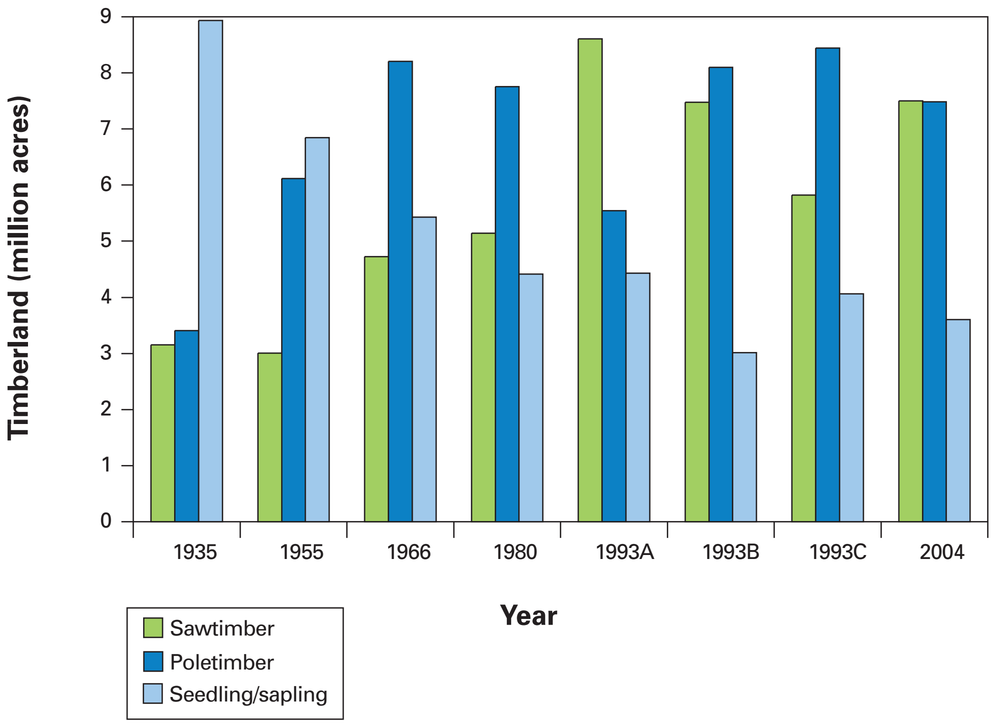


Figure 1.—Timberland by stand-size class and year, Michigan, 1935-2004. A comparison of definition changes and modeling is included (1993A with all plots using 1993 definitions, 1993B with all plots using 2004 definitions, 1993C with only nonmodeled plots using 2004 definitions).

In the 1993A approach, data from the original 1993 inventory are used (Schmidt et al. 1997). This includes all the plots (modeled and nonmodeled) and the stocking and stand-size definitions from the 1993 inventory. The 1993B approach includes all plots (modeled and nonmodeled) but stocking and stand-size definitions are from the 2004 inventory. The 1993C approach includes only nonmodeled plots and includes 2004 stocking and stand-size definitions. 1993A and 1993B each show how an overestimation of tree size and volume by the STEMS85 model adds to an overestimation of acreage in sawtimber stands. The overestimation in 1993A is the worst. 1993C is the preferred approach for trend analysis.

It is important to look at changes in number of trees by size class in conjunction with changes in stand-size class because methods for determining stand-size class are less precise and have changed over time. Methods for determining tree-size class are precise and have not changed. From 1980 to 2004, the changes in number of trees by size class support the changes in timberland by stand-size class. Since 1980, the number of sawtimber-size trees has increased by 55 percent. The number of saplings has increased by 16 percent and the number of poletimber-size trees has not changed significantly (see Fig. 15).

Sampling error—what is significant?

We measured approximately one plot for every 1,975 acres of land. Compared to the rates in many other states, this is a high sampling rate due to triple-intensity sampling. We could not measure every tree or every acre in Michigan, so there are sampling errors associated with the estimates. For instance, the estimate of timberland in Michigan is 18.75 million acres with a sampling error of ± 0.4 percent resulting in a range from 18.67 to 18.82 million acres. The sampling error represents one standard error, which is a 68-percent confidence interval. If the entire population were known, the odds are 2 to 1 (68-percent chance) that the area of timberland would be 18.67 to 18.82 million acres. All error bars presented in this report use one standard error to represent the uncertainty in the estimates but error bars are not shown for all estimates.

We often try to determine whether there are statistically significant differences among estimates. Throughout this report, a significant difference means that the ranges of the estimates do not overlap based on one standard error for the level of uncertainty. For example, the estimate of timberland acreage for the southern Lower Peninsula in 1980 ranged from 2.4 million to 2.5 million acres at one standard error. The estimate for the southern Lower Peninsula for 2004 ranges from 2.9 million to 3.0 million acres at one standard error. Consequently, we can conclude that there was significantly more timberland in the southern Lower Peninsula in 2004 versus 1980.

A word of caution on harvest suitability and availability

Land classified as timberland is not necessarily suitable or available for timber harvesting. FIA does not classify the suitability of lands for timber harvesting, or include public reserved forest land (land withdrawn from timber utilization by statute or administrative regulation) in the estimate of timberland. About 80 percent of the reserved plots in the 2004 inventory are in Isle Royale National Park, Porcupine Mountain State Park, Sylvania Wilderness and Recreation Area, McCormick Wilderness Area, Sturgeon River Gorge Wilderness Area, Sleeping Bear Dunes National Lake Shore, Seney National Wildlife Refuge, Tahquamenon Falls State Park, or Pictured Rocks National Lakeshore. The FIA definition of reserved forest land does not account for all forest land that is unsuitable or unavailable for timber harvesting. FIA does not identify timberland withdrawn from timber utilization or timberland that is not suitable or accessible for timber harvesting. It would be difficult to identify and maintain an up-to-date list of all lands withdrawn and not suitable or accessible for timber harvesting due to changing laws, owner objectives, markets, and site conditions.

There are many limiting factors that make timberland unsuitable or unavailable for timber harvesting. For example, operability on many sites is poor, e.g., wet or steep, and there are limitations related to wildlife. For example, threatened or endangered species habitat, deer yards, and potential old-growth areas can be subject to harvest restrictions. Some locations are landlocked by denied access and the cost of entering some sites is prohibitive. There also are visually sensitive areas where aesthetics outweigh gains from harvests. FIA does include variables such as slope, physiographic class, and disturbance class that could help identify lands with limiting factors.

It is difficult to determine the availability of wood from private land. Many private land owners do not consider harvesting timber as an option for their timberland. In response to the National Woodland Owner Survey conducted by the FIA program, only 5 percent of private land owners holding 12 percent of the private forest land in Michigan stated that they intend to harvest saw logs or pulpwood within the next 5 years. Further, 48 percent of the forest land is owned by people who have never commercially harvested trees. Michigan landowners tend to own forests more for aesthetics, privacy, and nature protection than for timber production. Also, the National Forests have not harvested as much as other ownership groups due to a number of factors (Bosworth and Brown 2007, Keele et al. 2006, USDA For. Serv. 2002). In Michigan, the Forest Service has the lowest average annual removals-to-volume percentage (0.7) compared to private (1.2 percent) or State and local government (1.1 percent) ownerships. The FIA data only can aid in identifying possible land available for timber production. Ever changing factors will dictate this availability.

Where can I find additional information?

The main web page for FIA is at http://www.fia.fs.fed.us/. From here there are resources such as publications (http://www.nrs.fs.fed.us/pubs/) and data and tools (http://www.fia.fs.fed.us/tools-data/default.asp and http://fiatools.fs.fed.us/fiadb-downloads/datamart.html). The primary web tool is FIDO or Forest Inventory Data Online (http://199.128.173.26/fido/index.html). Other tools also are available (http://www.fia.fs.fed.us/tools-data/other/default.asp).

State-level reports are available at http://nrs.fs.fed.us/fia/data-tools/state-reports/default.asp. In addition to these reports, this site has supporting tables and other up-to-date information for each state.

Looking to the Past to Understand the Present

Michigan has been shaped over time in profound ways. The Wisconsin glacier had a striking effect when it receded about 10,000 years ago. It formed lake and outwash plains with finer deposits and till plains that routinely contained coarser deposits. Upon these surfaces, soil began to form with the interaction of climate and pioneering organisms.

Paleo-Indian people arrived shortly after the glacier receded. These early people and others who followed shaped their environment. However, the arrival of Europeans and other immigrants (European settlement) marked the beginning of major changes. Initially, the attention of these immigrants was focused mostly on the fur trade. About the time that Michigan became a state in 1837, the emphasis turned to lumber, farming, and settling land. The lumber business started to boom in the 1830s but really took off with the introduction of railroads in the 1870s. Usually, only the choicest large logs were taken and the rest of the tree was left as slash. This contributed to numerous fires burning millions of acres from the 1870s through the 1920s. Around 1900, the boom was over in the Lower Peninsula but it continued until about 1920 in the Upper Peninsula.

In 1929, the U.S. Department of Agriculture (Sparhawk and Brush 1929) estimated that 92 percent of the original forest in Michigan had been cut or destroyed by fire in less than 100 years. There was an estimate of 380 billion board feet of sawtimber before European settlement; today's estimate is 82 billion board feet. After intensive land clearing and logging of the forests, most of the relatively untouched forests were in the Upper Peninsula. Before this era ended in the late 1880s, people began to talk about forestry.

Secondary succession began after the forests were cleared. The original forests could not always grow back. Fires removed organic matter and nitrogen. Soil erosion was prevalent and favored many of the early successional hardwood species. In the 1930s, the Civilian Conservation Corps contributed substantially to reforesting State and National Forests with softwoods. Hundreds of thousands of acres were planted in the late 1920s through the early 1940s. The 1930s and 1940s also saw large increases in acquisitions of public land.

Land managers began practicing "sustained yield management" in the 1940s and 1950s. Again, there were public planting programs in the 1950s. The forest-land base reached its post-settlement peak of 19.7 million acres in the 1955 FIA inventory (see Fig. 7). Stand-level management with a commodity theme was common in the 1960s.

Since the 1960s, management has evolved to address an array of values and concerns. Land managers now work on ecosystem management plans that typically incorporate economic, social, and ecological factors over large areas and long timespans. Some managers pursue the stamp of sustainability. A certification can be gained through several certification programs such as the Forest Stewardship Council (FSC) and the Sustainable Forestry Initiative (SFI). An audit by a third party ensures that the entity meets sustainable forest-management standards. The State of Michigan's forests are certified by the FSC and the SFI and large private ownerships often are certified under SFI and/or FSC. The U.S. Forest Service is investigating the possibility of having its forests become certified.

Michigan's Regions

The southern and northern Lower Peninsula and eastern and western Upper Peninsula are recognized as the four major regions in Michigan with distinct climate, geology, and physiology. The exact boundaries of these units depend on the objective and source of information. FIA has four inventory units following along county boundaries to aid in creating summary reports (Figs. 2 and 3). In this report, FIA inventory units are used as boundaries for the four major regions. These units are spatially similar to Albert's (1995) regional landscape ecosystem sections.

Figure 2.—Regional landscape ecosystem sections and FIA inventory units or regions, Michigan.

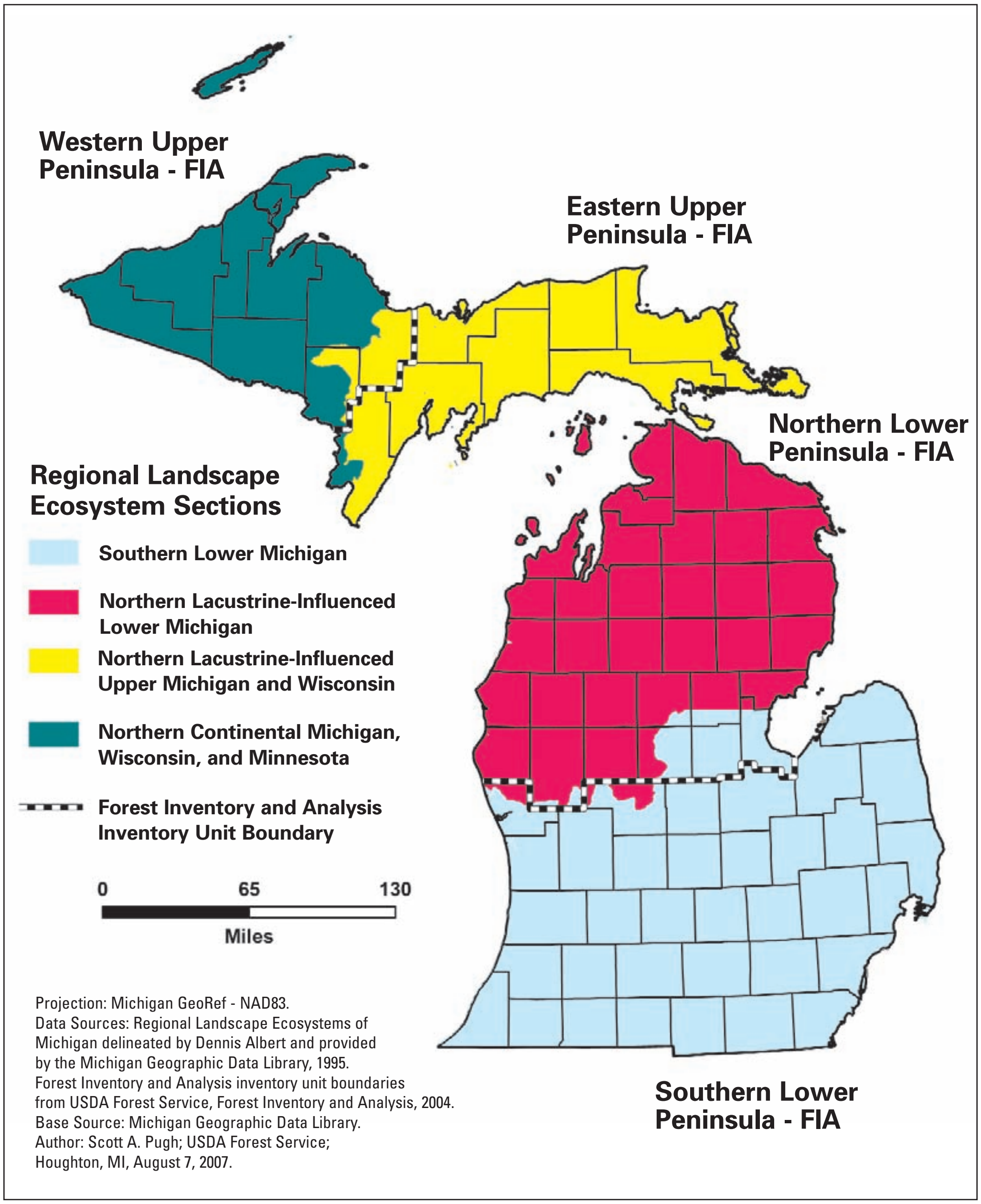
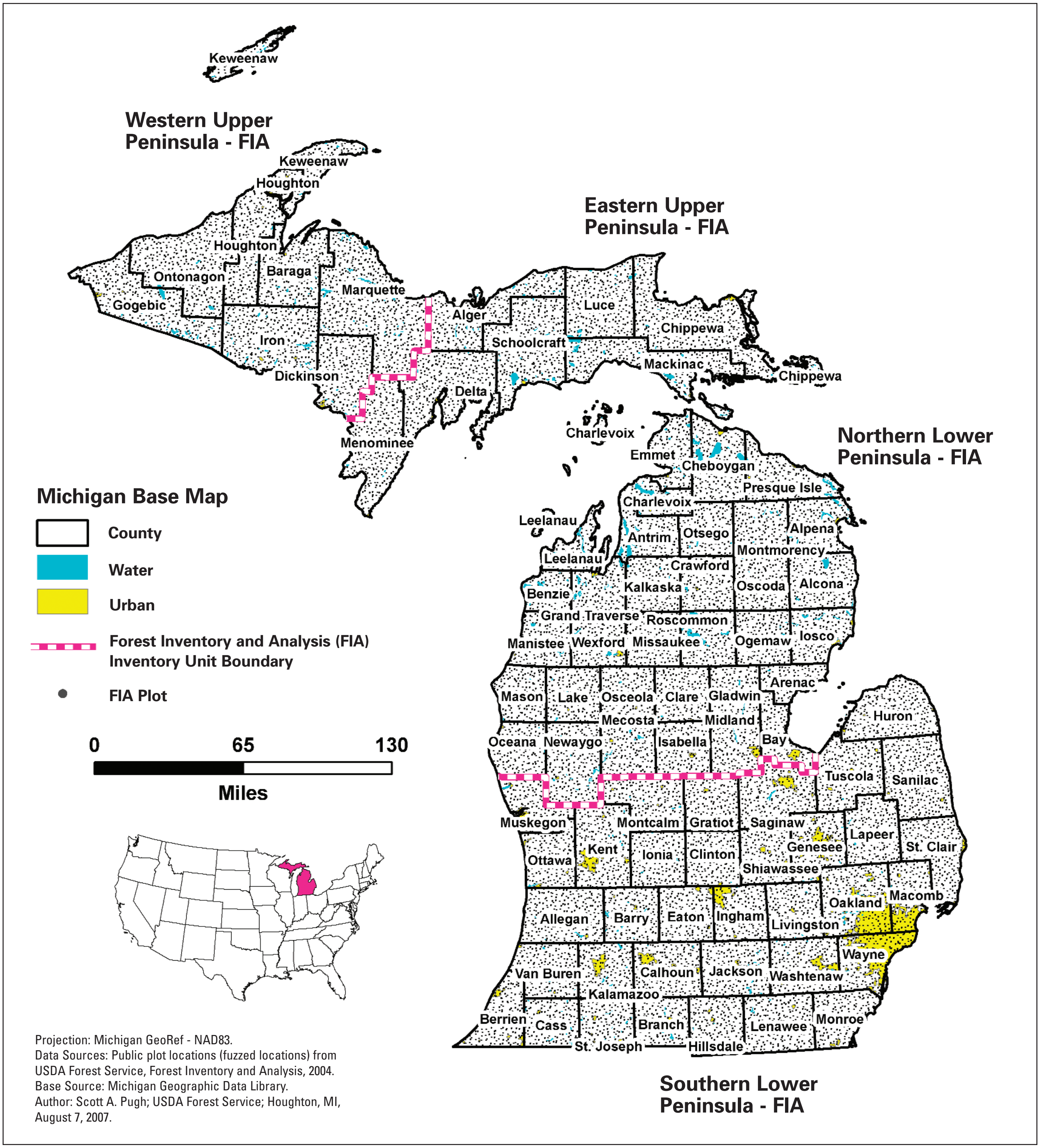


Figure 3.—Base map with FIA plots, Michigan, 2004.



The information presented here on climate, geology, physiology, and presettlement vegetation was summarized from parts of Comer et al. (1995) and Albert (1995). Otherwise, information on current land use and cover are based on FIA data.

The southern Lower Peninsula is influenced more by warm and humid air from the Gulf of Mexico and supports the most agriculture and urbanization. Underlain in the region is Paleozoic bedrock with sandstone, shale, limestone, and dolomite, which contribute to the loamy and calcium rich soil. At the beginning of the 19th century, this area supported a variety of cover types, including oak savannas and tallgrass prairies. Beech/maple, oak/hickory, northern hardwood-conifer, and hardwood swamp forest lands were prominent (Fig. 4; Austin et al. 1999). Wet prairies and coastal marsh also were common. Widespread drainage and land clearing have occurred since European settlement and upland softwood plantations have been established. Today, agriculture fields, forest woodlots, and developed lands prevail (Fig. 5). Oak/hickory, maple/beech/birch, and elm/ash/cottonwood are the common present forest-type groups in this region (Fig. 6).

South entry of Keweenaw Waterway, Houghton County, Michigan. Photo used with permission by Neil Harri, neilharriphotos.com.

Figure 4.—Land cover circa 1800 based on Government Land Office survey records (Austin et al. 1999), Michigan.

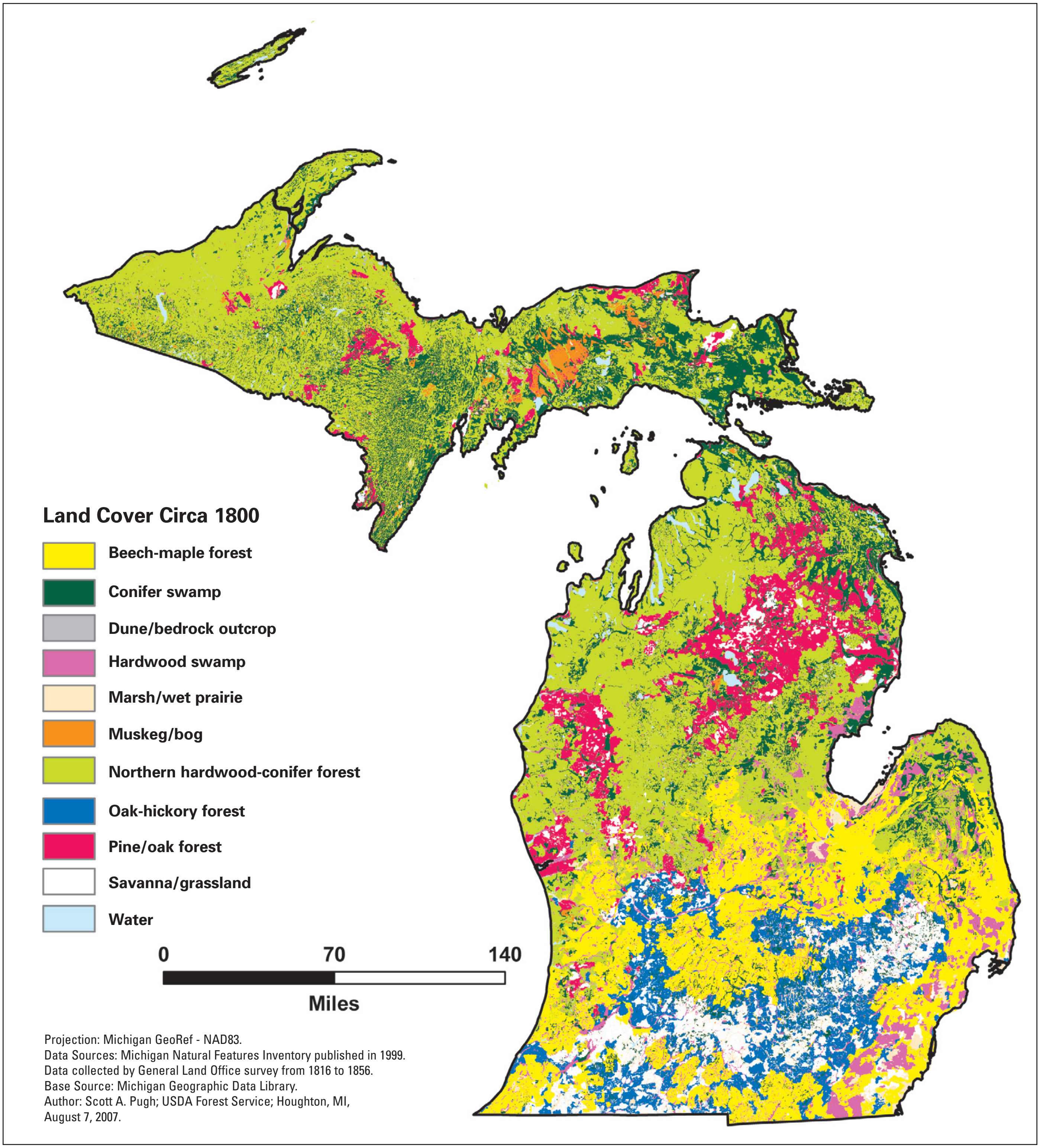


Figure 5.—Land cover based on the U.S Geological Survey National Land Cover Dataset, Michigan, 2001.

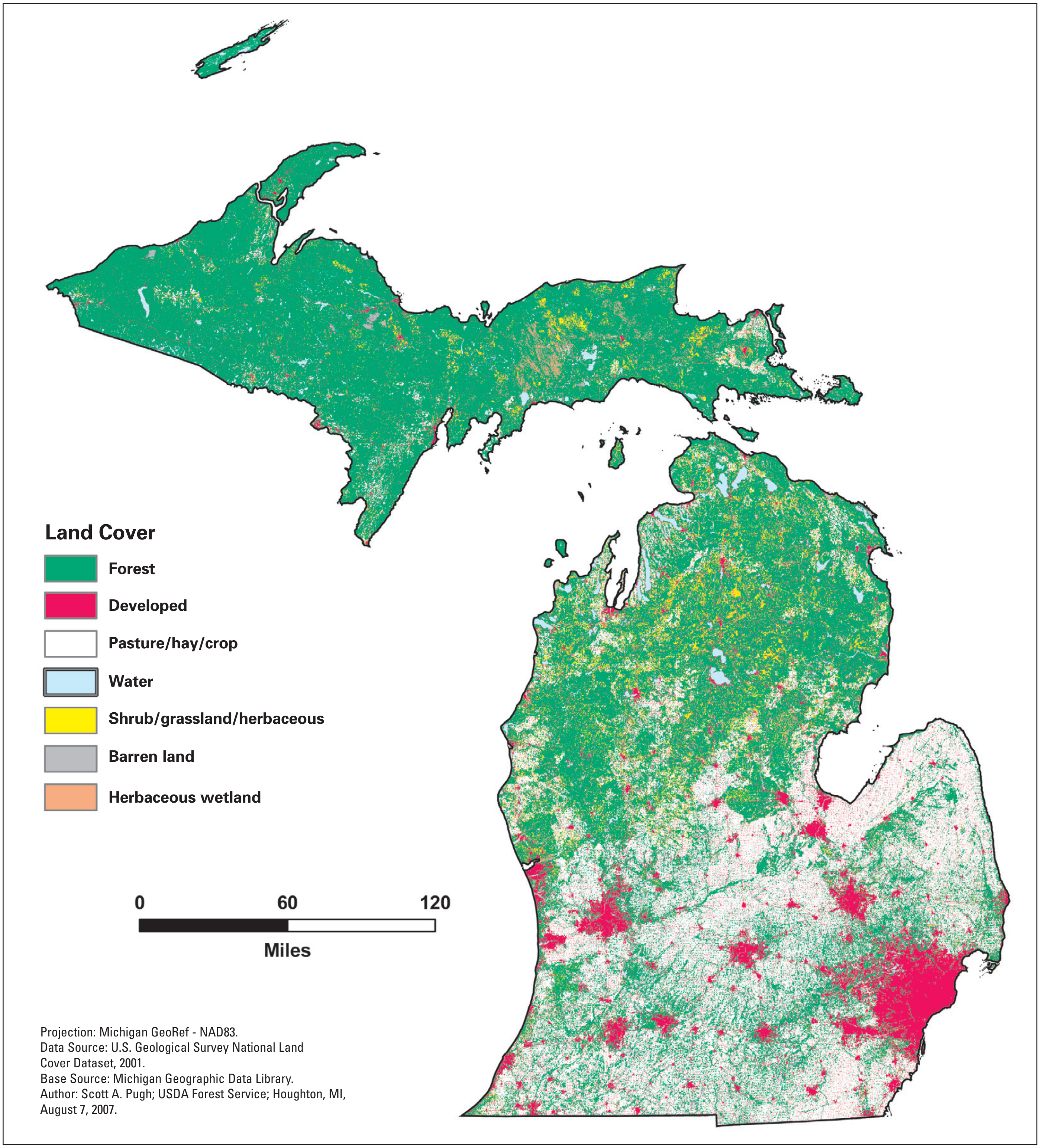
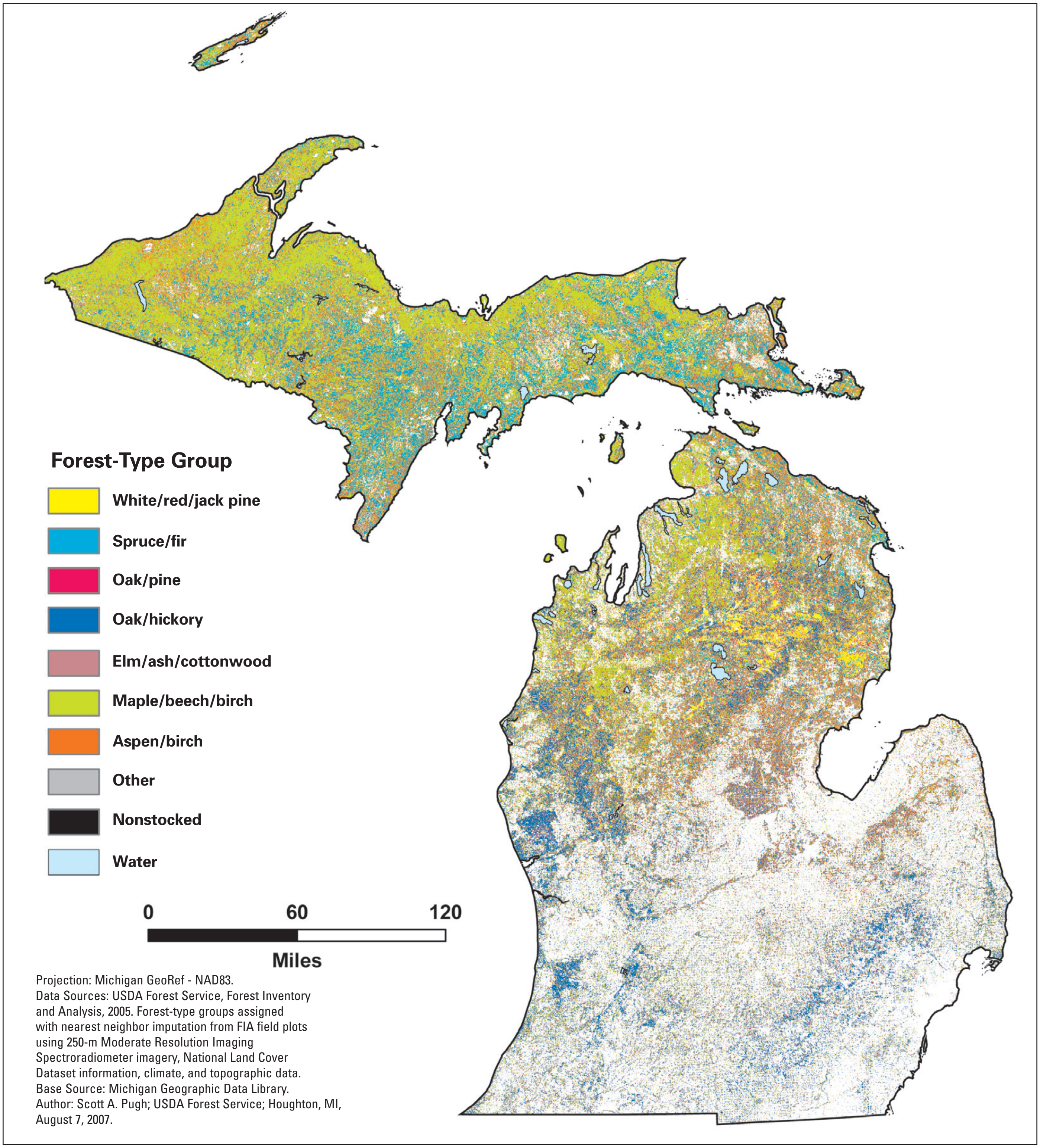


Figure 6.—Distribution of forest-type groups, Michigan, 2005.



The northern Lower Peninsula is influenced more by the Great Lakes along with cooler northern air masses from Canada and the northern Pacific. It experiences cooler and more variable temperatures compared to the southern Lower Peninsula and supports much more forest land and much less urbanization. As in the southern Lower Peninsula, this area has Paleozoic bedrock with sandstone, shale, limestone, and dolomite; however, prominent sandy glacial deposits above the bedrock dominate the soil type in this area more than in the southern Lower Peninsula. The region also boasts more topography and higher elevations. In presettlement times, pine/oak was one of the upland forest-type groups. Softwood swamps were prevalent in low areas. Yet, northern hardwoods were the most prevalent. This is true today, though, present-day northern hardwoods lack the huge white pine, red pine, and hemlock of yesteryear. This region was home to most of the revered pine monarchs. Currently, aspen/birch, oak, and pine are common forest-type groups. As in the past, the area also supports jack pine and northern pin oak on dry plain areas.

The eastern Upper Peninsula also is influenced by cooler air masses and the Great Lakes. The bedrock consists of Cambrian sandstone and Paleozoic limestone with shale and dolomite usually covered by thick glacial deposits. Again, forest land dominates this area but it is characterized by low, sandy and clay lake plains. These flat areas result in swamp forest land. Softwood swamps also were prevalent in presettlement times. Northern hardwoods and beech/maple forest-type groups were common in this area. Today, maple/beech/birch is the most common forest-type group followed closely by spruce/fir (mostly wet boreal spruce/fir). Aspen/birch and pine also are common.

Continental air masses influence the western Upper Peninsula more than the eastern Upper Peninsula. It receives slightly less precipitation along with more temperature extremes in inland areas. Unique to the western Upper Peninsula is the more frequently exposed Precambrian bedrock. Igneous and metamorphic rock poke through glacial drift in the northern stretches. Clay lake plains are found near Lake Superior with contrasting outwash plains farther inland. In the southern part of the region, Cambrian sandstone near the surface results in red soils. Compared to the eastern Upper Peninsula, there are higher elevations and fewer wetlands. Northern hardwoods have dominated this area even before European settlement and there were softwood swamps and oak/pine forests similar to those today. Unlike the present, aspen/birch was not prominent. The aspen/birch forest-type group was not prevalent in Michigan until European settlement. Note that the northern hardwood forest-type group in the western Upper Peninsula has contained relatively few American beech. The western Upper Peninsula is the northwestern edge of the range for this species.

Forest Features

White pine stand. Photo by Scott A. Pugh, U.S. Forest Service.

Forest and Timberland Area

Background

Area estimates are the most basic and standard of all forest inventory attributes. Changes in amount of forest land can be indicative of natural factors or human caused trends in land use, sustainability, and forest health. Summarizing general stand characteristics like size and age class can provide additional information on the status of the forest resource. We have more historical information on timberland, so the main focus of this section is on timberland rather than forest land.

What we found

Fifty-three percent of land in Michigan is forested (19.3 million acres; Fig. 7). Timberland accounts for 97 percent of this forest land or 18.7 million acres. Two percent of the forest land is reserved and 1 percent is other forest land.

The Upper Peninsula of Michigan only accounts for 29 percent of the land in Michigan but has 46 percent of the timberland (4.0 and 4.6 million acres for eastern and western Upper Peninsula, respectively). The southern Lower Peninsula has the least amount of timberland (3 million acres or 16 percent of timberland) even though it is the largest region. The northern Lower Peninsula has the most timberland (7.2 million acres).

Timberland is owned by public and private ownership groups. In this report, public timberland is composed of three major ownership groups: USDA Forest Service (2.5 million acres or 13 percent), other Federal (0.1 million acres or less than 1 percent), and State and local government (4.3 million acres or 23 percent). Private ownership accounts for most timberland at 63 percent or 11.8 million acres (see Fig. 50).

Forest land around Brockway Mountain, Keweenaw County, MI. Photo by Scott A. Pugh, U.S. Forest Service.

Since the first FIA inventory in 1935, timberland has held at a fairly constant ratio to all forest land (95 to 98 percent). The peak of forest land was observed in the 1955 inventory and the low was noted in the 1980 inventory (Fig. 7). Changes in forest land are depicted in Figures 8 and 9, which show the percentage of forest land by county and changes in forest land by county. The peak was the result of the forest base recovering from the land clearing, timber harvests, and fires in the 1800s and early 1900s. During the 1980s and early 1990s, the area of forest and timberland increased. Abandoned cropland and pasture reverted to forest and marginal forest lands, once classed as unproductive, were reclassified as productive timberland (Schmidt et al. 1997). From 1993 to 2004, there was no significant change in forest or timberland. The eastern Upper Peninsula was the only region that showed a change—a slight increase in forest land. Except in the eastern Upper Peninsula, reversions to and diversions from forest and timberland resulted in no net change (see page 107).

The 1993 data include 7,188 modeled plots as mentioned previously. Forest and nonforest land-use classifications were not modeled. Even on modeled plots, classifications were performed using aerial photographs and field checks. Aerial photo interpretation works well where the land-use classes are not detailed.

Figure 7.—Forest land and timberland by year, Michigan, 1935-2004 (error bars represent 68-percent confidence interval around estimate).

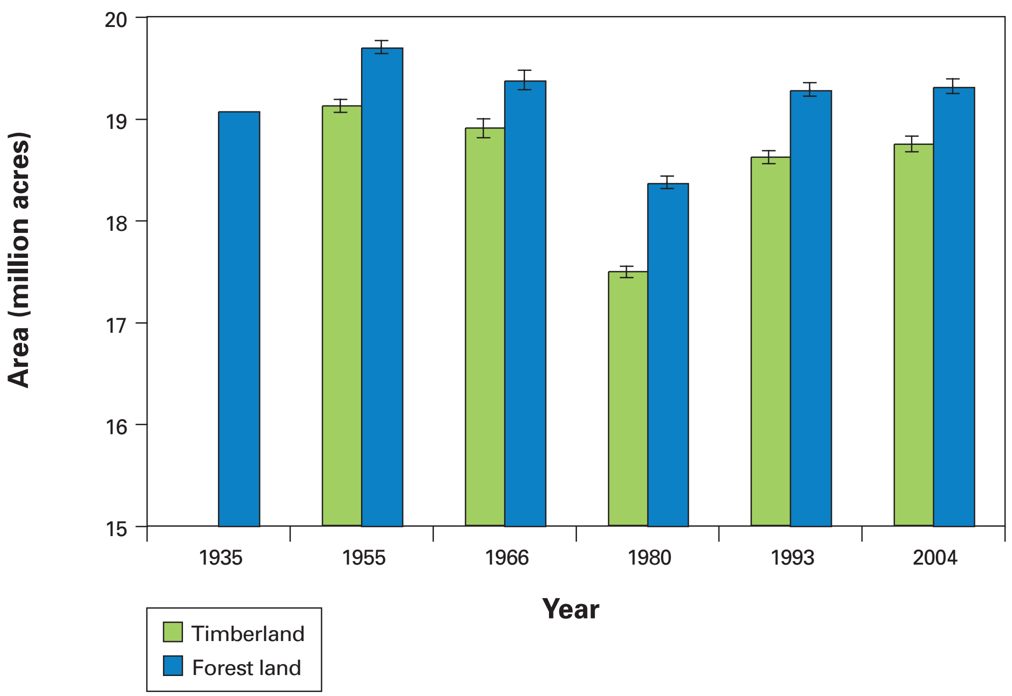


Figure 8.—Forest land by county, Michigan, 1955-2004.

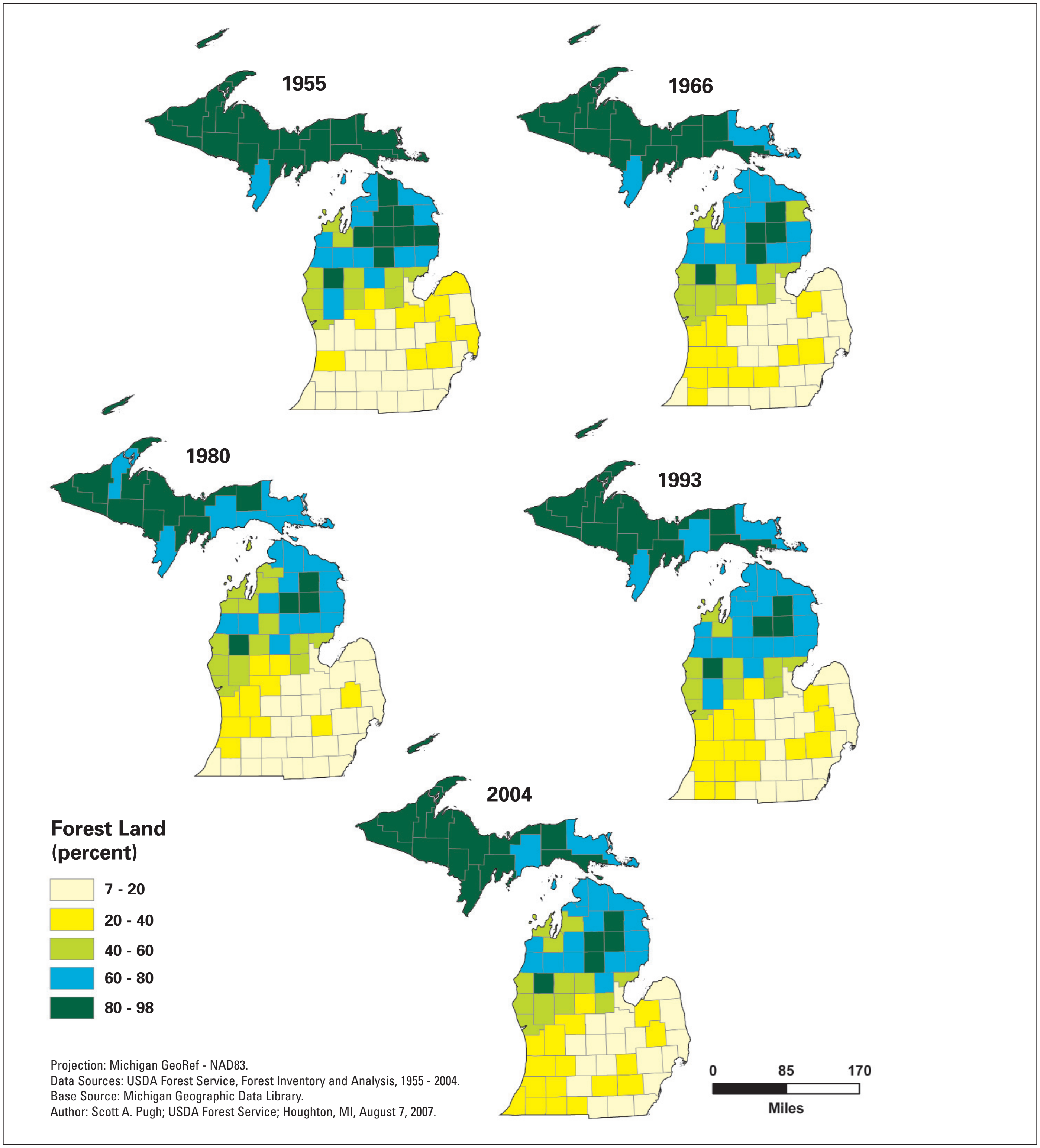
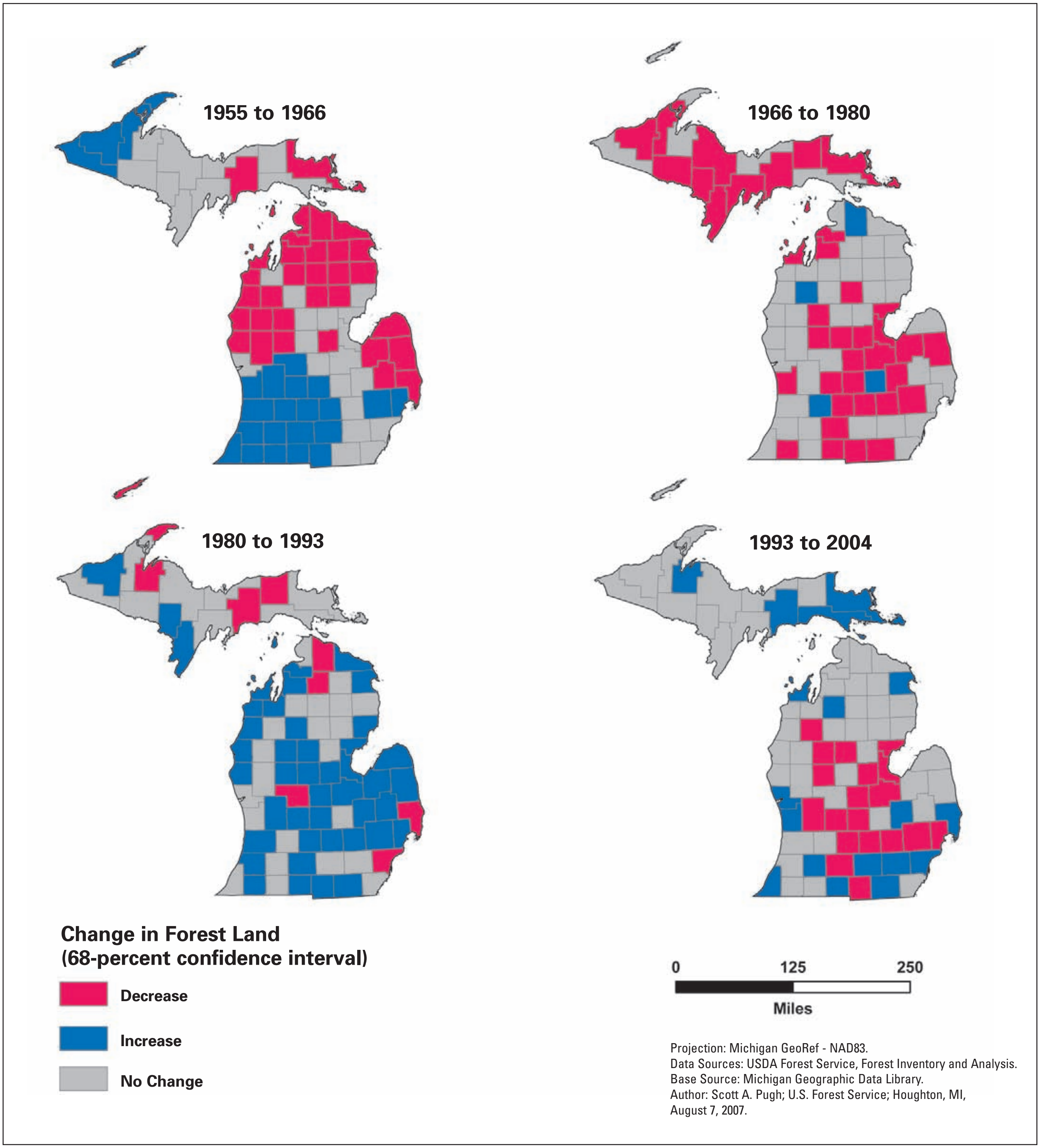


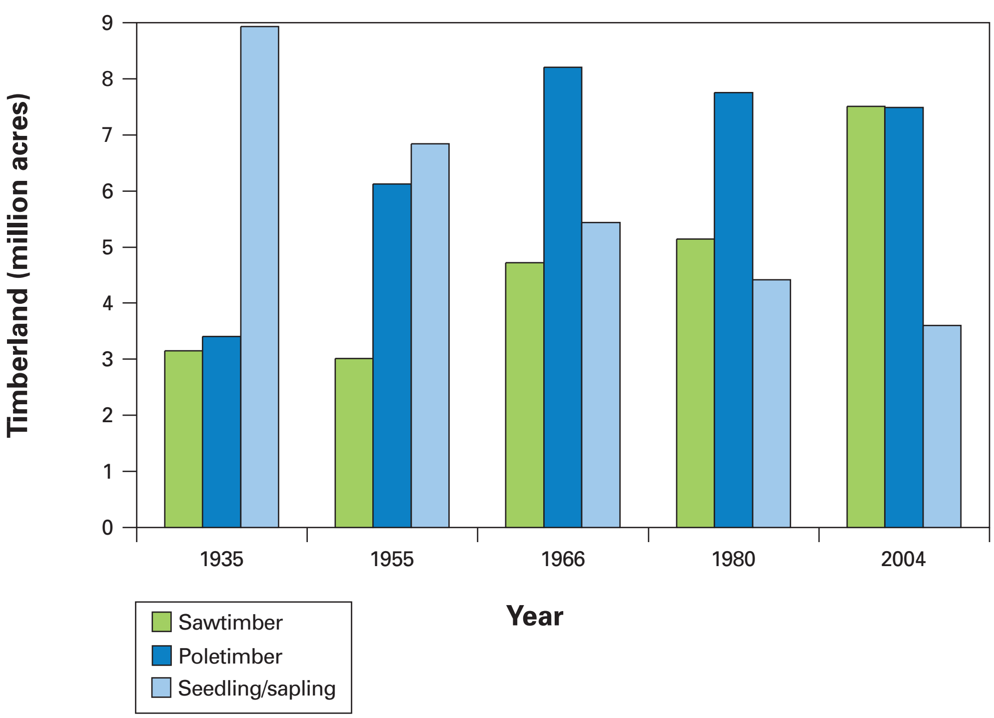
Figure 9.—Change in forest land by county, Michigan, 1955-2004.



Michigan's forests have been maturing, as can be seen in the distribution of timberland by stand-size classes (Fig. 10). Stand-size classes represent the size of the trees that form the plurality of stocking based on the dominant trees sampled. Since the 1935 inventory, sapling acreage has been declining while sawtimber stands have increased. Forest types and type groups like aspen, red pine, oak/hickory, and elm/ash/red maple experienced noticeable shifts in acreage from pole to sawtimber in the 1993 inventory (Schmidt et al. 1997). From 1980 to 2004, decreases in poletimber and increases in sawtimber-size trees for the major species associated with these types support this general trend (see page 36 and Table 3).

It is important to look at changes in number of trees by size class in conjunction with changes in stand-size class since methods for determining stand-size class are less precise and have changed over time. By contrast, methods for determining tree-size class are more precise and have not changed. Since 1980, the number of sawtimber-size trees has increased by 55 percent. The number of saplings has increased by 16 percent and the number of poletimber-size trees has not changed significantly (see Fig. 15).

Figure 10.—Timberland by stand-size class and year, Michigan, 1935-2004.



The current stand-age class distribution in Michigan indicates that most stands are 40 to 80 years old and that 25 percent of the stands are younger (Fig. 11). Estimates of stand age are less precise than most other stand variables. The estimate of stand age is based on the composition of all age classes within a stand. Often, stands are heterogeneous by age but a single value must be assigned to them.

There are nearly 1.2 million acres of timberland designated as plantations in this 2004 inventory. Eighty-five percent of these artificially regenerated stands are softwood types with red pine comprising roughly half of them. Jack pine ranks second. Most of these stands are young (mean age of 38 years). Seventy-two percent of all red pine stands (both plantations and natural) are 40 to 60 years old. Thirty percent of the jack pine stands (both plantations and natural) are more than 45 years old. Jack pine stands more than 45 years old are more vulnerable to pests (see page 156).

Figure 11.—Timberland by stand-age class, Michigan, 2004.

What this means

Although people continue to change the land, Michigan's forest-land base has remained relatively stable at the state level. There has been substantial change in the forest-land base by county. This change has been more pronounced in the southern and northern Lower Peninsula. Losses in forest land are expected as development continues to increase.

Current forest stand-size and age-class distributions indicate a maturing forest resource. This trend is expected to continue. Over time, the large acreage in the 40- to 80-year range probably will decrease due to management or a natural progression to older age classes. This will result in a more even balance among age classes and greater acreage in the 100+ age range.

Forest-type Distribution

Background

Forest type is determined by the stocking (relative density) that tree species contribute to a sampled condition (see page 47). Presettlement forest types (see Fig. 4) that were influenced by a number of factors over time resulted in the current cover-type distribution. In Figure 6, the modeled distribution is based on FIA plot attributes and ancillary data, e.g., information on topography and climate (see page 179). Related forest types are combined into forest-type groups which can then be used with other information like soils and climate to create regional ecosystem classifications. Earlier, we discussed the distribution of forest-type groups. Here, we focus primarily on specific forest types.

What we found

The timberland base is split into 73 percent hardwood (predominately hardwood species), 25 percent softwood (predominately softwood species), and 3 percent mixed forest types (predominately jack or red pines and hardwood species like oak and aspen).

The top 15 forest types by acreage occupy 81 percent of timberland (Table 2, Figs. 12-14). Sugar maple/beech/yellow birch is the predominate forest type in Michigan. Every region and ownership group has at least some of this forest type. Seventy-two percent is privately owned and the largest portion (45 percent) is in the western Upper Peninsula. Aspen is the second most abundant forest type with 55 percent privately owned and 51 percent occurring in the northern Lower Peninsula. Northern white-cedar is the most abundant softwood forest type; 55 percent is privately owned and 50 percent is in the eastern Upper Peninsula.

Forest-type distributions vary by region. For example, black spruce (50 percent) and balsam fir (45 percent) are relatively abundant in the eastern Upper Peninsula. The northern Lower Peninsula has most of the other pine/hardwood (71 percent), northern red oak (70), red pine (67), and jack pine (55). The southern Lower Peninsula has relatively little acreage in many of the top 15 forest types; however, this region has the bulk of the white oak/red oak/hickory (57 percent), and green ash/red maple/elm (66 percent) forest types.

Some forest types are relatively more abundant in certain ownership groups given the amount of timberland in each group. For example, red pine (71 percent), jack pine (73), other pine/hardwood (56), and black spruce (49) are relatively more abundant on public land. Aspen (30 percent) and northern white-cedar (32) are more common on State and local government land. Sugar maple/beech/yellow birch (72 percent), sugar maple/basswood (68), white oak/red oak/hickory (68), black ash/American elm/red maple (73), red maple/upland (70), and green ash/red maple/elm (86) are found most often on private land. Some forest types like green ash/red maple/elm and white oak/red oak/hickory are low in acreage on U.S. Forest Service land. These forest types are primarily in the southern Lower Peninsula where the U.S. Forest Service has virtually no timberland ownership.

Table 2.—Distribution of live-tree volume (trees at least 5 inches d.b.h) on timberland by species and forest type, Michigan, 2004, in thousand ft^3 (top 30 species by live-tree volume for top 15 forest types by acreage).

Species	Total	Sugar maple/ beech/ yellow birch	Aspen	Northern white-cedar	Sugar maple/ basswood	White oak/ red oak/ hickory	Red pine	Jack pine	Black ash/ American elm/ red maple	Red maple/ upland	Northern red oak	Black spruce	Balsam fir	Other pine/ hardwood	Paper birch	Green ash/ red maple/ elm	Other forest types
Sugar maple	4,378,376	2,729,699	58,887	6,009	1,368,233	16,346	9,798	0	10,569	62,516	20,277	192	2,663	5,372	12,553	3,312	71,951
Red maple	3,575,288	1,257,705	256,696	69,634	38,690	221,948	24,026	7,386	103,066	725,796	80,741	12,981	23,658	34,853	43,516	34,806	639,785
Northern white-cedar	2,461,149	195,394	91,428	1,727,276	12,359	3,090	4,469	756	120,054	15,777	133	33,734	49,666	989	63,406	8,452	134,163
Red pine	1,962,903	25,824	39,819	4,885	2,083	22,635	1,513,173	87,842	184	3,804	11,668	9,287	4,561	134,620	2,141	221	100,156
Quaking aspen	1,580,458	208,723	922,567	47,272	61,115	27,263	17,840	11,865	26,069	30,188	6,328	8,648	22,827	19,101	35,427	11,284	123,944
Northern red oak	1,474,170	244,797	69,501	558	44,580	269,192	15,000	8,922	5,731	14,749	648,036	85	266	28,589	2,928	4,708	116,529
Eastern white pine	1,252,370	114,546	108,976	72,873	7,093	50,918	94,123	24,296	8,043	20,464	19,988	35,441	29,925	19,088	11,677	2,484	632,436
Bigtooth aspen	1,218,449	135,605	707,211	5,837	44,565	96,801	13,902	3,871	11,708	19,774	40,030	500	3,732	28,727	4,007	4,339	97,840
American basswood	820,683	134,550	12,642	4,055	578,823	17,007	2,832	0	20,586	5,902	5,436	0	942	1,545	1,380	9,168	25,817
Eastern hemlock	776,374	432,611	13,377	28,678	11,411	1,265	437	0	7,105	38,323	2,922	888	2,283	678	1,601	0	234,796
Black cherry	740,840	189,680	31,807	1,736	27,885	120,970	19,915	2,103	11,027	23,386	14,976	1,093	5,431	5,781	1,527	10,619	272,904
Balsam fir	662,209	150,321	139,258	96,280	15,386	190	2,330	4,344	22,416	28,783	550	14,305	87,332	1,687	33,143	1,323	64,562
White oak	638,346	11,309	12,750	506	2,822	254,698	12,910	3,479	3,843	121	45,007	0	0	12,304	275	1,661	276,659
Paper birch	635,529	134,055	93,079	83,995	13,668	6,552	7,357	6,953	15,887	21,752	4,829	11,005	17,813	7,821	151,971	1,170	57,622
Yellow birch	591,712	439,297	7,292	28,693	19,446	121	93	0	25,114	25,330	1,159	388	3,118	0	4,342	981	36,337
Black oak	547,028	2,145	8,889	0	1,776	391,832	14,207	4,956	536	62	7,700	0	0	13,710	0	2,645	98,569
Green ash	536,143	142,734	17,113	2,657	8,460	37,109	402	0	44,789	4,788	2,802	0	319	509	1,163	155,266	118,033
Jack pine	518,444	4,895	9,394	0	0	10,069	48,142	365,028	0	672	3,572	9,336	1,480	46,366	1,065	25	18,401
American beech	509,662	402,973	12,056	0	26,769	17,625	3,517	56	1,040	15,786	8,829	125	0	2,085	677	406	17,718
White spruce	499,584	89,427	90,688	53,802	11,922	1,724	11,142	4,802	16,045	14,317	1,132	7,023	37,522	1,303	15,619	257	142,859
Silver maple	487,588	35,907	3,917	158	2,300	25,971	92	0	144,806	163	69	0	0	0	1,001	24,278	248,926
Black spruce	454,832	13,347	18,648	116,791	717	61	4,006	6,032	3,798	1,339	0	207,381	22,262	626	9,507	174	50,142
White ash	430,167	122,914	14,173	1,133	95,260	37,876	545	0	16,269	6,233	8,534	28	600	1,739	801	14,217	109,844
Black ash	369,859	75,829	14,765	31,747	19,243	4,447	55	0	166,293	5,756	1,092	606	4,267	1,551	4,095	8,778	31,334
Tamarack (native)	258,777	2,307	6,468	82,310	56	1,442	668	1,466	7,426	451	0	33,903	5,111	117	5,000	870	111,182
Northern pin oak	243,075	1,138	7,809	14	503	27,327	15,967	14,057	544	16	3,286	0	49	24,791	89	1,389	146,098
Balsam poplar	225,796	10,941	37,453	45,216	2,842	509	359	0	8,519	1,450	26	1,662	6,048	932	12,016	3,132	94,691
American elm	216,099	43,466	10,341	1,576	7,060	28,975	460	44	22,268	4,289	568	0	383	1,324	540	23,376	71,431
Bitternut hickory	65,997	9,751	369	0	6,881	34,321	0	0	1,372	0	1,198	0	0	42	0	4,321	7,742
Shagbark hickory	62,720	2,413	462	0	1,086	50,539	0	0	934	0	1,056	0	0	0	0	1,750	4,480
Top 30 species	28,194,628	7,364,302	2,817,835	2,513,690	2,433,032	1,778,823	1,837,767	558,260	826,039	1,091,986	941,945	388,609	332,260	396,251	421,465	335,412	4,156,953
All species	29,283,473	7,468,560	2,837,550	2,515,100	2,474,205	1,940,649	1,852,675	559,898	865,837	1,095,961	952,834	388,665	332,499	401,381	423,984	400,730	4,772,942

Figure 12.—Percentage of timberland by forest type, Michigan, 2004 (top 15 forest types by timberland acreage).

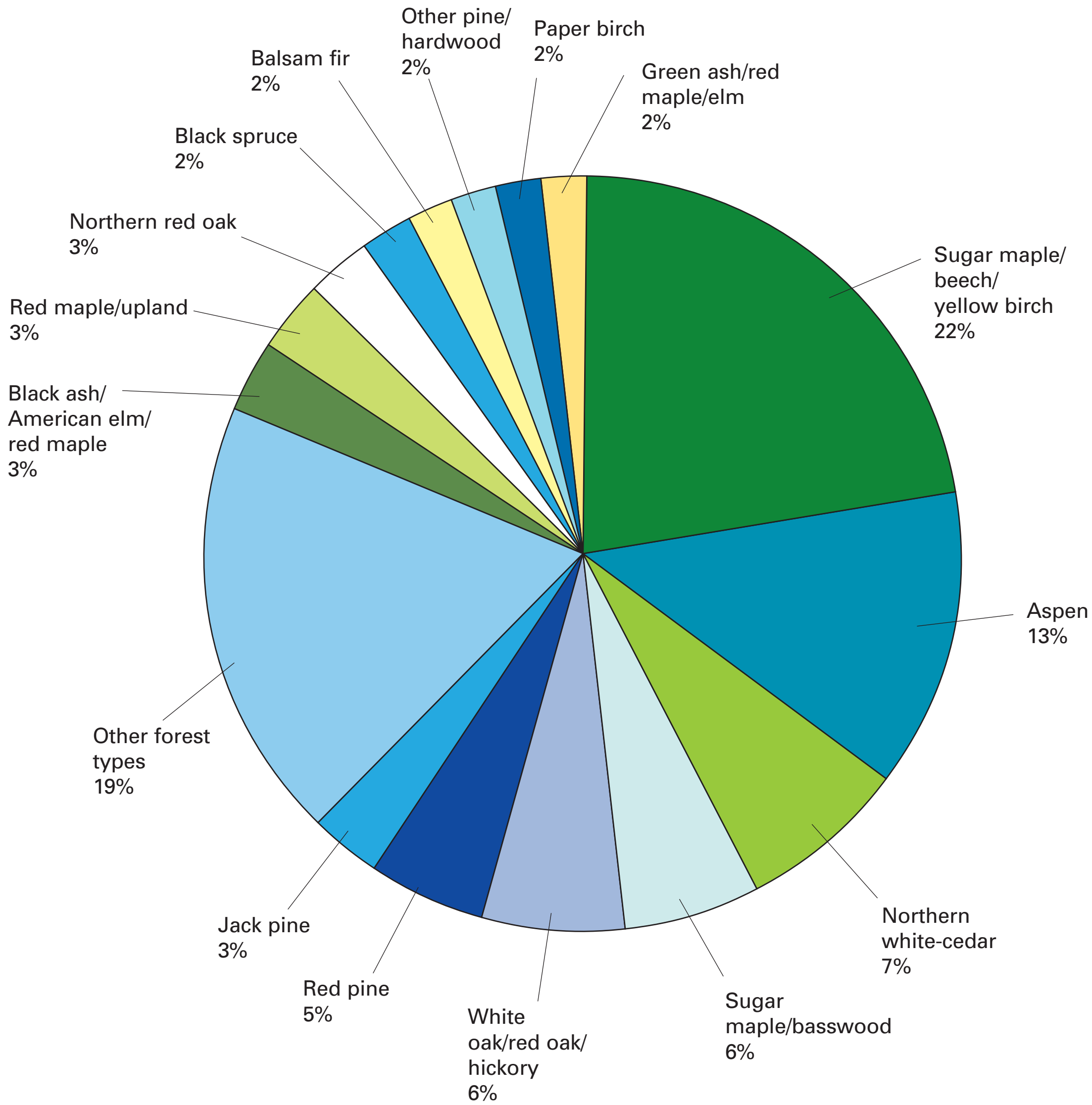


Figure 13.—Area of timberland by forest type and region, Michigan, 2004 (top 15 forest types by timberland acreage).

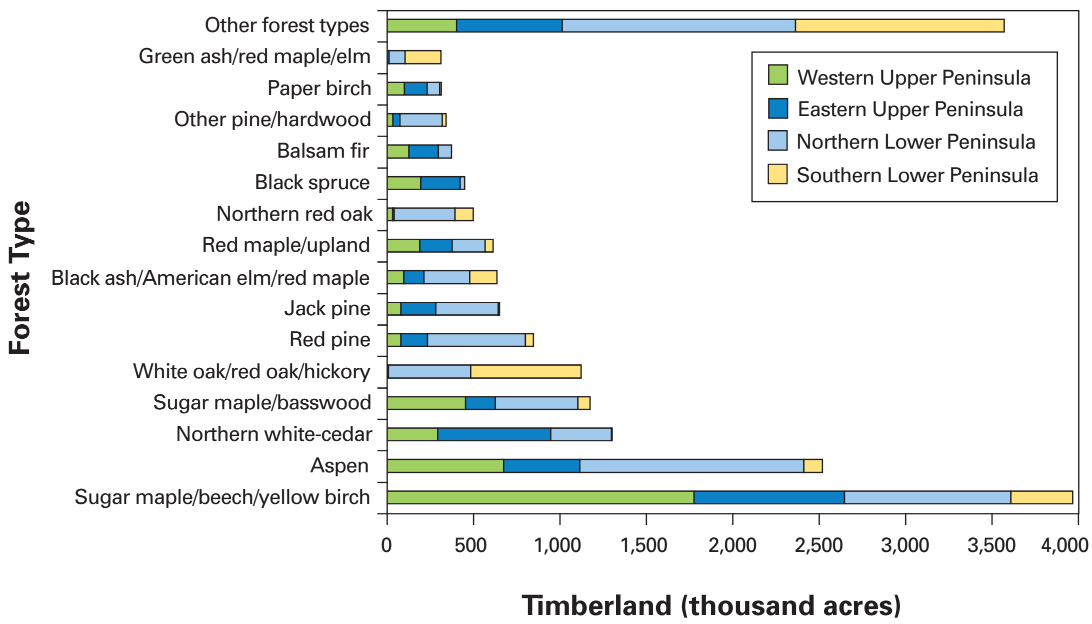
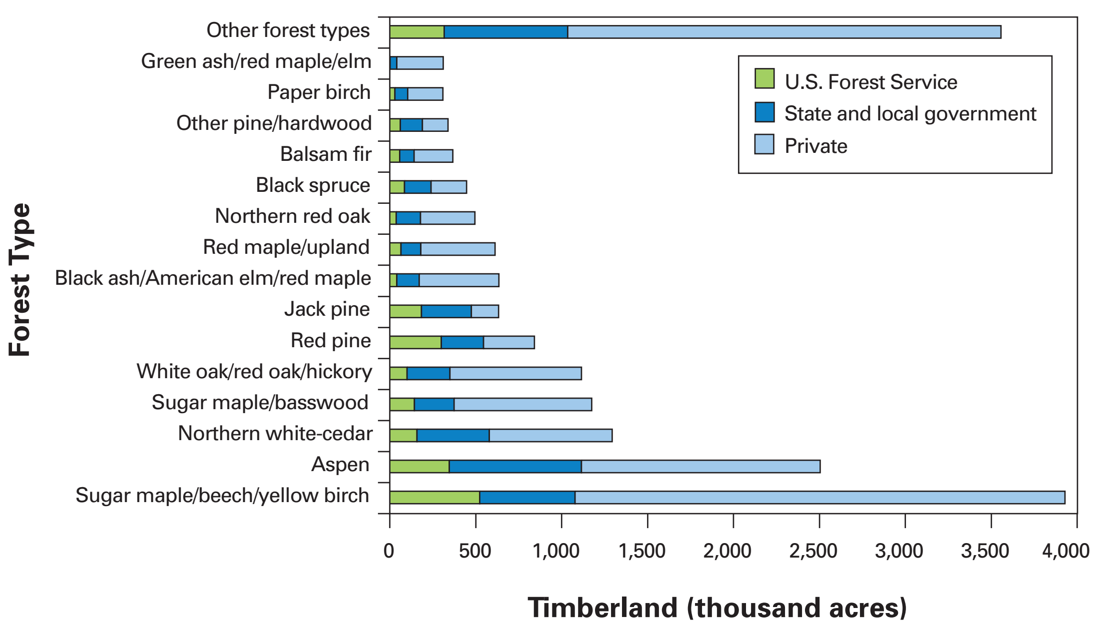


Figure 14.—Area of timberland by forest type and ownership group, Michigan, 2004 (top 15 forest types by timberland acreage).



What this means

The forest-type distribution in Michigan is primarily a product of site characteristics, past utilization, and adaptive abilities of species within forest types. As land was cleared and logged, early successional species and associated forest types like aspen and paper birch became more established. Through succession, these forest types have peaked and declined in acreage. Many of these early successional species have depended on fire to regenerate but wildfire has been suppressed. Aspen and paper birch forest types have converted to late-successional forest types, primarily sugar maple/beech/yellow birch. Within the sugar maple/beech/yellow birch and aspen forest types, sugar maple, red maple, and aspen are the most abundant species based on live-tree volume. These species are among the most important species to the State's wood-products industry (see page 162).

There are many other examples where forest type acreage has changed over time. For instance, there have been gradual increases in softwood forest types like northern white-cedar and black spruce since the first inventory in 1935. The increase in these forest types is partly due to succession, operability constraints (too wet), and wildlife concerns. Another example is the result of public planting programs in the last century. Hundreds of thousands of acres were planted with mostly softwood species. Red pine was the most popular plantation species 45 to 75 years ago. The red pine forest type has increased with the planting and maturing of these red pine trees. Public planting programs are also partially responsible for the relative abundance of red pine, jack pine, and other pine/hardwood forest types on public land.

Forest types are adapted to occupy specific sites or ecological niches and each region is unique. The difference in these niches is greatest between the southern Lower Peninsula and the rest of the State. The transition between the southern and northern Lower Peninsula is the southern range of many northern tree species, e.g., northern white-cedar, jack pine, and black spruce, and the northern range for many southern tree species, e.g., black oak and hickory. Climate, soils, physiography, and land-use change quite appreciably between these two regions. Consequently, there is a stark contrast in forest-type distributions between the southern Lower Peninsula and the rest of Michigan.

There also are many examples where a forest type is preferentially adapted to particular niches and appears more often in these areas. For example, most of the acreage in softwood forest types like northern white-cedar, black spruce, and balsam fir is in the eastern Upper Peninsula. The species in these forest types are adapted to the relatively low and wet soils of this region. By contrast, most of the acreage in softwood and mixed-forest types like jack pine, red pine, and other pine/hardwood is in the northern Lower Peninsula. The species in these forest types are adapted to the relatively high and dry soils in this region.

Number of Trees

Background

An estimate of the number of trees in a forest is useful when combined with data on diameter-class distribution. Young forests generally have many more trees per acre than older forests but the latter usually have much more biomass than younger forests. The number of trees by size and species defines stocking density, which is an indicator associated with variables such as wildlife habitat and timber value. Looking at current numbers and changes over time can identify management issues.

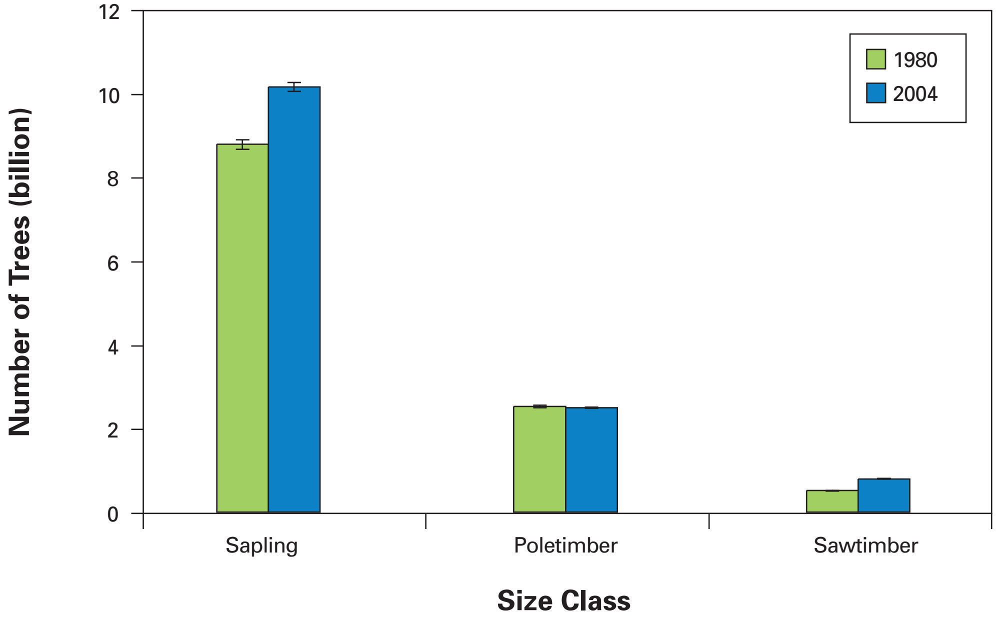
What we found

In Michigan, there are 13.8 and 13.4 billion live trees (at least 1 inch d.b.h.) on forest and timberland, respectively, or about 716 trees per acre on timberland. Sixty-five percent of the trees on timberland are hardwoods. Softwoods and hardwoods generally follow the same size-class distribution. Seventy-five percent of these trees are saplings (1 to less than 5 inches d.b.h.), 18 percent are poletimber-size trees (5 to less than 9 inches for softwoods and 5 to less than 11 inches for hardwoods), and 6 percent are sawtimber-size trees. The numbers of trees are fairly well distributed with no species accounting for more than 14 percent of all trees.

The number of trees on timberland increased significantly from 1980 to 2004 (675 to 716 trees per acre). There was a 21-percent increase in the number of softwood and a 10-percent increase in hardwoods. The number of sawtimber trees increased by 55 percent and saplings increased by 16 percent. The number of poletimber trees remained virtually unchanged (Fig. 15).

Sugar maple saplings. Photo by Scott A. Pugh, U.S. Forest Service.

Figure 15—Number of live trees (at least 1 inch d.b.h.) on timberland by size class, Michigan, 1980-2004 (error bars represent 68-percent confidence interval around estimate).



The top 20 species based on the number of trees on timberland account for 85 percent of the total on timberland (Figs. 16-17). Changes since the 1980 inventory are shown in Table 3. Red maple, eastern white pine, and white spruce experienced significant increases in all size classes. Red maple had the second largest increase in total number of trees at 216 million. Balsam fir had the largest overall increase but this was due to the increase in saplings. Balsam fir had fewer poletimber and sawtimber trees.

Quaking and bigtooth aspen both experienced a significant increase in saplings but a decrease in poletimber trees. Overall, both species increased.

Northern white-cedar, red pine, and sugar maple experienced significant declines in saplings. All had increases in the sawtimber-size class. Northern white-cedar and sugar maple also increased significantly in poletimber. Red pine is the only species with an estimate of more poletimber trees than saplings (Fig. 17).

Paper birch, yellow birch, and jack pine have experienced significant losses since 1980. Yellow birch lost in all size classes while paper birch and jack pine lost in the sapling and poletimber sizes.

Figure 16.—Number of live trees (at least 1 inch d.b.h.) on timberland by size class and species, Michigan, 2004; error bars represent 68-percent confidence interval around estimate (top 20 species by number of live trees).

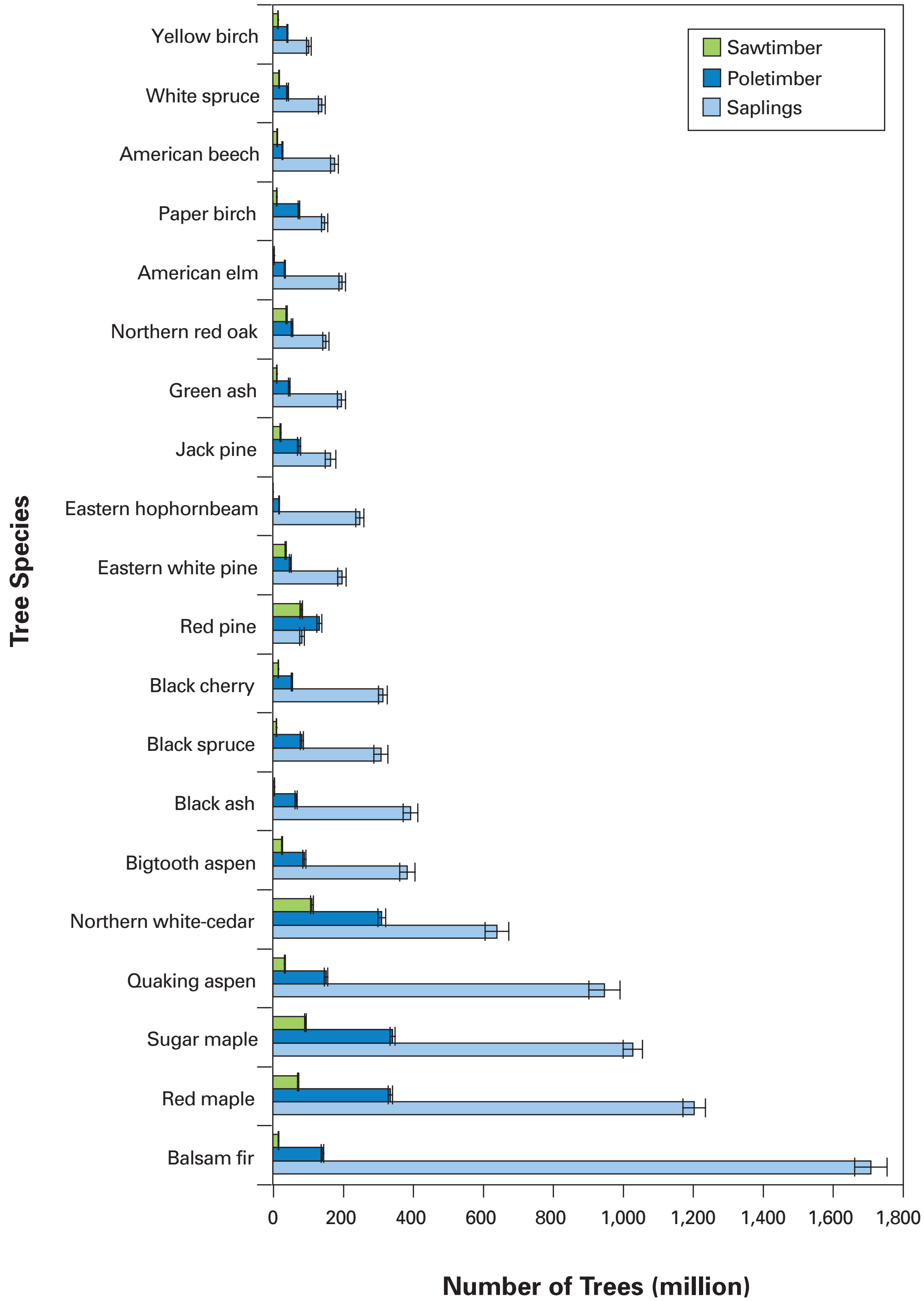


Figure 17.—Percentage of number of live trees (at least 1 inch d.b.h.) on timberland by size class and species, Michigan, 2004 (top 20 species by number of live trees).

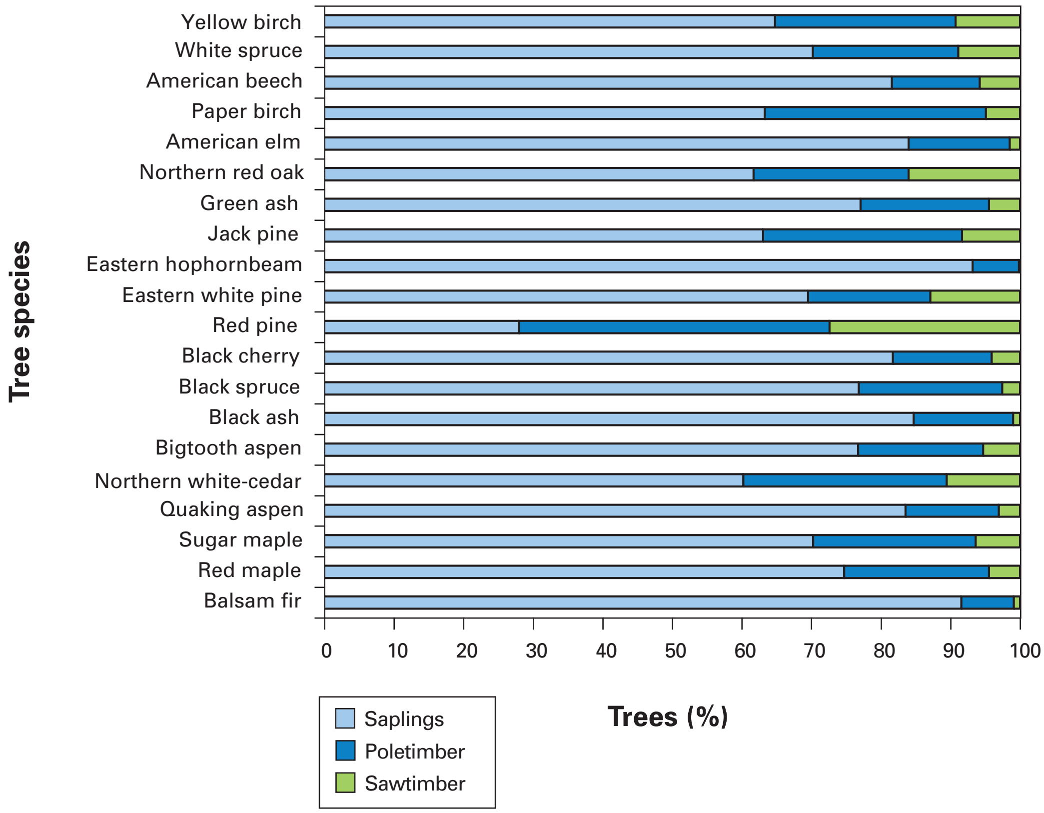


Table 3.—Change in number of live trees on timberland by size class and species, Michigan, 1980-2004 (top 20 species by number of live trees shown; numbers in bold and italics indicate a significant change using 68-percent confidence interval).

	Sapling		Poletimber		Sawtimber	
Species	**Trees** million	**Percent**	**Trees** million	**Percent**	**Trees** million	**Percent**
Balsam fir	***737***	***76***	***-28***	***-17***	***-4***	***-20***
Red maple	***146***	***14***	***40***	***13***	***31***	***76***
Sugar maple	***-436***	***-30***	***28***	***9***	***39***	***70***
Quaking aspen	***156***	***20***	***-60***	***-28***	-2	-6
Northern white-cedar	***-129***	***-17***	***29***	***10***	***45***	***68***
Bigtooth aspen	***121***	***46***	***-14***	***-13***	***7***	***33***
Black ash	***77***	***24***	***16***	***31***	***1***	***22***
Black spruce	24	8	4	5	***5***	***78***
Black cherry	***118***	***60***	***8***	***16***	***9***	***136***
Red pine	***-94***	***-53***	13	11	***59***	***270***
Eastern white pine	***101***	***105***	***28***	***123***	***17***	***86***
Eastern hophornbeam	***89***	***55***	0	1	0	0
Jack pine	***-51***	***-24***	***-46***	***-38***	-1	-6
Green ash	***104***	***112***	***34***	***251***	***10***	***653***
Northern red oak	5	3	***-33***	***-37***	***10***	***33***
American elm	10	5	-2	-7	***-2***	***-38***
Paper birch	***-44***	***-23***	***-55***	***-43***	0	2
American beech	***75***	***73***	***4***	***15***	***2***	***16***
White spruce	***62***	***80***	***10***	***31***	***3***	***17***
Yellow birch	***-21***	***-17***	***-8***	***-16***	***-2***	***-12***

The number of trees by size class does not vary much by region or ownership group. There is a small but significant difference in the southern Lower Peninsula compared to the rest of the State. The proportion of sawtimber trees within the southern Lower Peninsula is slightly more than in the other regions (7 percent versus 5 to 6 percent in other regions). In addition, sawtimber trees of the southern Lower Peninsula are slightly larger on average compared to sawtimber trees of the northern Lower and Upper Peninsula (14.6, 13.2, 12.9, and 12.5 inches d.b.h. for southern Lower, western Upper, northern Lower, and eastern Upper Peninsula, respectively). This explains the larger estimates for biomass and volume per acre for the southern Lower Peninsula compared to the rest of Michigan (see pages 51 and 64).

What this means

The number of sawtimber trees has increased considerably. Some shade-tolerant species are increasing in number and several intolerant species are declining in number. Although overall numbers for the shade species are on the rise, some like sugar maple and northern white-cedar are losing recruitment (young trees). In particular, there is concern over continuing impacts on regeneration from deer browsing (Cook 2008, Cote et al. 2004).

Red pine experienced the largest absolute increase in the number of sawtimber trees and also large increases in volume (see Figs. 29 and 31). Red pine was the most popular plantation species 45 to 75 years ago and now much has grown to a commercially harvestable size. The level of planting has been low over the past 45 years. Most red pine are poletimber trees.

Balsam fir has more saplings than any other species in Michigan. The area of balsam fir could increase in the future because of the large increase in saplings. Some of this potential increase will be offset by the fact that balsam fir also has decreased in volume and has the highest average annual mortality to volume (see Figs. 29 and 42). Over time, the annual inventory will make it possible to identify emerging trends linked to balsam fir.

The rise in red maple numbers is not isolated to Michigan. It is the most common tree in the United States. Red maple is shade tolerant but it can grow in full sunlight, is found on wet and dry sites, is a prolific seeder, and responds well to disturbance.

Yellow birch, a midtolerant species, has been declining for several decades. It grows primarily in canopy gaps of the sugar maple/beech/yellow birch forest type. Without aggressive forest management promoting canopy gaps, yellow birch probably will continue its decline.

Some species are on a steep decline. Paper birch and jack pine have decreased sharply in number by 30 and 27 percent, respectively since 1980 and they are losing most of this in the sapling and poletimber-size classes. They have also decreased significantly in volume (see Fig. 29). Both of these species are intolerant and were dependent on fire to regenerate but wildfire has been suppressed. These species are threatened by various elements (see pages 134 and 156) and are more susceptible at times partly because Michigan is located in the southern edge of their distribution. Paper birch will continue to decline but active management can maintain the jack pine resource. For example, smaller jack pine trees are preferred by important wildlife species like the Kirtland warbler. In Michigan, there are management areas where the focus is on improving habitat for this warbler. In these areas, the decline in smaller jack pine trees is expected to level off in response to management.

Stocking

Background

The number of trees, sizes, spacing, and species define stocking. The growth potential of a stand is considered to be reached when it is fully stocked. For example, some fully stocked poletimber stands have a basal area of more than 80 square feet (ft^2) per acre. Using this example, a fully stocked seedling-sapling stand would have a sufficient number of trees to attain a basal area of 80 ft^2/acre when the trees reach poletimber size. For additional information on stocking, see "National Algorithms for Determining Stocking Class, Stand Size Class, and Forest Type for Forest Inventory and Analysis Plots" at http://www.fia.fs.fed.us/library/field-guides-methods-proc/. As mentioned previously, stocking can identify potential management opportunities. For example, the health of overstocked stands could be threatened and experience a decline in growth. A management activity such as thinning could improve growth and vigor.

What we found

Seventy-seven percent of Michigan's forest land is medium or fully stocked. Eight percent is overstocked and 14 percent is poorly stocked or nonstocked. Stocking varies by owner, region, and forest type (Figs. 18-20). Forest Service lands have the greatest percentage of fully and overstocked stands at 53 and 11 percent, respectively. Private lands have the lowest percentage of fully and overstocked stands at 44 and 7 percent, respectively. State and local government ownerships have 45 and 11 percent fully and overstocked stands, respectively. The Forest Service has a significantly lower percentage of poorly and nonstocked stands (8 percent) compared to private (15 percent) and State and local government (14 percent). These poor and nonstocked areas do not include nonforest land such as barrens, marshes, and rangeland.

Figure 18.—Percentage of forest land by stocking class and ownership group, Michigan, 2004.

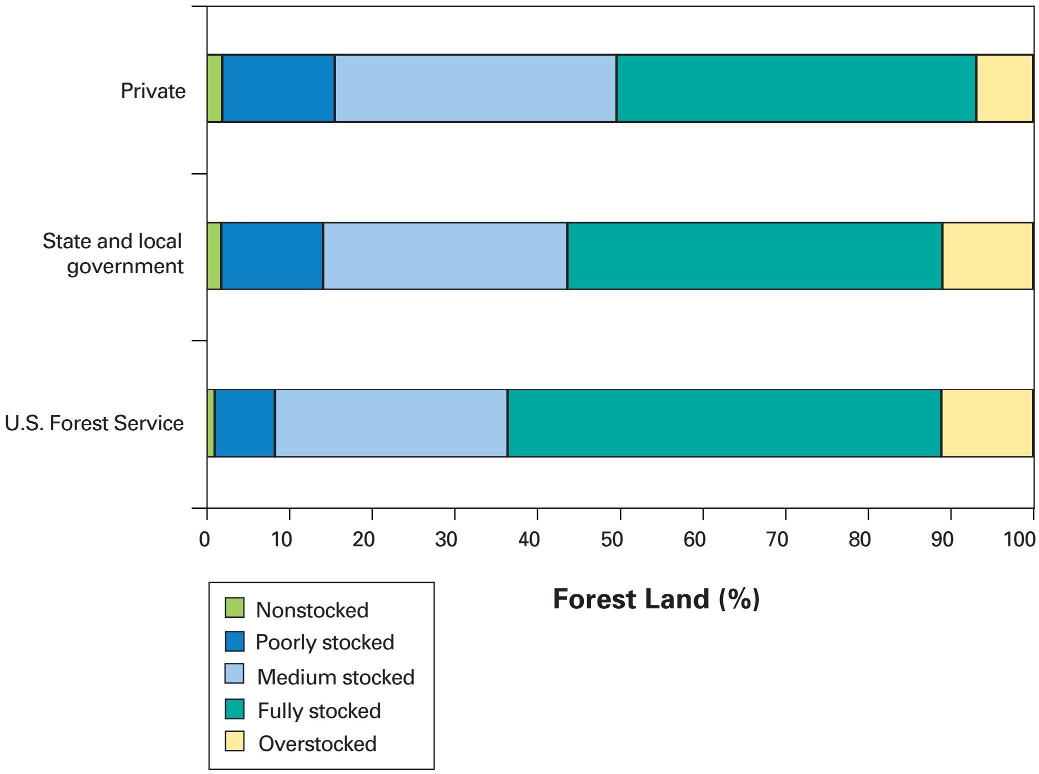
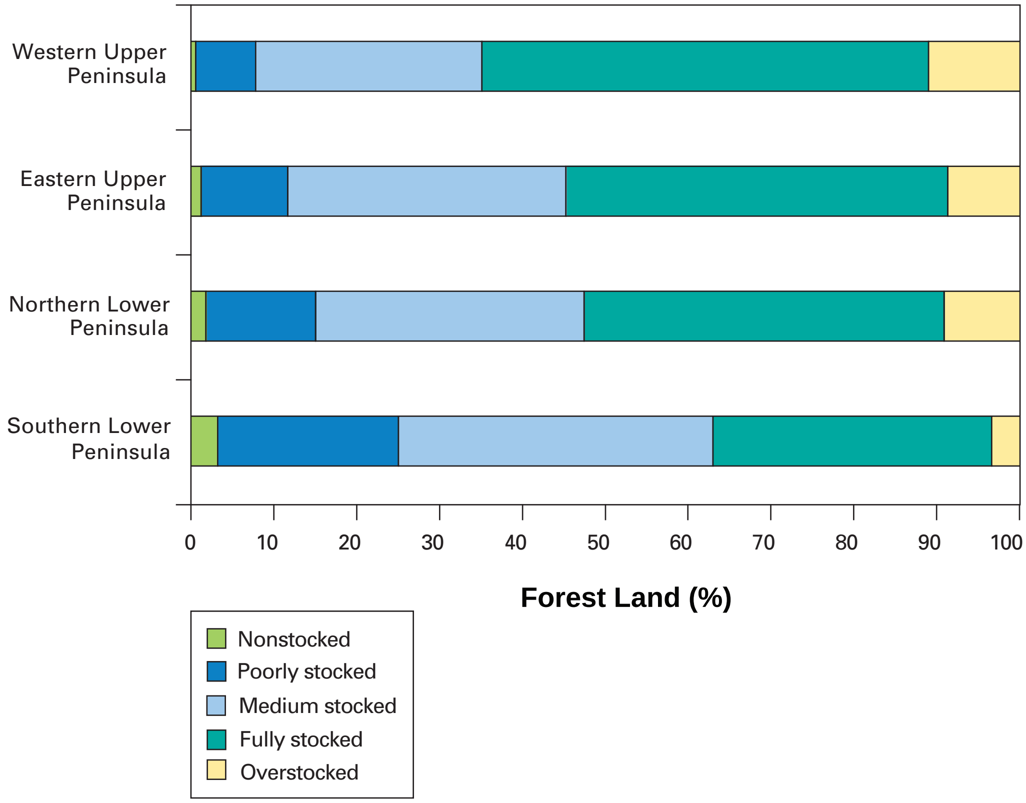


Figure 19.—Percentage of forest land by stocking class and region, Michigan, 2004.



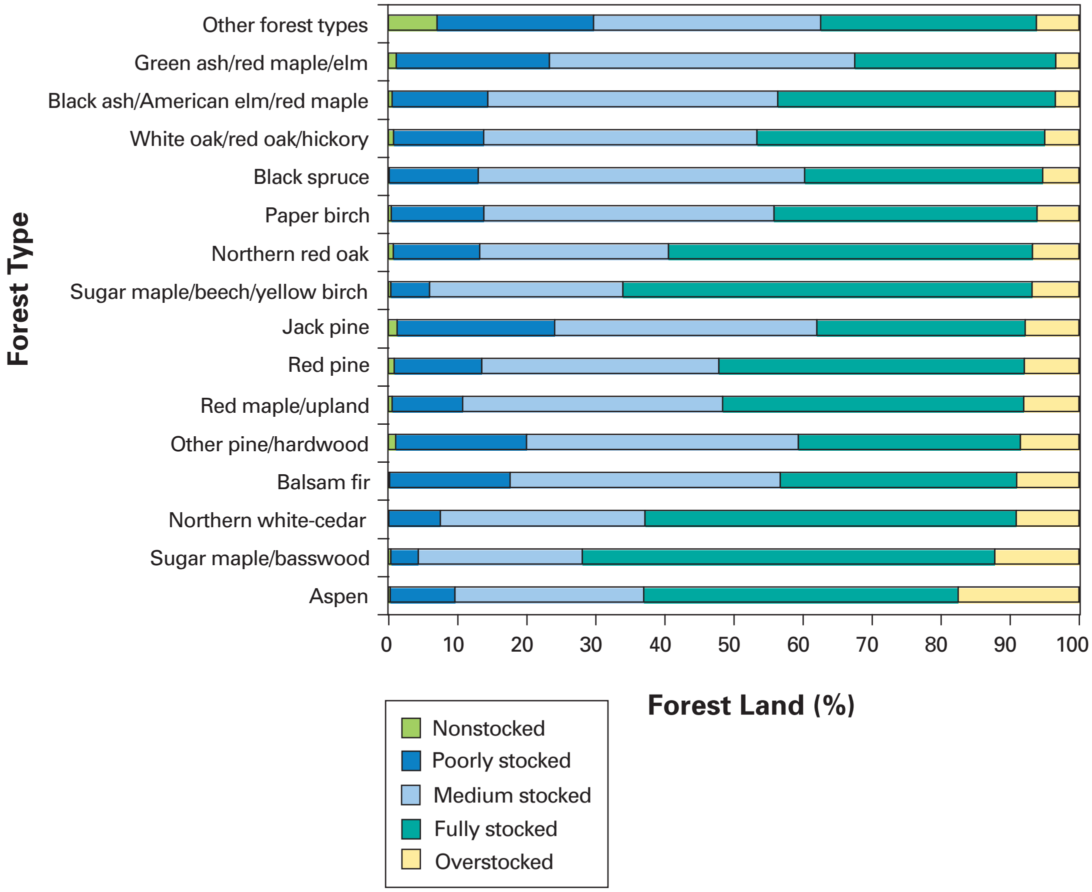


Figure 20.—Percentage of forest land by stocking class and forest type in Michigan, 2004 (top 15 types by timberland acreage).

The eastern Upper Peninsula and the northern Lower Peninsula have stocking distributions that closely follow the State as a whole (Fig. 19). By contrast, the southern Lower Peninsula has a significantly lower percentage of its stands in the fully and overstocked classes at 34 and 3 percent, respectively. The southern Lower Peninsula has a higher percentage in the lower stocking classes (38-percent medium and 25-percent poorly or nonstocked). The western Upper Peninsula has the greatest percentage of fully and overstocked stands at 54 and 11 percent, respectively. The western Upper Peninsula has the lowest percentage of poorly and nonstocked stands at 8 percent.

Stocking levels vary by forest type (Fig. 20). This variation is influenced by the inherent characteristics of the forest types, site characteristics, and past utilization of the forest types. As expected, forest types like sugar maple/basswood, sugar maple/beech/yellow birch, aspen, northern white-cedar, and northern red oak have higher percentages of fully stocked stands. Forest types like jack pine, other pine/hardwood, and green ash /red maple/elm have lower percentages of fully stocked stands and higher percentages of poorly and nonstocked stands.

Forest types with the highest stocking are more common on mesic sites. Forest types with the lowest stocking usually are on hydric or xeric sites, very wet or dry, respectively. Jack pine and other pine/hardwood often are poorly stocked and are found primarily on xeric sites. Green ash /red maple/elm, black spruce, and black ash/American elm/red maple forest types occur usually on hydric sites. These types have relatively lower stocking levels. Northern white-cedar is an exception with many medium to overstocked stands on hydric sites. The occurrence of these medium to overstocked stands is partly due to the historical development of these stands and limited utilization affected by operability constraints and wildlife concerns.

What this means

The high percentage of fully and medium stocked lands in Michigan is conducive to maintaining forest health, quality timber products, and efficient timber production. Lower stocking levels are expected with forest types common to relatively wet and dry sites.

The southern Lower Peninsula of Michigan tends to have lower stocking and at much better soils and site productivity. Forty-nine percent of timberland in the southern Lower Peninsula has a site productivity of at least 85 ft^3/acre/year. The next most productive area is the northern Lower Peninsula, where 26 percent of timberland has a site productivity of at least 85 ft^3/acre/year.

A number of factors contribute to the lower stocking in the southern Lower Peninsula. Some lower stocking in this region is due to nonforest land reverting to forest land. Thirty-eight percent of the low and nonstocked forest land in 2004 was nonforest land in 1993. Most of this reverting nonforest land was cropland and pasture. Some lower stocking is due to the forest types and activities such as grazing and high-grading in the region. For example, most of the green ash/red maple/elm type is in the southern Lower Peninsula (see Fig. 13).

The western Upper Peninsula has a higher percentage of fully stocked stands. The high proportion of U.S. Forest Service and State and local government land contributes to the high stocking in the region. This region also has higher stocking levels than the rest of the State regardless of ownership group. Predominate forest types in the region such as sugar maple/beech/yellow birch, aspen, and sugar maple/basswood tend to have higher stocking levels that also contribute to high stocking in the region.

Biomass

Background

There is increasing interest in biomass. Tree biomass can include the whole tree, including roots. Here, the focus is on live aboveground tree biomass (at least 1 inch d.b.h., including bark but excluding foliage). Among other things, biomass estimates are important in determining carbon sequestration, fuel availability, and fuel loading in forest stands. The Michigan Biomass Energy Program and the Great Lakes Biomass State-Regional Partnership are working to encourage increased production and use of energy derived from biomass. Forests and wood waste from industry are important sources of biomass.

What we found

Biomass, measured as live aboveground tree biomass on forest land, is estimated at 793.7 million dry tons (41.1 dry tons/acre on average). The distribution of forest biomass per acre on forest land is presented in Figure 21. Results are presented by EMAP hex (Environmental Monitoring and Assessment Program; see page 179). Although biomass per acre of forest land is highest in the southern Lower Peninsula, most of the State's biomass is in the northern Lower Peninsula and the western Upper Peninsula (Table 4).

Uinta National Forest, aspen regeneration. Photo by Doug Page, USDI Bureau of Land Management, www.forestryimages.org.

Figure 21.—Live-tree biomass per acre (dry tons for trees at least 1 inch d.b.h.) on forest land by EMAP hex, Michigan, 2004.

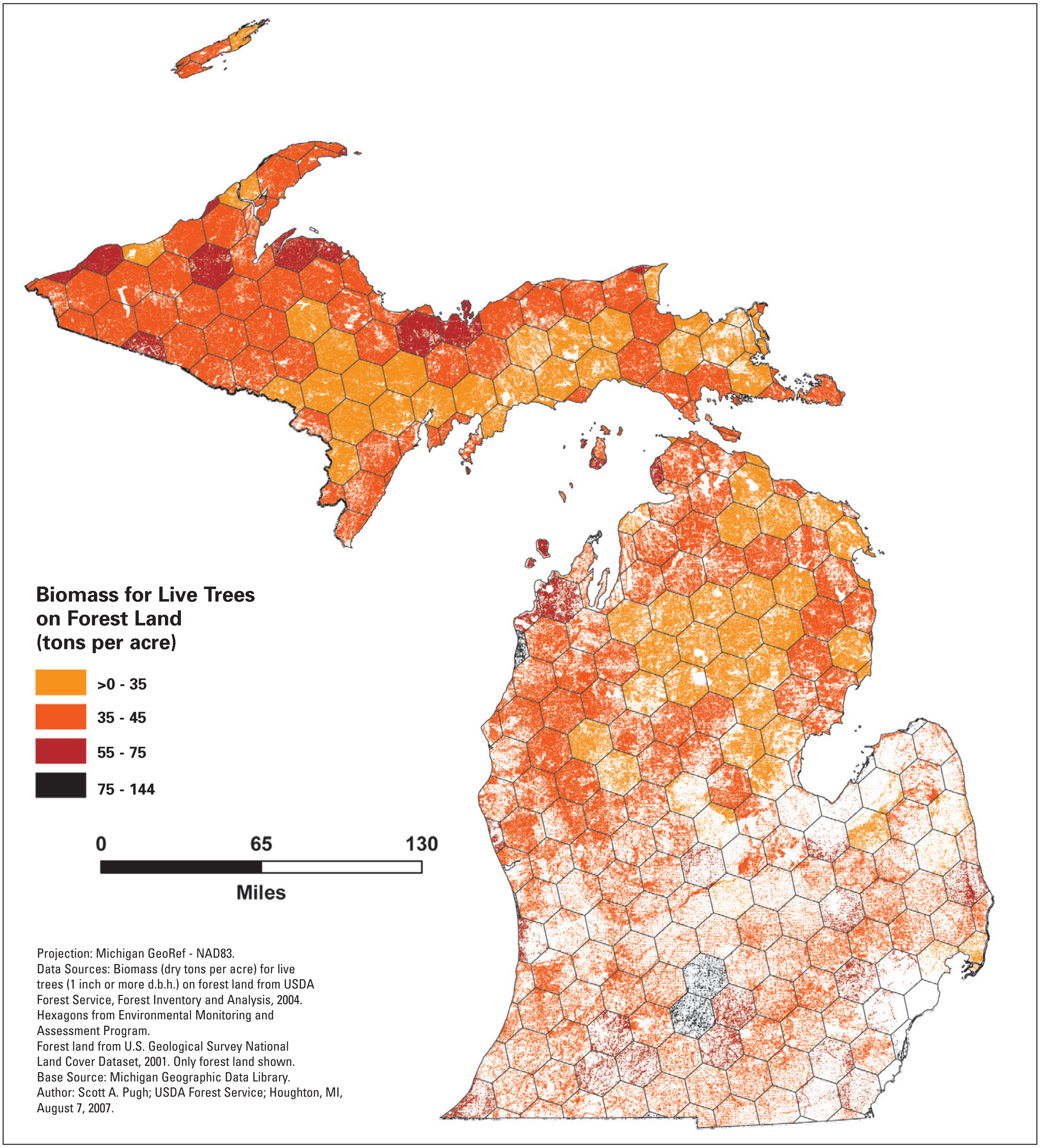


Table 4.—Biomass and forest land by region, Michigan, 2004.

Region	Forest land	Biomass	Biomass	Biomass
	million acres	million dry tons	dry tons/acre	percent
Eastern Upper Peninsula	4.1	149.8	36.4	18.9
Western Upper Peninsula	4.9	218.9	44.8	27.6
Northern Lower Peninsula	7.3	280.4	38.4	35.3
Southern Lower Peninsula	3.0	144.6	48.1	18.2
All units	**19.3**	**793.7**	**41.1**	**100**

The average dry weight of a tree increases dramatically with increasing tree diameter (Table 5). For example, trees in the 7.0- to 8.9-inch class weigh slightly more than twice that of trees in the 5.0- to 6.9-inch class.

Table 5.—Average tree biomass (dry pounds) by diameter class (inches d.b.h.) and species group, Michigan, 2004.

D.b.h. class (inches)	Softwoods	Hardwoods
	-------------------------- *dry pounds*	-------------------------
1.0 - 2.9	5	7
3.0 - 4.9	30	47
5.0 - 6.9	89	148
7.0 - 8.9	186	323
9.0 - 10.9	321	561
11.0 - 12.9	503	860
13.0 - 14.9	734	1,225
15.0 - 16.9	1,021	1,669
17.0 - 18.9	1,399	2,197
19.0 - 20.9	1,831	2,794
21.0 - 22.9	2,353	3,488
23.0 - 24.9	2,877	4,228
25.0 - 26.9	3,482	5,007
27.0 - 28.9	4,429	6,014
29.0 - 30.9	5,187	6,781
31.0 - 32.9	5,727	7,971
33.0 - 34.9	6,952	8,799
35.0 - 36.9	9,401	11,407
37.0 - 38.9	8,356	12,118
39.0 - 40.9	12,922	12,411
41.0 +	15,753	17,491
Average	**76**	**136**

Eighty-two percent of the total biomass is in growing-stock trees, 10 percent is in saplings (1 to less than 5 inches d.b.h.), and 8 percent is in nongrowing-stock trees (5+ inches d.b.h.) on forest land (Fig. 22). Nongrowing-stock trees larger than saplings are rough or rotten cull trees (saplings are also excluded from growing stock). Seventy-seven percent of the total biomass consists of hardwood species. Biomass ownership is split consistently with forest-land ownership (Fig. 23).

Figure 22.—Percentage of live-tree biomass (trees at least 1 inch d.b.h.) on forest land by aboveground component, Michigan, 2004.

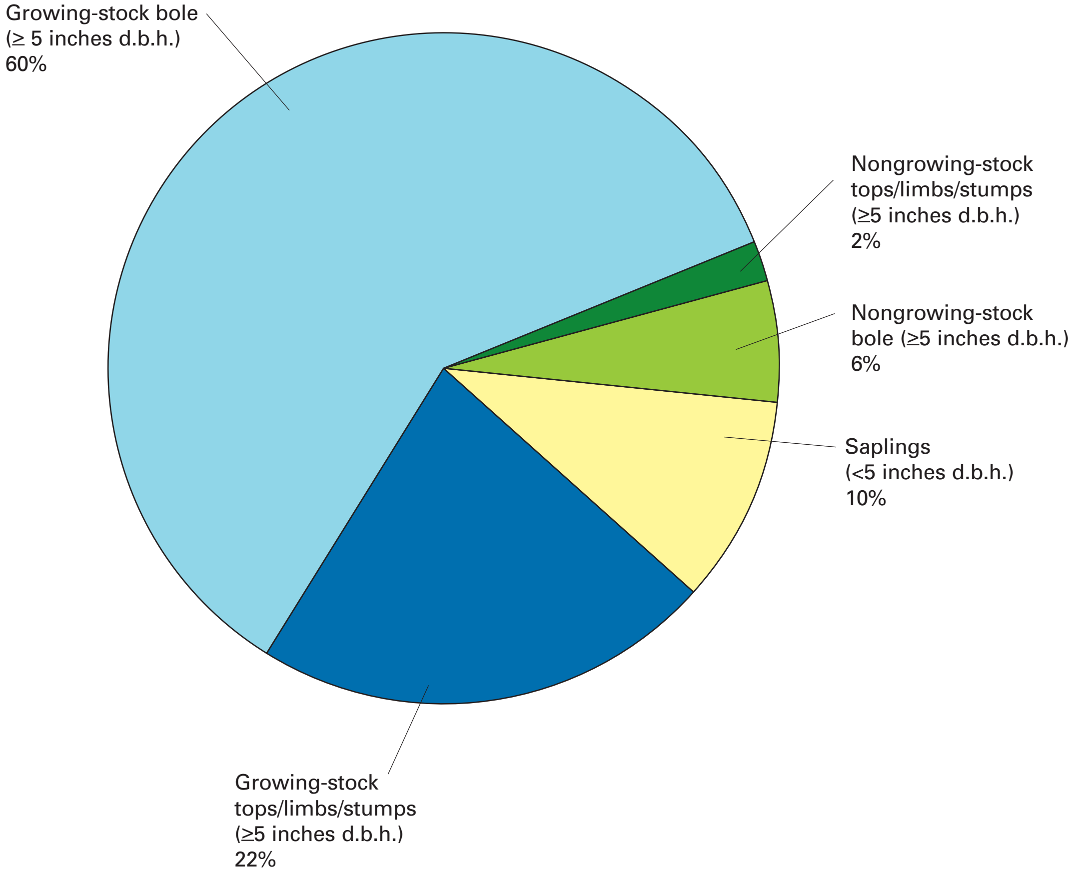
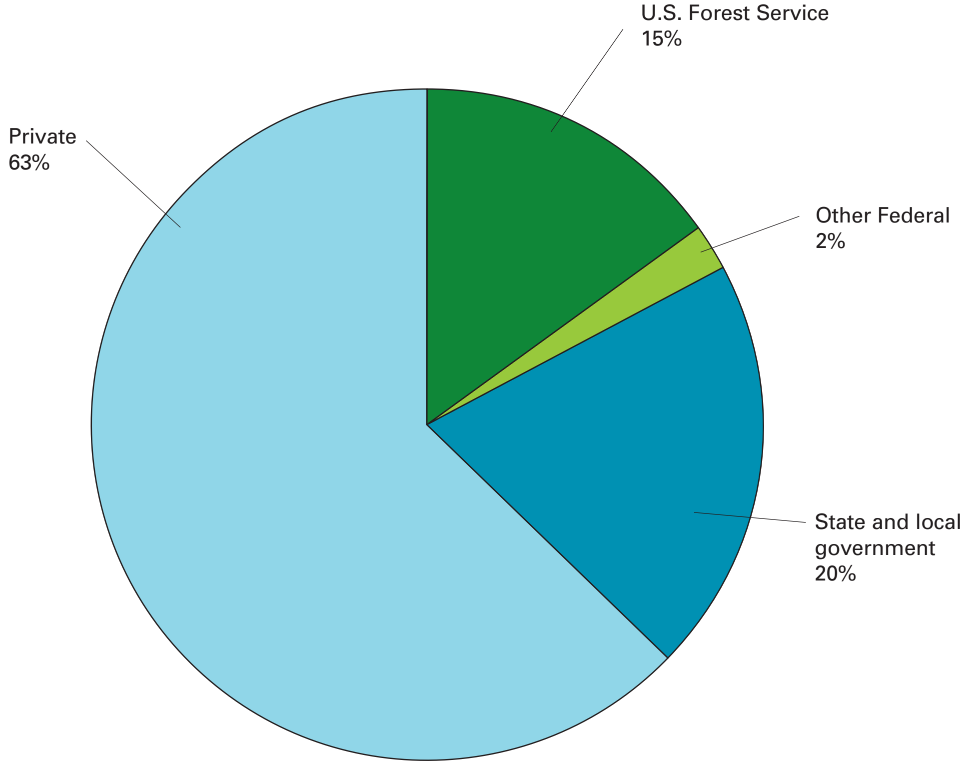


Figure 23.—Percentage of live-tree biomass (trees at least 1 inch d.b.h.) on forest land by ownership class, Michigan, 2004.



Total live dry biomass (trees at least 1 inch d.b.h.) on timberland in 1980 was 631.5 million tons. By 2004, this had increased 18 percent to 769.8 million tons. This increase was mainly due primarily to the increasing size of the trees in Michigan. Biomass increased in sawtimber and poletimber trees but decreased in saplings. In 1980, half of the live-tree biomass on timberland was in the 8-inch d.b.h. class and smaller; by 2004, it shifted to the 10-inch d.b.h. class and smaller (Fig. 24).

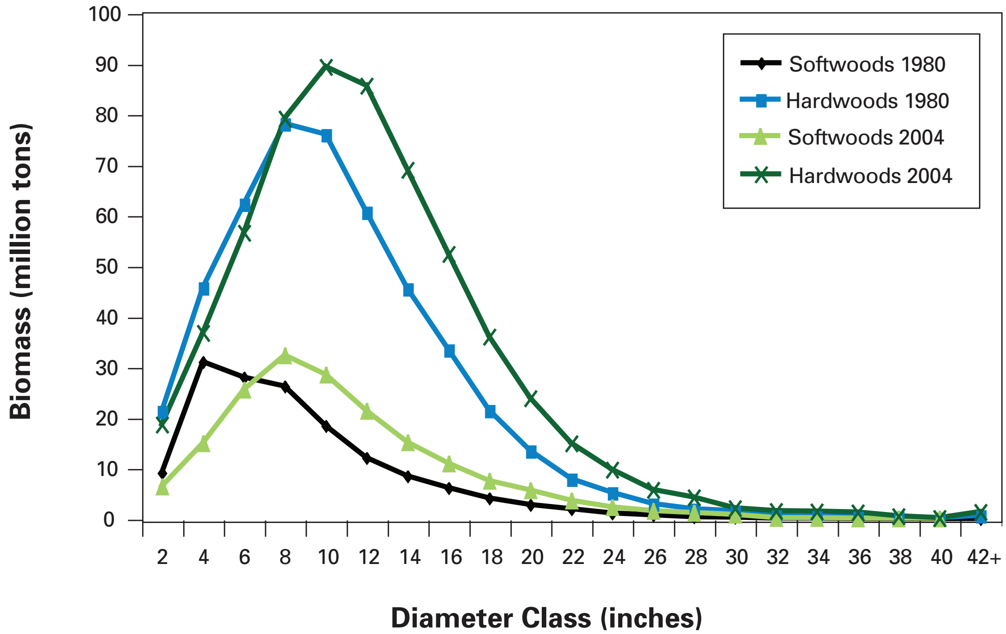


Figure 24.—Distribution of live-tree biomass (trees at least 1 inch d.b.h.) on timberland by species group and 2-inch diameter class, Michigan, 1980 and 2004.

What this means

There is an interest in the use of wood biomass for future energy production. Michigan is continuing to gain biomass as the forests mature. Most of this biomass is in the boles of the growing-stock trees and most of the increases are in the higher value sawtimber-size trees. There are markets for these today and future demand for biomass may compete with these markets or enhance forest management for these markets. Live aboveground tree biomass is an important carbon pool but there are others, including standing dead trees, down woody materials, roots, nontree vegetation, and forest soils. Forest soils contain most of the carbon (Lal 2004).

Volume

Background

Like stocking, current volumes and change in volume over time characterize the forests and reveal important resource trends. In addition, it is useful to compare components of change like net growth, removals, and mortality to current volumes. Although some information is presented for live-tree volume on forest land, we focus primarily on growing stock on timberland because past estimates of net growth, removals, and mortality are available only for this specification.

Estimates of live-tree volume include live, rough, rotten, and noncommercial species of trees at least 5 inches d.b.h. Growing-stock volume includes trees at least 5 inches d.b.h. and excludes rough, rotten, and dead trees in addition to noncommercial tree species, e.g., eastern hophornbeam and apple.

What we found

There are about 27.3 billion ft^3 of growing stock on timberland or about 1,457 ft^3/acre. Of this volume, 68 and 32 percent are in hardwood and softwood species, respectively. Sugar maple (22 percent), red maple (18 percent), quaking aspen (8 percent), northern red oak (7 percent), and bigtooth aspen (6 percent) account for 62 percent of hardwood growing-stock volume. Northern white-cedar (26 percent), red pine (22 percent), and eastern white pine (14 percent) account for 60 percent of softwood growing-stock volume.

Sixty-three percent of the growing stock on timberland is in private ownership. Twenty-one percent is owned by State and local governments and 16 percent is in Federal ownership. The proportion of softwoods is higher on the public land base. Only 37 percent of timberland is publicly owned; however, it has 48 percent of the softwood growing-stock volume due to public planting programs since the 1920s.

Quaking aspen stand. Photo by Scott A. Pugh, U.S. Forest Service.

Total growing-stock volume on timberland has increased significantly in each inventory since 1955 (Fig. 25). This increase has slowed over time. From 1955 to 1966, the increase was nearly 4 percent per year. From 1966 to 1980, the increase was just over 2 percent per year. Since 1980, the increase has been just under 2 percent per year. Both softwood and hardwood growing-stock volumes have increased significantly. Since the 1980 inventory, growing-stock volumes for softwoods and hardwoods have increased by 2 and 1 percent per year, respectively. The increases have occurred throughout most of the State (Fig. 26).

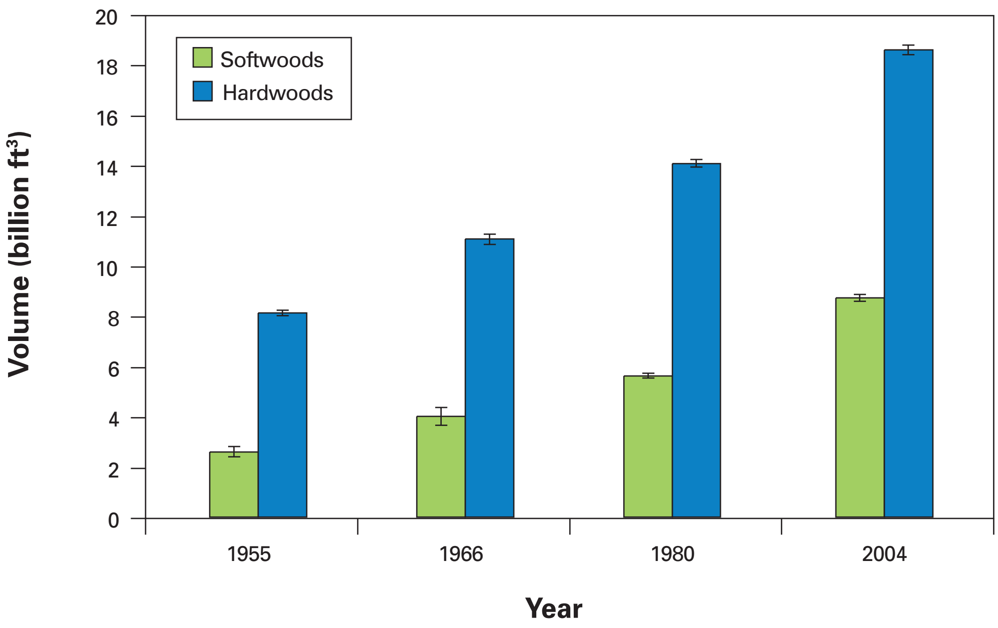


Figure 25.—Distribution of growing-stock volume on timberland by species group, Michigan, 1955-2004 (error bars represent 68-percent confidence interval around estimate).

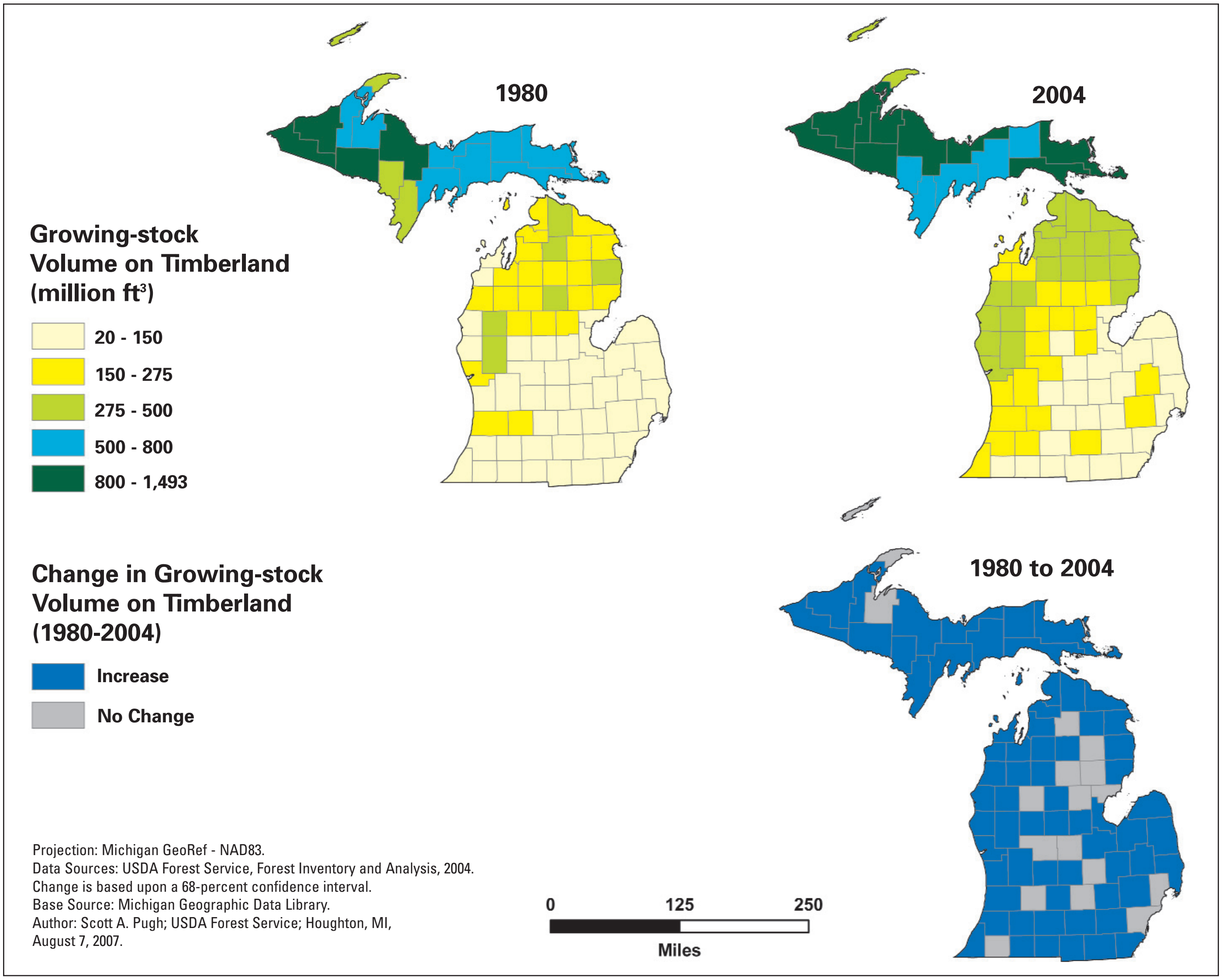


Figure 26.—Growing-stock volume and change in growing-stock volume on timberland by county, Michigan, 1980-2004.

Total live net volume on all forest land is 30.2 billion ft^3 (at least 5 inches d.b.h.) and includes rough and rotten cull trees. Six percent of this live-tree volume on all forest land is in live-cull trees, some of which are used in commercial production. Salvable dead trees contribute 785 million ft^3 of volume. These dead trees are important for wildlife and are often used for firewood.

Volume per acre by species varies spatially. The distribution of softwood volume compared to all species is shown in Figure 27. Note the higher concentration of softwood volume in the eastern Upper Peninsula and the northeastern Lower Peninsula. The distribution of live-tree volume for the top five species by volume is shown in Figure 28. These vary considerably except for red maple which is found throughout most of Michigan.

Figure 27.—Percentage of live-tree softwood volume to total live volume (gross volume of trees at least 5 inches d.b.h.) on forest land by EMAP hex, Michigan, 2004.

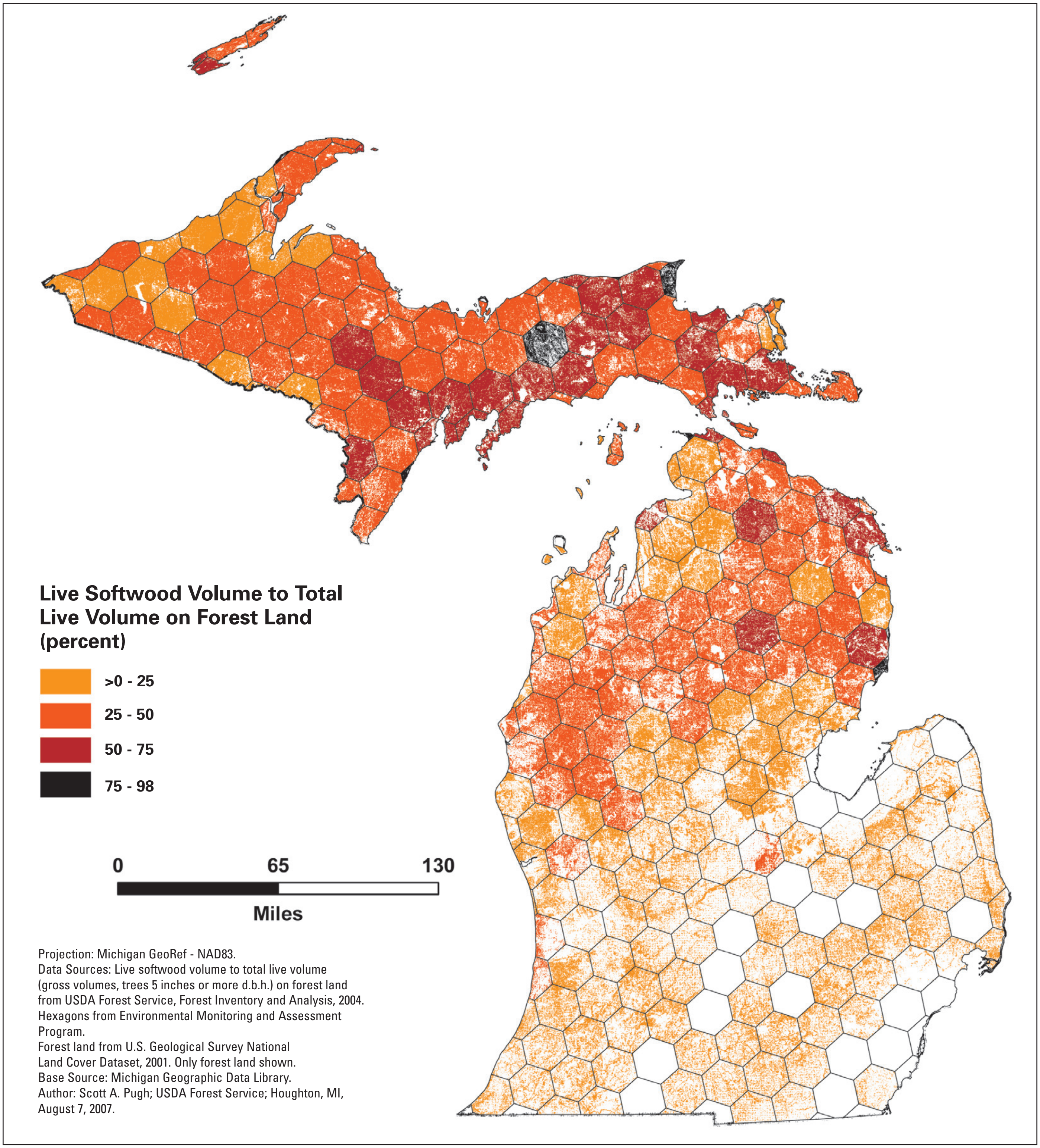
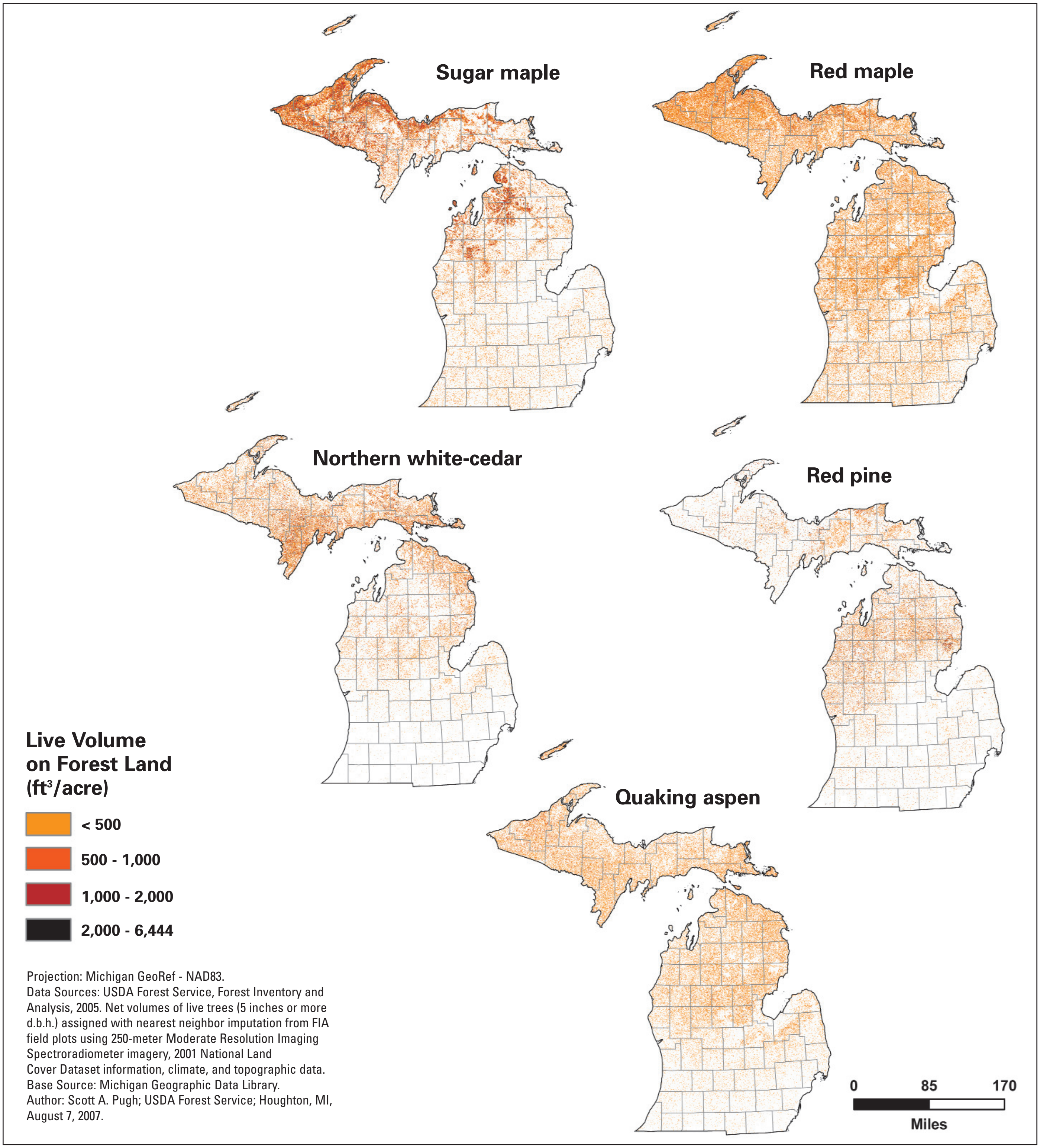


Figure 28.—Volume of live trees per acre (trees at least 5 inches d.b.h.) on forest land for top five species, Michigan, 2005.

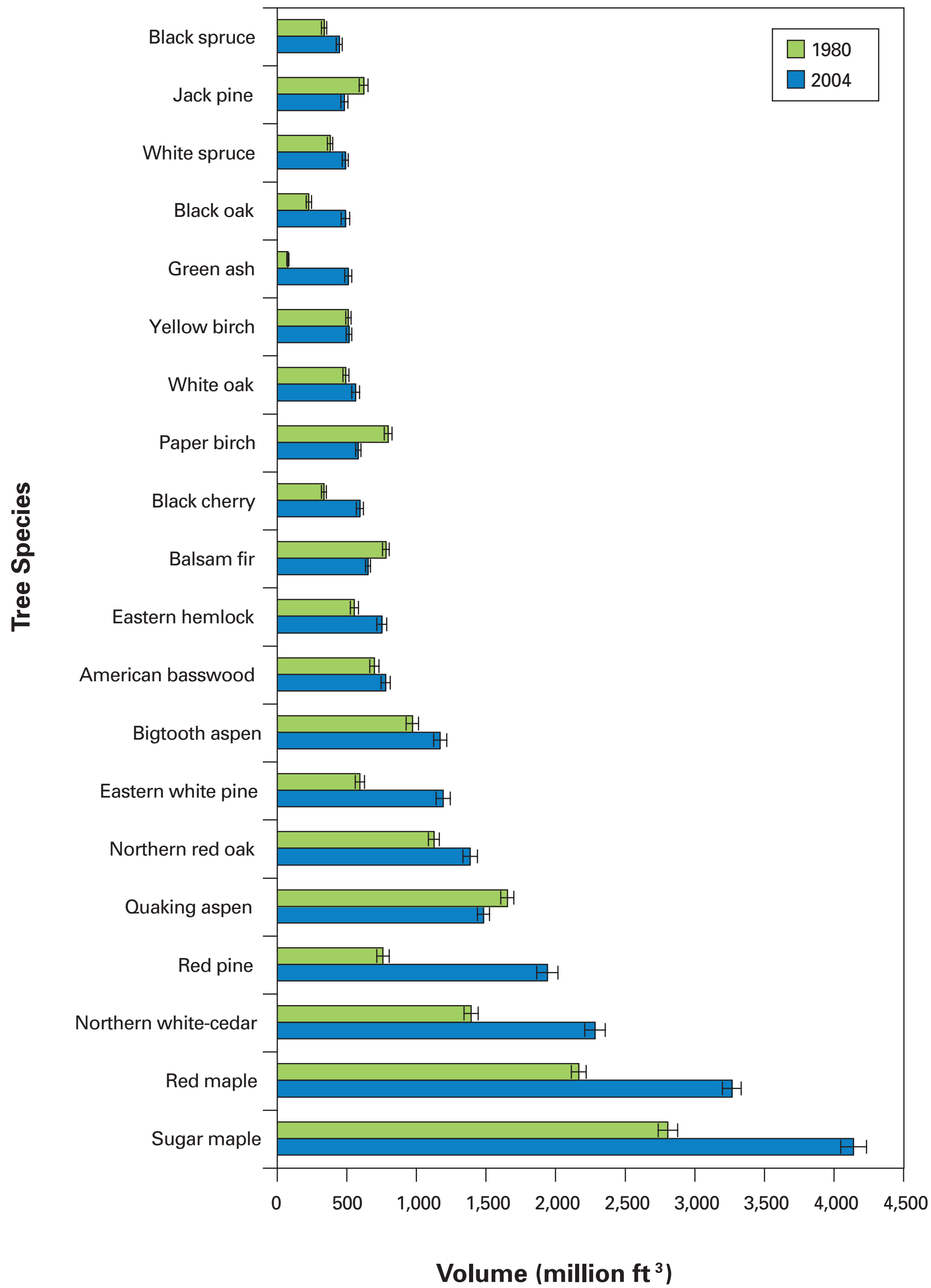


The top 20 species in Figure 29 account for 87 percent of the growing-stock volume on timberland in 2004. The following results cover change from 1980 to 2004. Most of the top 20 species have experienced significant increases in growing-stock volume since 1980. Eastern white pine, black oak, and red pine at least doubled in volume. Green ash has increased more than any other species since 1980 but there were only 81 million ft^3 of it in 1980. The other ash species are not shown but white and black ash also increased by 14 and 41 percent, respectively. The emerald ash borer (see page 143) is expected to reverse this upward trend in ash volume. Quaking aspen, balsam fir, paper birch, and jack pine experienced significant losses while yellow birch remained constant.

Total growing-stock volume and growing-stock volume per acre on timberland varies by ownership group and region. Increases have been significant in every region and for every major ownership group since 1980. Forest Service land has the most growing-stock volume per acre (1,748 ft^3/acre) followed by private (1,455 ft^3/acre) and State and local government ownership (1,292 ft^3/acre). Since 1980, the Forest Service has seen the largest gain in growing-stock volume per acre (51-percent increase). Both private ownership and State and local government ownership increased by about 26 percent.

The western Upper Peninsula (1,607 ft^3/acre) and the southern Lower Peninsula (1,556 ft^3/acre) have significantly higher growing-stock per-acre estimates than the eastern Upper Peninsula (1,365 ft^3/acre) and the northern Lower Peninsula (1,370 ft^3/acre). Since 1980, the greatest increase was in the southern Lower Peninsula (49 percent). The smallest increase was in the western Upper Peninsula (20 percent).

Figure 29.—Volume of growing stock on timberland by species, Michigan, 1980-2004; error bars represent 68-percent confidence interval around estimate (top 20 species by growing-stock volume for 2004).



What this means

Since 1980, increases in timberland and the number of trees, particularly sawtimber-size trees, have led to increases in growing-stock volume. As stated previously, the gains were greatest for the Forest Service and in the southern Lower Peninsula. The Forest Service has the greatest proportion of fully stocked stands (see Fig. 18) and the southern Lower Peninsula has the highest proportion of sawtimber trees (see page 45). Although Michigan still is experiencing an increase in growing-stock volume, this increase has slowed, partially due to the lower rate of growth that accompanies the maturing of Michigan's forests (see Fig. 35).

Only several species have declined since 1980. In particular, jack pine and paper birch stand out. Although quaking aspen and balsam fir have dropped in growing-stock volume, they have gained significantly over these same years in sapling-size trees (see Table 3). The opposite is true for jack pine and paper birch, which have dropped in the number of sapling and poletimber-size trees.

For a number of species, gains were particularly large. Red maple is more widespread and continues to increase in numbers of trees and volume. Eastern white pine continues a comeback with increases in number and growing-stock volume. Ash species, especially green ash, have increased in number and growing-stock volume. It is expected that increases in ash will cease due to infestation by the emerald ash borer.

Sawtimber Volume and Quality

Background

Sawtimber volume is an important indicator of value for the trees in Michigan. To qualify as sawtimber, softwoods must be at least 9 inches d.b.h. and hardwoods must be at least 11 inches d.b.h. Sawtimber volume is estimated for the saw-log portion of live growing-stock trees measured in board feet (International 1/4–inch rule). Softwood sawtimber is valued primarily for dimensional lumber while hardwood sawtimber usually is valued for flooring and furniture.

Tree grade is based on tree diameter and the presence or absence of defects such as knots, decay, and curvature of the bole. The value of sawtimber varies greatly by species and tree grade. Trees are graded 1 through 5. Grades 1 through 4 are assigned to trees that contain a 12 feet grading section in the butt 16 feet of the tree. Tree quality decreases from 1 through 4. Grade 5 is assigned to a growing-stock tree that has at least one merchantable 12-foot upper log (above the butt 16 feet of the tree) or two merchantable noncontiguous 8-foot logs. Softwoods are graded only 1 through 3 except for white pine, which is graded 1 through 4. The grading system has changed for this inventory, so direct comparison to tree grades of earlier inventories is not possible. For this inventory, hardwood volume by tree grade is reported consistently lower than for previous inventories due to changes in the grading process rather than to changes in actual quality.

What we found

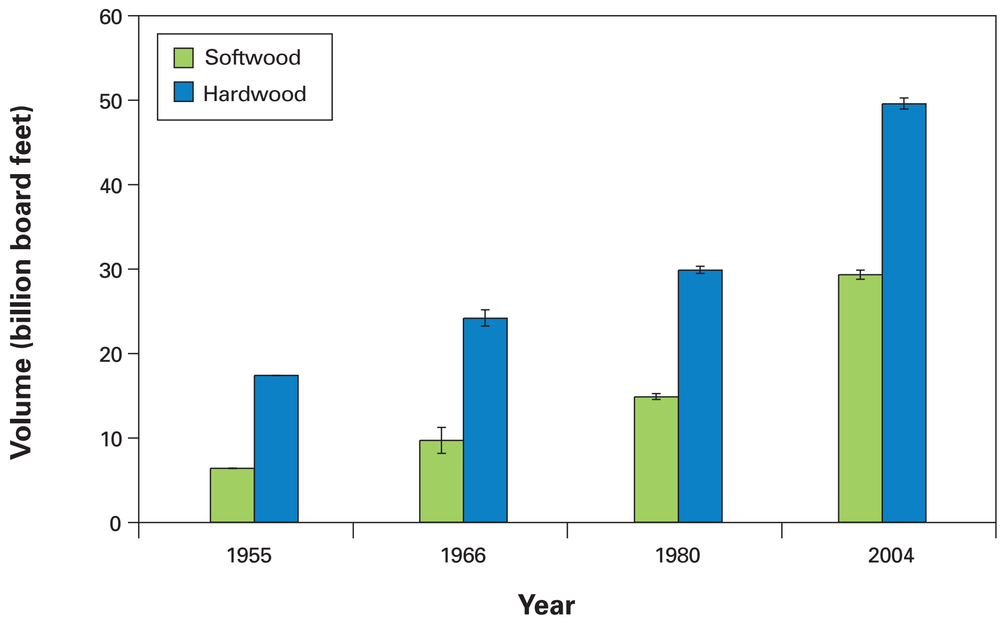
There are 82.2 billion board feet of sawtimber on forest land in Michigan. About 4 percent of the sawtimber volume is on reserved and/or unproductive forest land. There are 78.9 billion board feet of sawtimber on timberland. Of this total, 63 and 37 percent are in hardwood and softwood species, respectively. Sugar maple (21 percent), red maple (15 percent), northern red oak (10 percent), quaking aspen (7 percent), and bigtooth aspen (6 percent) account for 59 percent of hardwood sawtimber volume. Red pine (25 percent), northern white-cedar (24 percent), and eastern white pine (19 percent) account for 67 percent of softwood sawtimber volume.

Northern red oak stand. Photo by Scott A. Pugh, U.S. Forest Service.

Considering only timberland, 62 percent of sawtimber occurs on private ownership. Twenty percent is owned by State and local governments and the remainder is in Federal ownership.

Total sawtimber volume on timberland has increased significantly in each inventory since 1966 (Fig. 30) and probably even since 1955 (confidence intervals not available for 1955). From 1955 to 1966, the increase was nearly 4 percent per year. From 1966 to 1980, the increase was just over 2 percent per year. Since 1980, the increase has been just over 3 percent per year. Both softwood and hardwood sawtimber volumes have increased significantly. Since the 1980 inventory, sawtimber volumes for softwoods and hardwoods have increased by 4 and 3 percent per year, respectively.

Figure 30.—Sawtimber volume on timberland by species group, Michigan, 1955-2004 (error bars represent 68-percent confidence interval around estimate).



The top 20 species in Figure 31 account for 89 percent of sawtimber volume on timberland in 2004. The following results cover change from 1980 to 2004. Most of these species followed trends similar to those observed for growing-stock volume (see Fig. 29). All but jack pine and yellow birch have had significant increases in sawtimber volume. Species such as eastern white pine, northern white-cedar, and red pine increased at least twofold. Balsam fir (not shown) decreased significantly in sawtimber volume (17 percent).

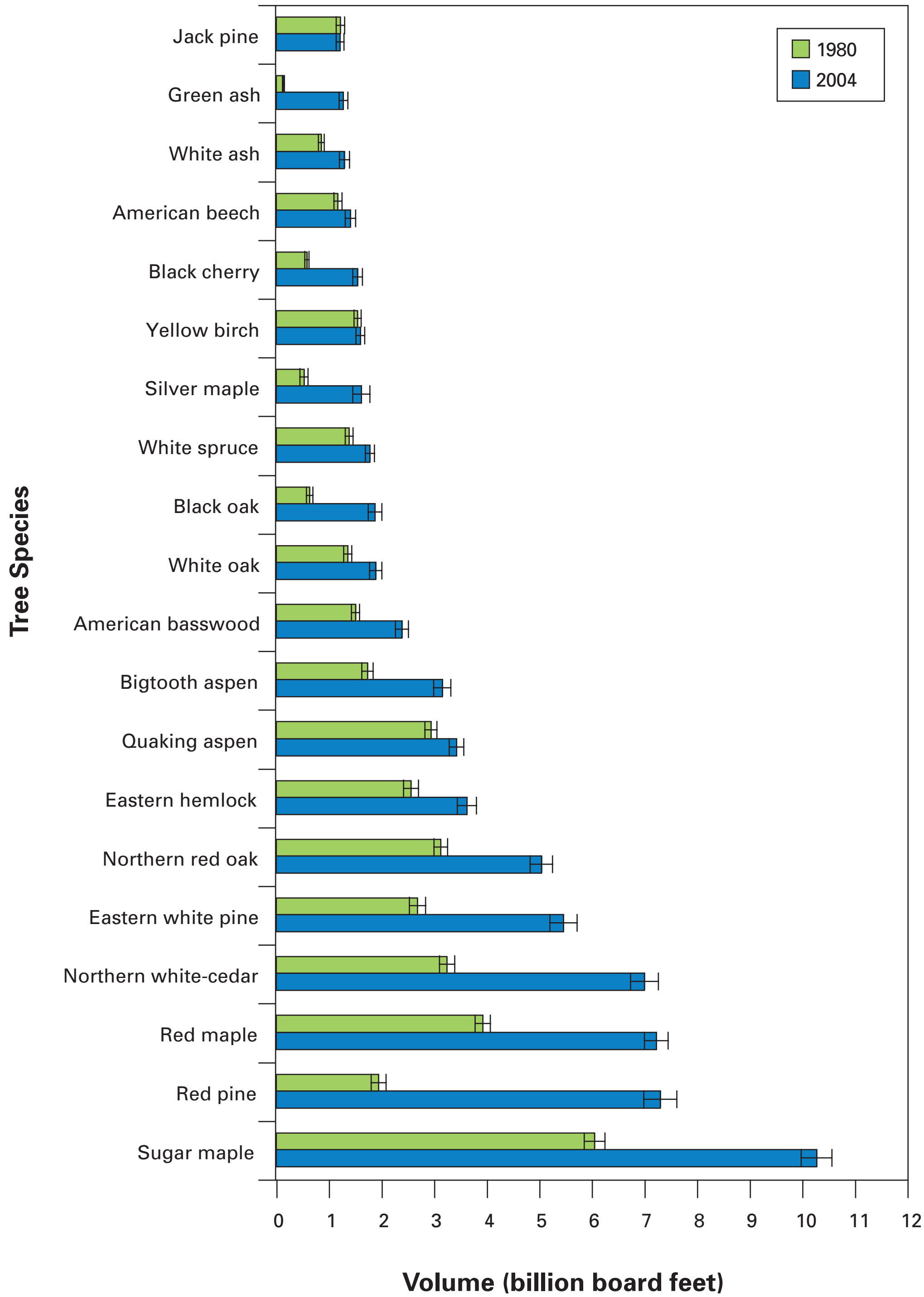


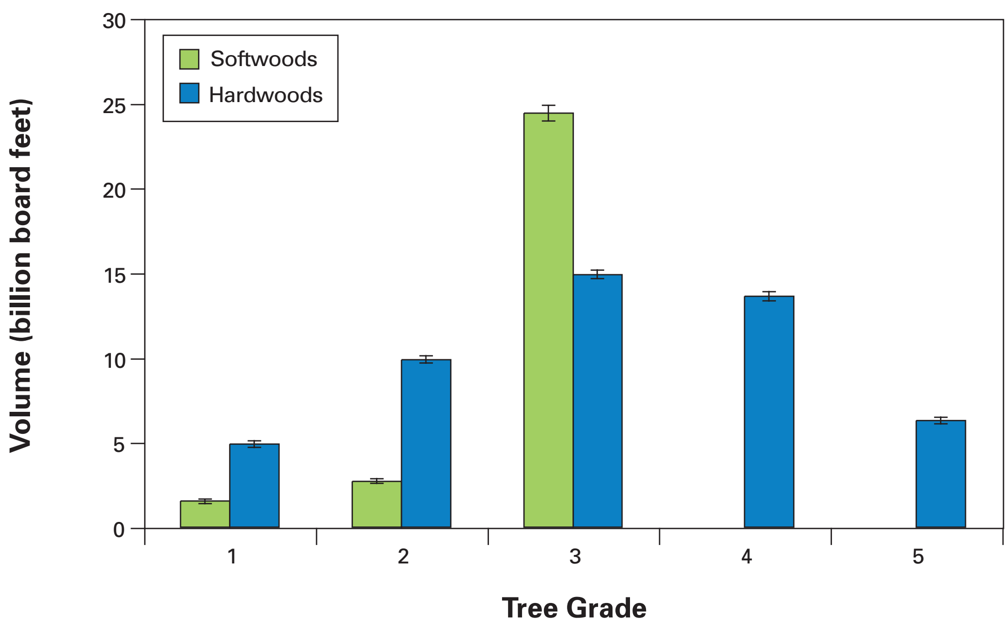
Figure 31.—Sawtimber volume on timberland by species, Michigan, 1980-2004; error bars represent 68-percent confidence interval around estimate (top 20 species by sawtimber volume for 2004).

Similar to that for growing stock, sawtimber volume has increased significantly for every region and for every major ownership group since 1980. Forest Service land has the most sawtimber volume per acre (5,378 board feet/acre) followed by private (4,143 board feet/acre) and State and local government ownership (3,694 board feet/acre). Since 1980, the U.S. Forest Service has seen the largest gain in sawtimber volume per acre (115 percent). State and local government had a 72-percent increase and private ownership had a 53-percent increase.

The southern Lower Peninsula has the highest sawtimber volume per acre (5,049 board feet/acre). The western Upper Peninsula has the second highest sawtimber volume per acre (4,596 board feet/acre). The northern Lower Peninsula and the eastern Upper Peninsula were not significantly different at 3,818 and 3,837 board feet/acre, respectively. Since 1980, the greatest increase has been in the northern Lower Peninsula (86 percent). The western Upper Peninsula had the smallest increase (42 percent).

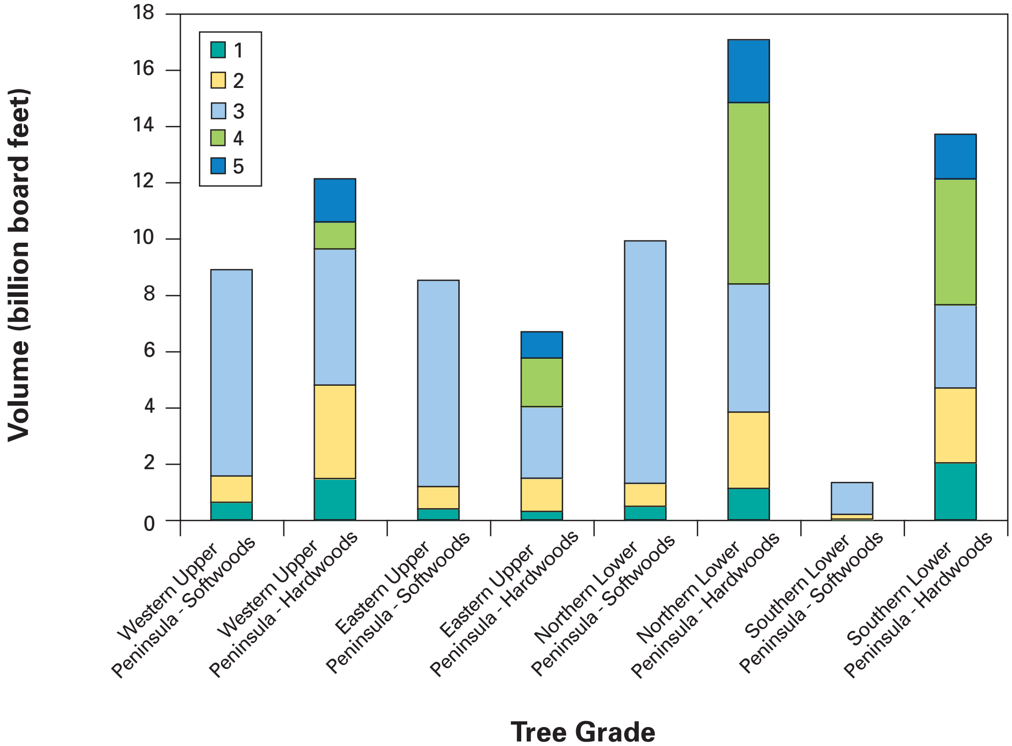
The 2004 tree grades are presented in Figure 32. Grades 1 through 3 are assigned to softwoods (white pine is the exception with 684 million board feet in grade 4). Most (83 percent) of the softwood sawtimber volume is in grade 3. The hardwoods are graded 1 through 5. Of the hardwood sawtimber volume, 30 percent is in grade 3 and 27 percent is in grade 4.

Figure 32.—Sawtimber volume on timberland by tree grade and species group, Michigan, 2004; error bars represent 68-percent confidence interval around estimate (softwoods are not included in grades 4 and 5).



The northern Lower Peninsula has the most timberland area and sawtimber volume in hardwoods and softwoods. Even so, the northern Lower Peninsula does not have a significantly greater amount of grade 1 and 2 softwood sawtimber than the amount in the western Upper Peninsula (Fig. 33). The northern Lower Peninsula has the most grade 3 softwood sawtimber. The southern Lower Peninsula has the most grade 1 hardwood sawtimber volume while the western Upper Peninsula has the most hardwood sawtimber volume in grades 2 and 3.

Figure 33.—Sawtimber volume on timberland by tree grade, species group, and region, Michigan, 2004 (softwoods are not included in grades 4 and 5).



The U.S. Forest Service has a greater percentage (67) of hardwood sawtimber volume in grades 3 and higher compared to private (58 percent) and State and local government (59 percent) ownerships; 12 to 16 percent of all softwood sawtimber volume is in grades 2 and higher for all ownership groups.

What this means

Sawtimber volume on timberland has increased over time. The changes among regions and ownership groups were similar to those for growing-stock volume. The southern Lower Peninsula and western Upper Peninsula have the most sawtimber in higher grades.

A number of species made significant and substantial gains in sawtimber volume. Many of these are late-successional species like eastern white pine and sugar maple. Species like red maple are associated with forest-cover types that have made recent gains in acreage. It is not surprising that balsam fir has experienced significant losses in sawtimber and growing-stock volume since 1980. Due in part to drought and spruce budworm outbreaks, the mortality-to-volume rate for this species is one of the highest (see Fig. 42).

Annual Net Growth

Background

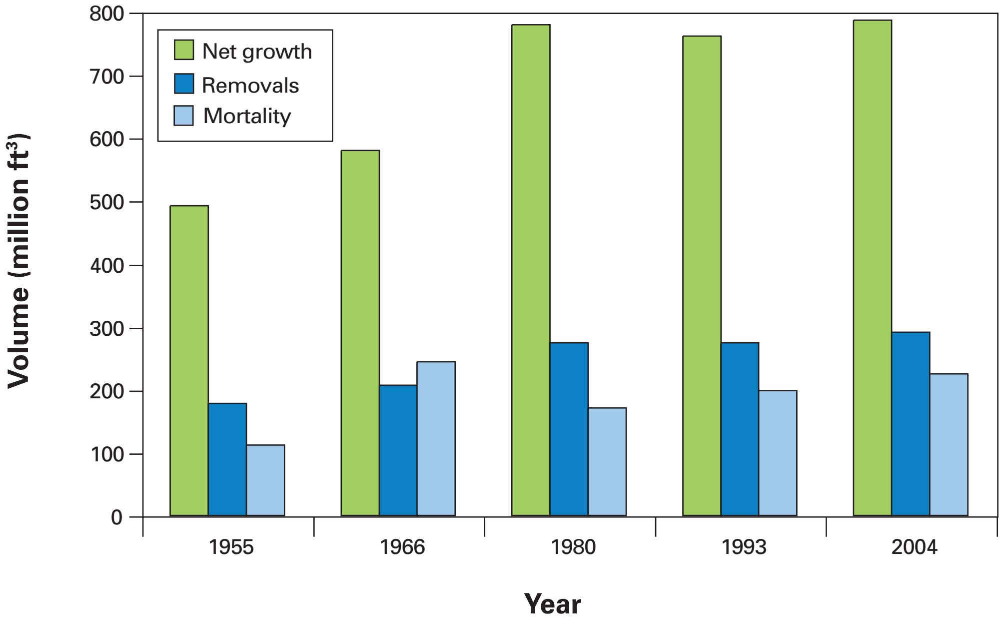
Analyzing growth provides information on forest succession, disturbance, sustainability, and the ability of a species to grow well. Average annual net growth (growth including ingrowth minus mortality and cull) is computed by measuring trees at two points in time and determining the average annual change in volume over the period. Net growth is negative when mortality exceeds growth. The percentage of annual net growth to current volume is a useful measure for analysis. A negative number indicates that mortality is exceeding growth. In general, a lower growth rate will be indicated by a percentage less than or equal to 1.0. Moderate growth rates are about 1.0 to 3.0; high growth rates exceed 3.0. These guides vary somewhat by species. Here, we look at average annual net growth (not current net growth) of growing stock on timberland between inventories.

In this report for the 2004 inventory, new methods were used to calculate average annual net growth of growing stock. Previously published estimates for the 2004 inventory (Hansen and Brand 2006) added the volume of a tree to growing-stock net growth if the tree changed from nongrowing stock or cull in the previous inventory of 1993 to growing stock in the current inventory of 2004. The volume of the tree was subtracted from the estimate if it changed from growing stock to cull. Using the new methods, only the growth of a tree from the previous inventory to the current inventory is added or subtracted from growing-stock net growth. This modification is an improvement, more in line with inventories from other years. The new estimate (786.8 million ft^3) of average annual net growth of growing stock on timberland is 15 percent less than the previously published estimate (923.3 million ft^3). To make meaningful comparisons, the new methods were also used in the net-growth calculations of other states mentioned in this report.

What we found

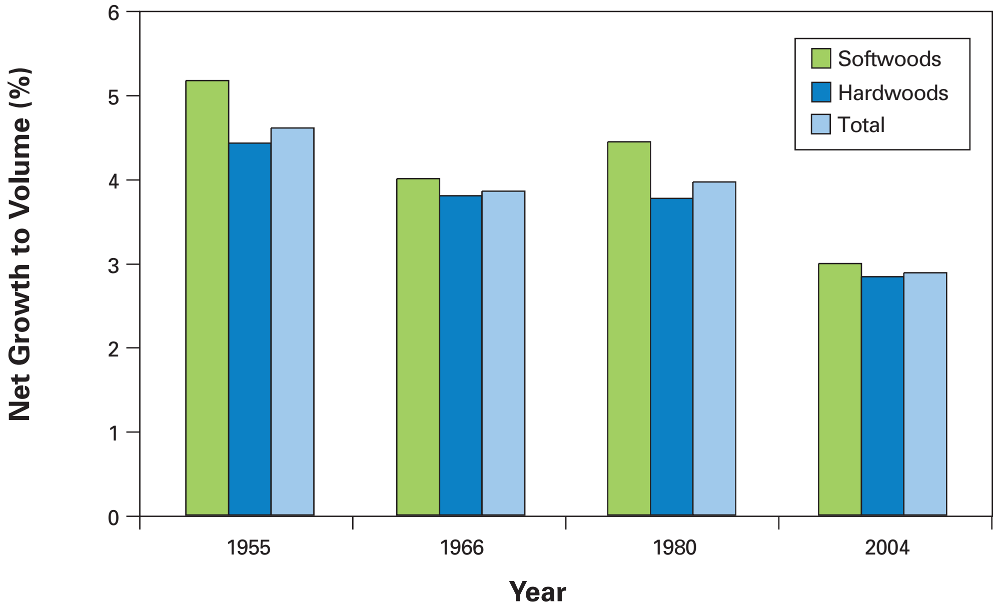
Average annual net growth of growing stock on timberland was 786.8 million ft^3 from 1993 to 2004 (Fig. 34). This is about 2.9 percent of growing-stock volume on timberland in 2004. In comparison, Minnesota (1990-2003) and Wisconsin (1996-2004) have values of 2.4 and 3.0 percent, respectively. For Michigan, 68 percent of the net growth was in hardwoods and 67 percent was in private ownership.

Figure 34.—Net growth, removals, and mortality of growing stock on timberland, Michigan, 1955-2004. Estimates for net growth and mortality before 1980 and estimates for removals before 1993 are for a single year compared to an average over an inventory period for the more recent inventories.



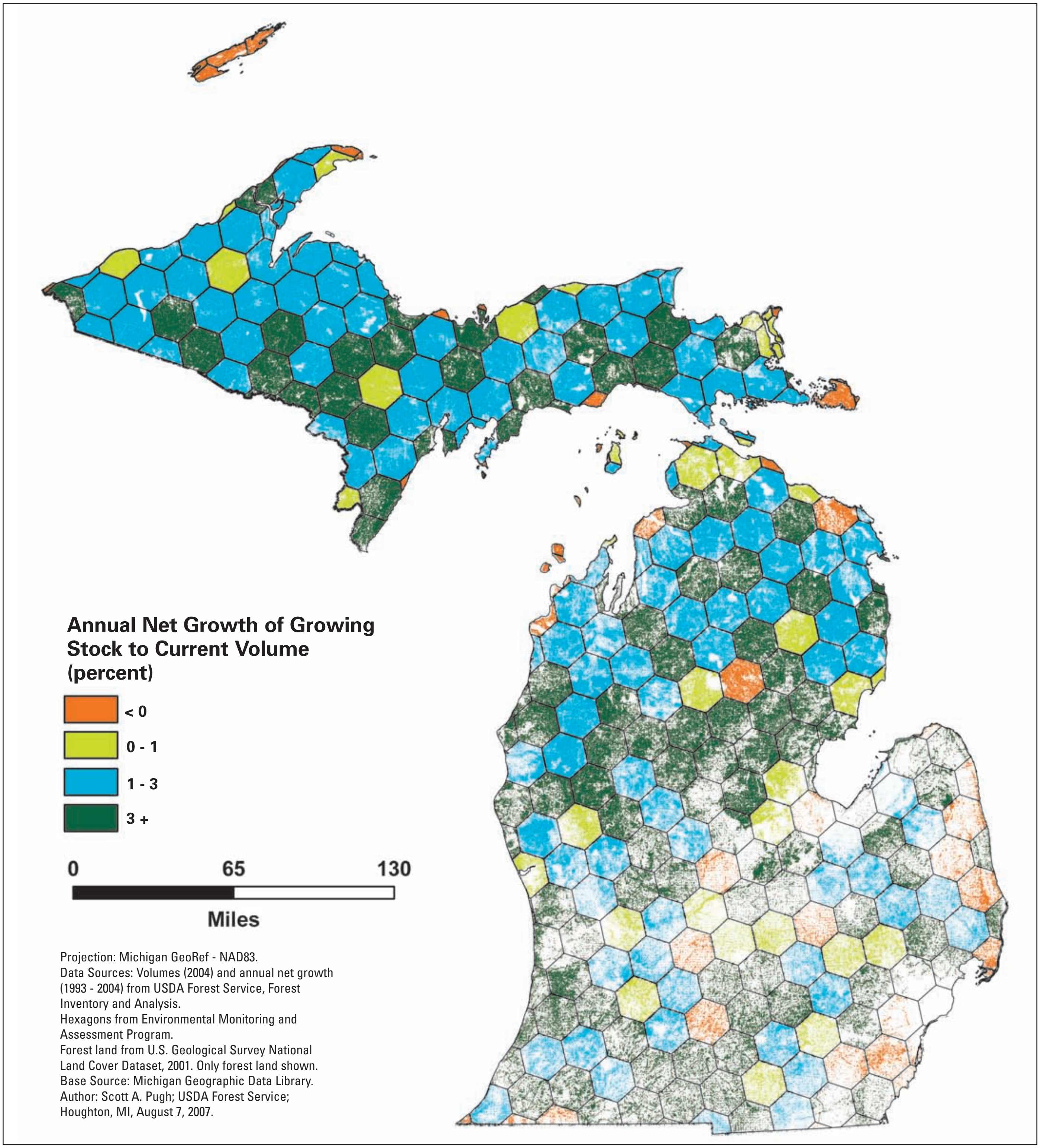
From 1955 (492,600 million ft^3) to 1980 (779,063 million ft^3), annual net growth increased from 1.6 to 2.5 percent per year. Since 1980, annual net growth has remained steady. Although annual net growth has risen and leveled, the percentage of annual net growth to volume has been decreasing gradually (Figs. 34-35).

Figure 35.—Net growth of growing stock on timberland as a percent of volume by species group and total, Michigan, 1955-2004. Estimates before 1980 are for a single year as opposed to an average over an inventory period for the more recent inventories.



Average annual net growth of growing stock to current volume varies spatially (Fig. 36). The southern Lower Peninsula has the highest rate at 4.0 percent followed by the northern Lower Peninsula at 3.0 percent. The other regions have lower rates that are not significantly different (western Upper Peninsula at 2.3 and eastern Upper Peninsula at 2.5). The average annual net growth of growing stock per acre on timberland was 37, 34, 41, and 63 ft^3 for the western Upper Peninsula, eastern Upper Peninsula, northern Lower Peninsula, and southern Lower Peninsula, respectively.

Figure 36.—Average annual net growth of growing stock on timberland as a percentage of current volume (2004) by EMAP hex, Michigan, 1993-2004.



The top 20 species in Figures 37 and 38 accounted for 88 percent of the average annual net growth of growing stock on timberland from 1993 to 2004. All of these species have moderate to high average annual rates of net growth to volume. Note that white spruce, black cherry, and white and green ash had relatively moderate amounts of net growth overall but have high rates of net growth to volume. By contrast, red pine, red maple, and quaking aspen had high average annual net growth and have high amounts of net growth to volume. Paper birch (not listed) has a low net growth to volume percentage (0.5 percent).

Figure 37.—Average annual net growth of growing stock on timberland by species, Michigan, 1993-2004; error bars represent 68-percent confidence interval around estimate (top 20 species by average annual net growth).

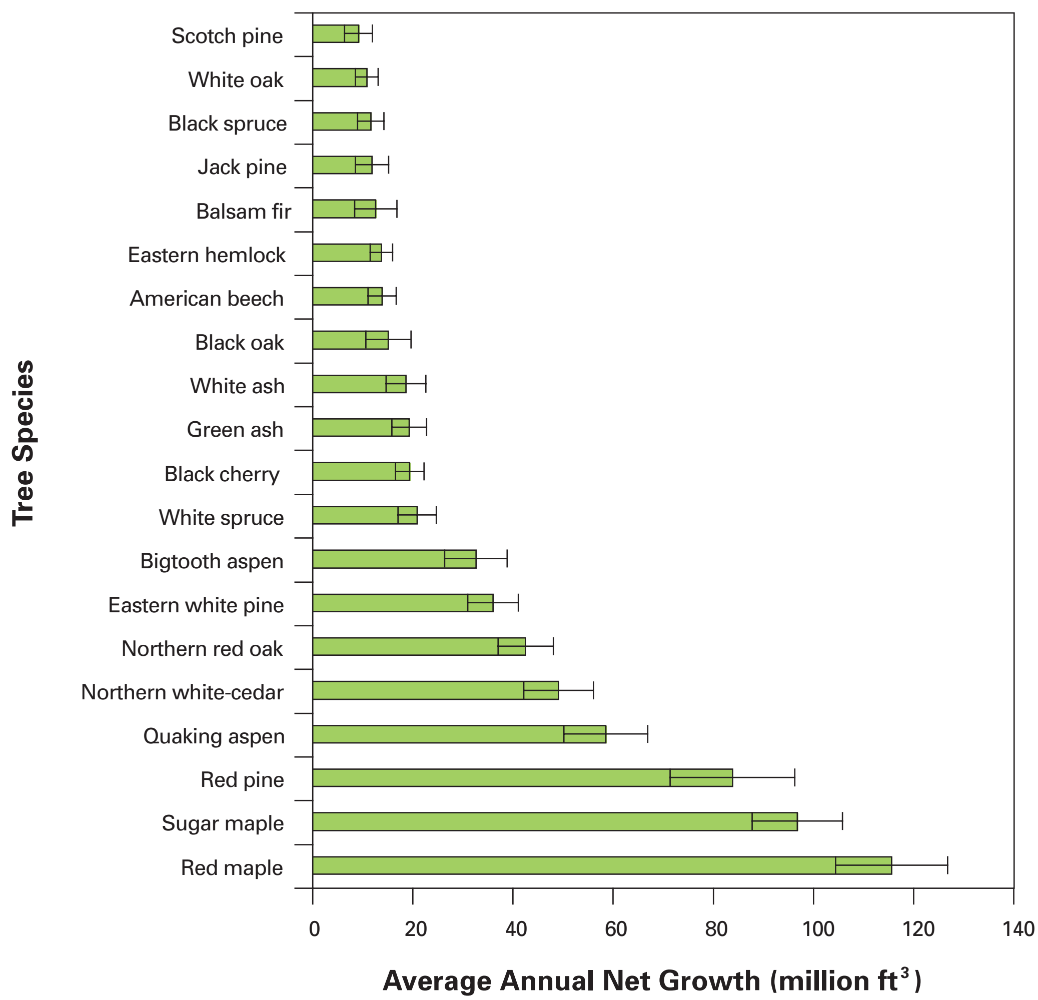
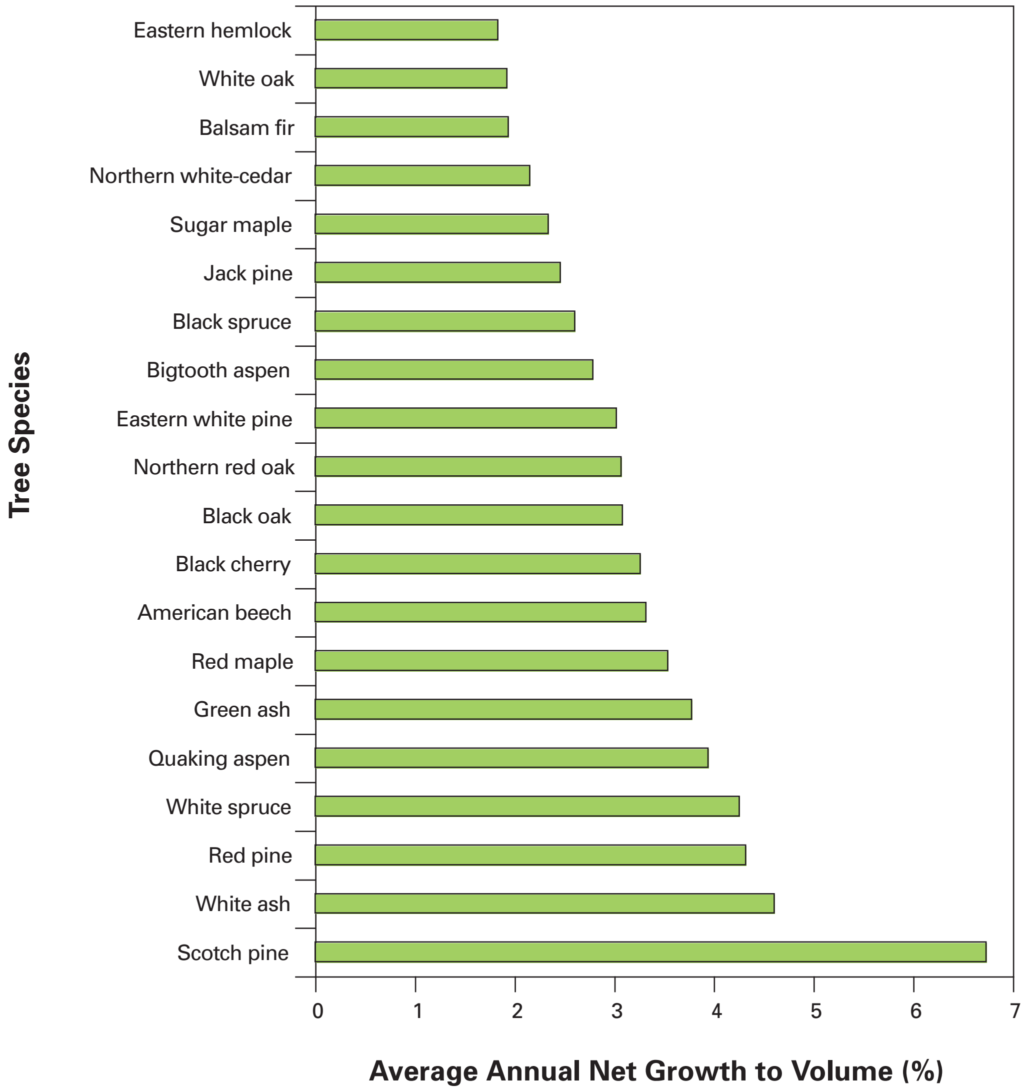


Figure 38.—Average annual net growth of growing stock on timberland as a percentage of current volume (2004) by species, Michigan, 1993-2004 (top 20 species by average annual net growth).



Average annual net growth of growing stock to current volume on timberland varies by ownership group. Private (3.1 percent) and State and local government (2.8 percent) owners have significantly higher rates than the U.S. Forest Service (2.2 percent). There were changes in rates from 1980 to 2004. The rate for the U.S. Forest Service dropped from 5.6 percent in 1980 to 2.2 percent in 2004. There was less change on private and State and local government timberland. The State and local government rate was 3.8 percent in 1980 and 2.8 percent in 2004. The private rate was 3.6 percent in 1980 and 3.1 percent in 2004.

What this means

Michigan's forests have matured overall and built up volume. With this maturation comes a lower rate of growth. This is evident in the lower increase in volume since 1980 (see page 58). Fortunately, net growth to volume remains high, evidence of the vitality of Michigan's forests. Even at the species level, moderate to high percentages for net growth to volume are common.

On a per-acre basis, forest land in the southern Lower Peninsula is more productive than forest land in the other regions of Michigan. The southern Lower Peninsula has some lands with lower stocking but has high volume-per-acre estimates and the highest estimate for net growth per acre. This region also has the highest site productivity level (see page 50). This is not a surprise given the more productive climate and soils in this region (see page 23). As stated, the other regions have lower estimates for net growth per acre.

Net growth on U.S. Forest Service lands is slowing and there have been large gains in volume (see page 62). Average annual removals to current volume are lower on U.S. Forest Service land than on private or State and local government land (see page 87). Mortality does not seem to be a contributing factor to the decrease in net growth (see page 78). The National Forests have been unable to harvest like other ownership groups due to a number of factors (Bosworth and Brown 2007, Keele et al. 2006, USDA For. Serv. 2002). This is contributing to the lower net growth on these lands due to higher stocking and factors such as an increase in mature stands compared to other ownerships.

Annual Mortality

Background

Mortality is a natural part of forest stand development. A number of biotic, e.g., disease, insects, animals, and competing plants, and abiotic factors, e.g., wind, fire, drought, floods, and air pollution, contribute to mortality. Mortality can be the result of numerous factors over many years, so it is difficult to identify the one or more causes that result in death. Drought can weaken trees and make them susceptible to pests years later. FIA plots are revisited at intervals in time, so it can be difficult to identify causes of mortality that occurred years before a plot visit. Mortality is a concern when it surpasses the capacity of the forest to respond (growth and regeneration) or it creates potential dangers like fire.

Here, we look at average annual mortality of growing stock on timberland between inventories. The average annual mortality is compared to current standing volume. Lower mortality rates are indicated with values less than or equal to 1.0. Moderate rates of mortality are about 1.0 to 3.0; high mortality rates exceed 3.0. These guides can vary somewhat by species. Trees cut by harvesting or land clearing are considered removals and are not included in the mortality estimates.

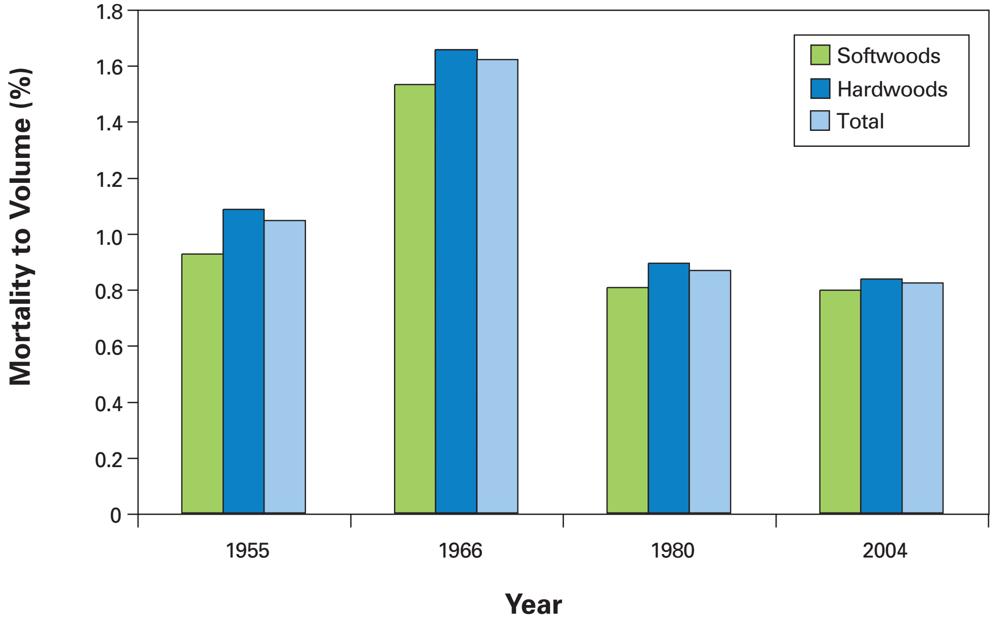
What we found

Average annual mortality of growing stock on timberland was 224.5 million ft^3 from 1993 to 2004 (see Fig. 34). This is about 0.8 percent of growing-stock volume on timberland in 2004 and only 29 percent of the average annual net growth over the same period. The percentage of average annual mortality to current volume is 1.8 and 0.9 for Minnesota (1990-2003) and Wisconsin (1996-2004), respectively. For Michigan, 69 percent of the mortality was in hardwoods and 59 percent was in private ownership.

Except for a spike upward in 1966 (1.62 percent), average annual mortality to current volume has remained fairly constant and low (0.7 to 1.0 percent, excluding 1966) since 1955 (Fig. 39).

Mortality of paper birch. Photo used with permission by Minnesota Department of Natural Resources, Minnesota DNR Archive, www.forestryimages.org.

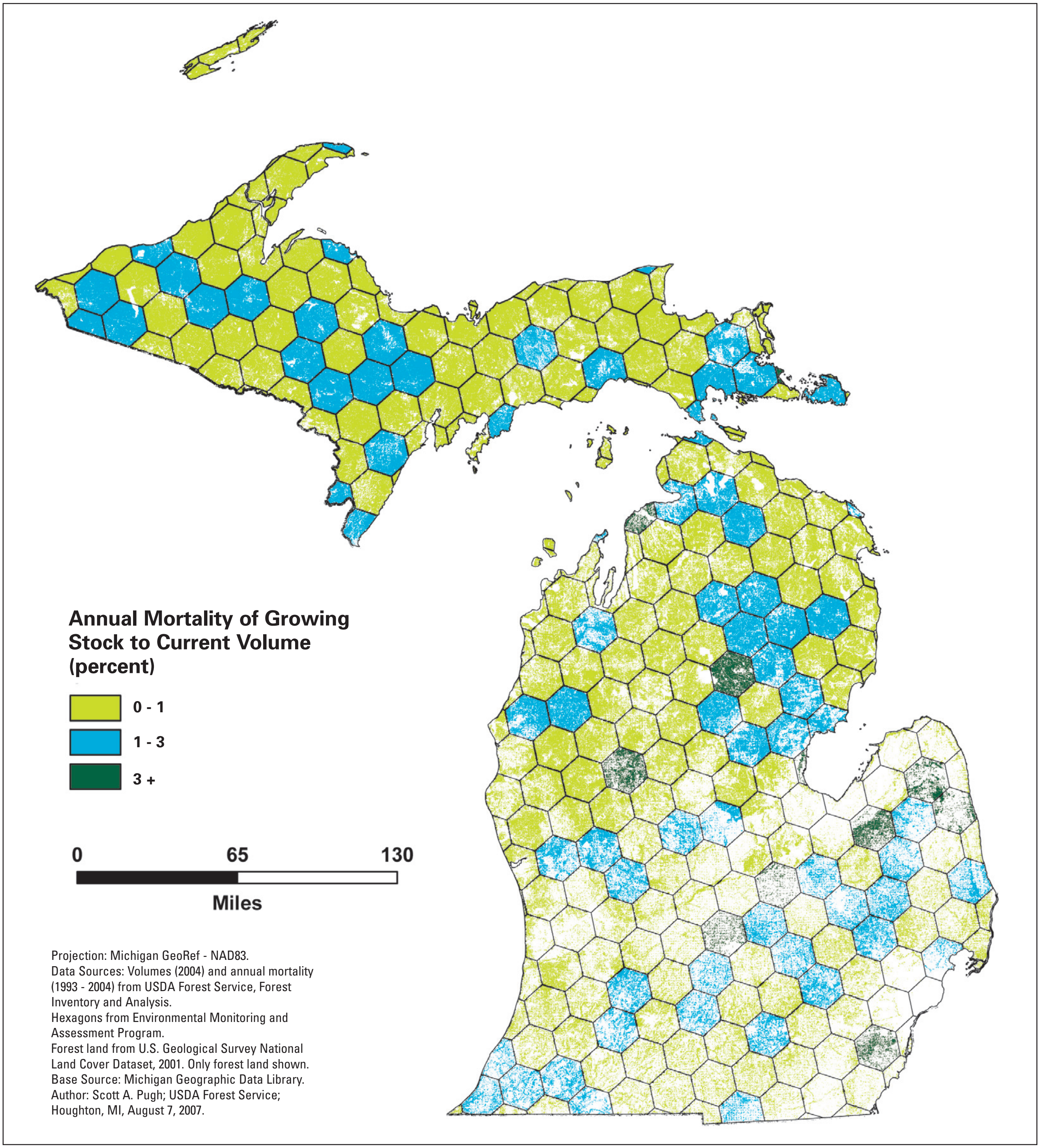
Figure 39.—Mortality of growing stock on timberland as a percent of volume by species group and total, Michigan, 1955-2004. Estimates prior to 1980 are for a single year as opposed to an average over an inventory period for the more recent inventories.



As in past inventories, the primary cause of mortality could not be determined in 90 percent of the instances for the 2004 inventory. The relatively long period that elapsed since the 1993 inventory added to the difficulty. In cases where the cause was identified, weather, animals, insects, disease, and fire were most common.

Average annual mortality of growing stock to current volume varies spatially but there is no significant difference among the regional estimates (Fig. 40). Also, there is no significant difference among the estimates for the major ownership groups. Average annual mortality of growing stock per acre on timberland was 13, 10, 12, and 14 ft^3 for the western Upper Peninsula, eastern Upper Peninsula, northern Lower Peninsula, and southern Lower Peninsula, respectively.

Figure 40.—Average annual mortality of growing stock on timberland as a percentage of current volume (2004) by EMAP hex, Michigan, 1993-2004.



The top 20 species in Figures 41 and 42 accounted for 89 percent of the average annual mortality of growing stock on timberland from 1993 to 2004. Quaking aspen had the most average annual mortality but it has a moderate percentage of annual mortality to volume. Balsam fir and American elm had relatively high amounts of average annual mortality and have the highest percentages of annual mortality to volume. Jack pine, paper birch, bigtooth aspen, balsam poplar, black spruce, and white spruce have moderate mortality-to-volume percentages.

Figure 41.—Average annual mortality of growing stock on timberland by species, Michigan, 1993-2004; error bars represent 68-percent confidence interval around estimate (top 20 species by average annual mortality).

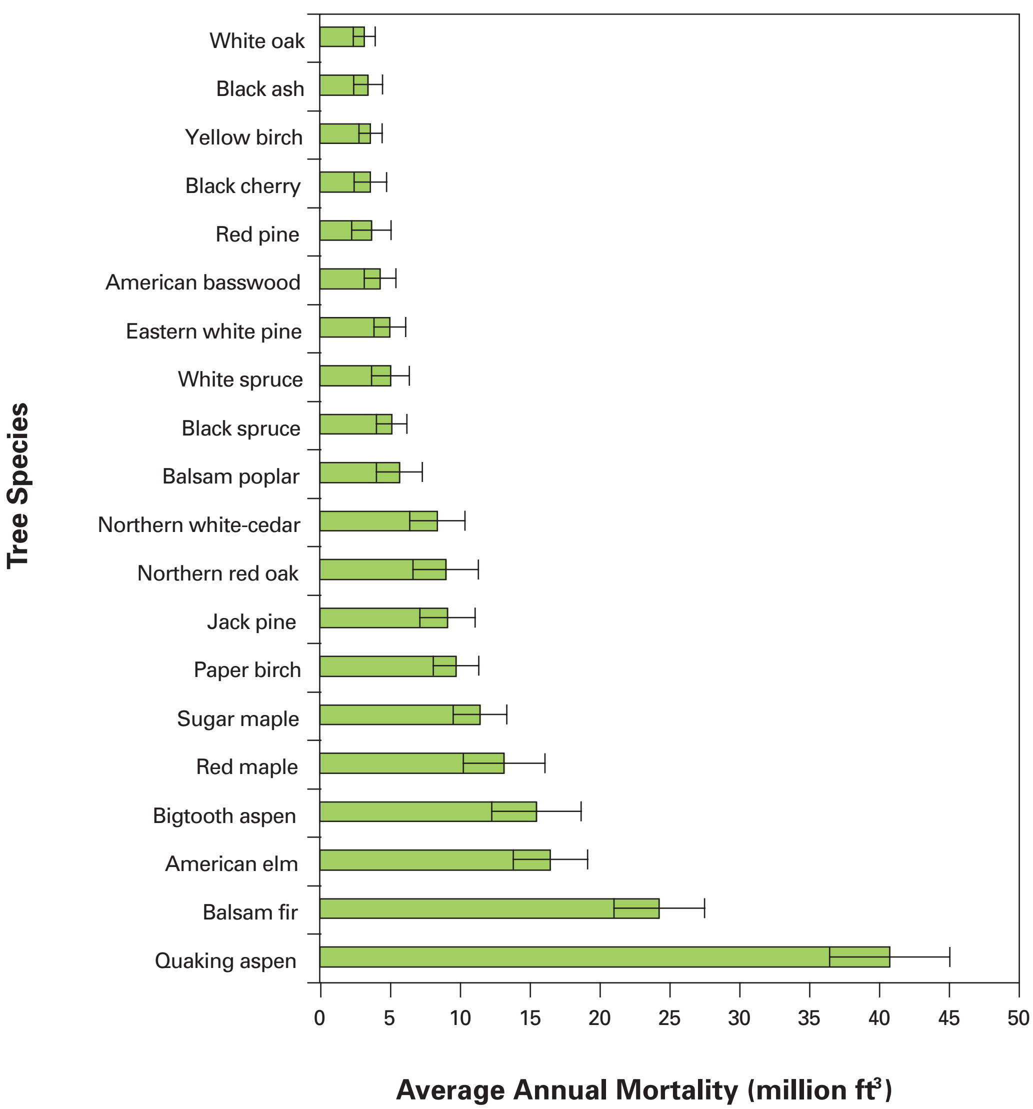
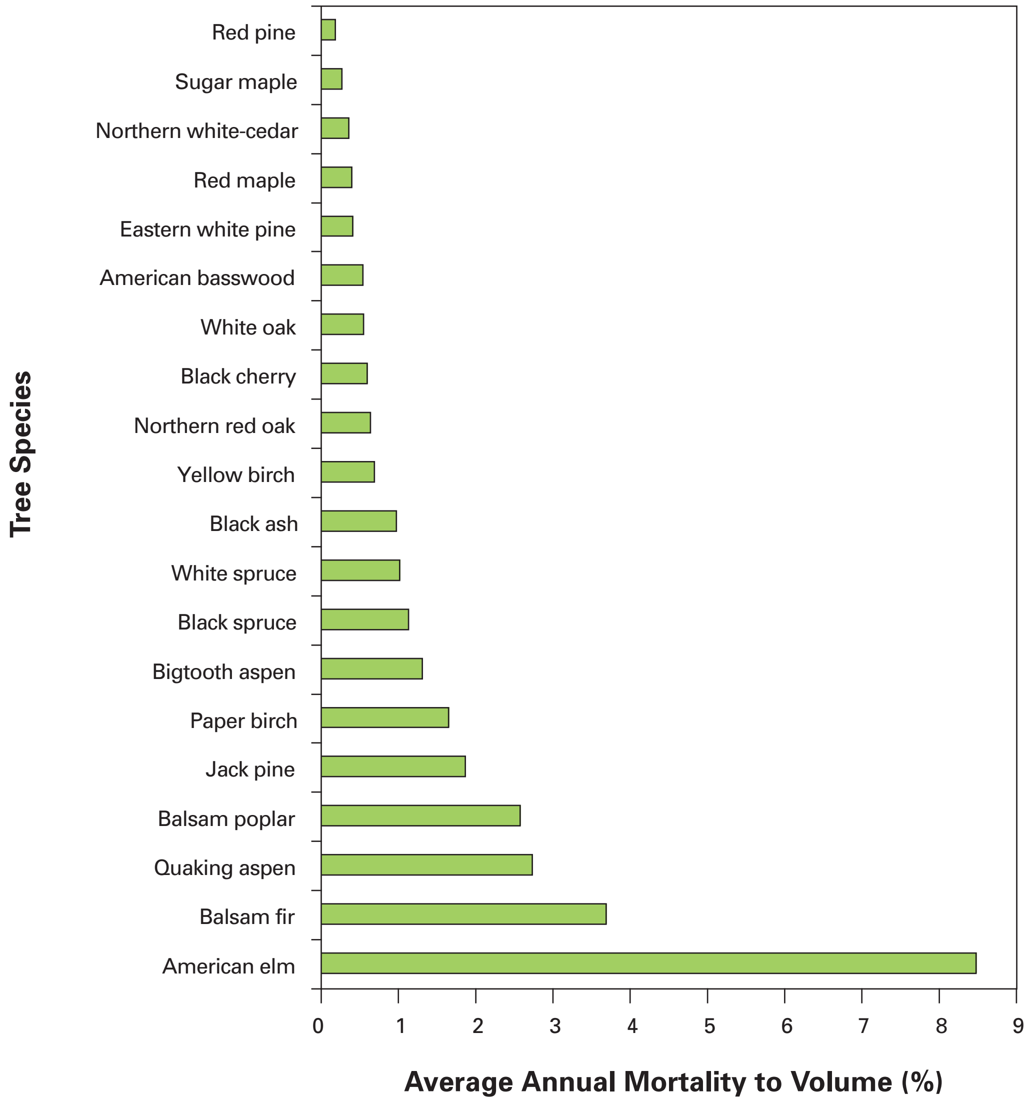


Figure 42.—Average annual mortality of growing stock on timberland as a percentage of current volume (2004) by species, Michigan, 1993-2004 (top 20 species by average annual mortality).



What this means

Michigan has been fortunate to have low rates of mortality. Although most species have experienced low mortality, some species are not so fortunate. Moderate to high mortality for balsam fir, American elm, balsam poplar, quaking aspen, jack pine, and paper birch have contributed to significant declines in growing-stock volume and often in the sawtimber volume of these species (see Figs. 29 and 31). These species also had significant reductions in number of trees for certain size classes (see Table 3). Factors such as succession, drought, and pathogens contribute to mortality. Higher rates of mortality to volume are expected in short-lived, early successional species. The declines in volume and number of trees might be a management concern.

In many cases, the forest types associated with the species exhibiting moderate to high rates of mortality are overmature and the trees are succumbing to various damage agents. Most of the high rate in balsam fir and moderate rates in black and white spruce likely are due to droughts in the late 1980s and the late 1990s combined with spruce budworm attacks in the late 1990s. Mature and overmature balsam fir stands are affected most severely by spruce budworm, which prefers balsam fir over spruce. Susceptible stands can lose 60 to 80 percent of balsam fir and 20 to 40 percent of spruce, and entire stands of mature balsam fir have been lost. Nearly 90,000 acres of forest land in 1997 and 1998 were damaged (no differentiation among affected species on these 88,000 acres). For additional information on damage agents and acreage affected since 1997, visit http://www.na.fs.fed.us/ims/aerial/viewer.htm. More severe than in the late 1990s, a spruce budworm outbreak occurred in the Upper Peninsula from the late 1960s to the early 1980s. Bark beetles and Armillaria root rot also cause mortality in balsam fir. The rate of average annual mortality to volume for balsam fir in Minnesota (1990-2003) is even higher (5 to 6 percent). The high rate of mortality for American elm can be attributed to Dutch elm disease. Other species with high mortality like jack pine, paper birch, bigtooth aspen, and balsam poplar are early successional species that require fire or other site preparation treatments to regenerate.

Annual Removals

Background

Of the three components of change (net growth, removals, and mortality), removals is the most directly tied to human activity and is thus the most responsive to changing socioeconomic conditions. Changes in demand for wood play a key role in removals. The removals estimate includes harvest removals, mortality removals (trees killed in the harvesting process and left on site), and diversion removals. Diversion removals occur when living trees are removed from the timberland base due to land-use change. Timberland can change to unproductive or reserved forest land or nonforest. Among the estimates of change, we have the least number of FIA plot observations for removals, so there is inherently more variability in the estimates.

The Timber Product Output (TPO) study provides another estimate of removals that is based on a survey of all known primary wood-using mills in Michigan, the most recent TPO mill surveys from other states that reported processing wood harvested from Michigan, and regional harvest utilizations studies (see page 162). Since the late 1970s, the survey usually has been conducted every 2 years. The survey produces an estimate of the total wood-usage in Michigan from all land. From this total wood usage, an estimate of growing-stock removals from timberland is derived.

When average annual removals are compared to current standing volume, lower removal rates are indicated with values less than or equal to 1.0. Moderate removals are about 1.0 to 3.0; high removals exceed 3.0.

What we found

Average annual removals of growing stock on timberland totaled 291.2 million ft^3 from 1993 to 2004 (see Fig. 34). This is approximately 1.1 percent of growing-stock volume on timberland in 2004. This also is 37 percent of average annual net growth during that time. Seventy percent of the removals was in hardwood and 67 percent was in private ownership. Although removals on public ownership account for only 33 percent of the average annual removals, 48 percent of the average annual softwood removals came from public land. This follows the estimate that 48 percent of the softwood growing-stock volume is on public timberland.

From 1955 (177.5 million ft^3) to 1980 (274.6 million ft^3), annual removals increased from 1.5 to 2.4 percent per year. Since 1980, removals have remained steady or increased slightly. Annual removals were the lowest in 1955 but the percentage of removals to volume was at its peak (1.7 percent) (Fig. 43). There was much less volume in 1955.

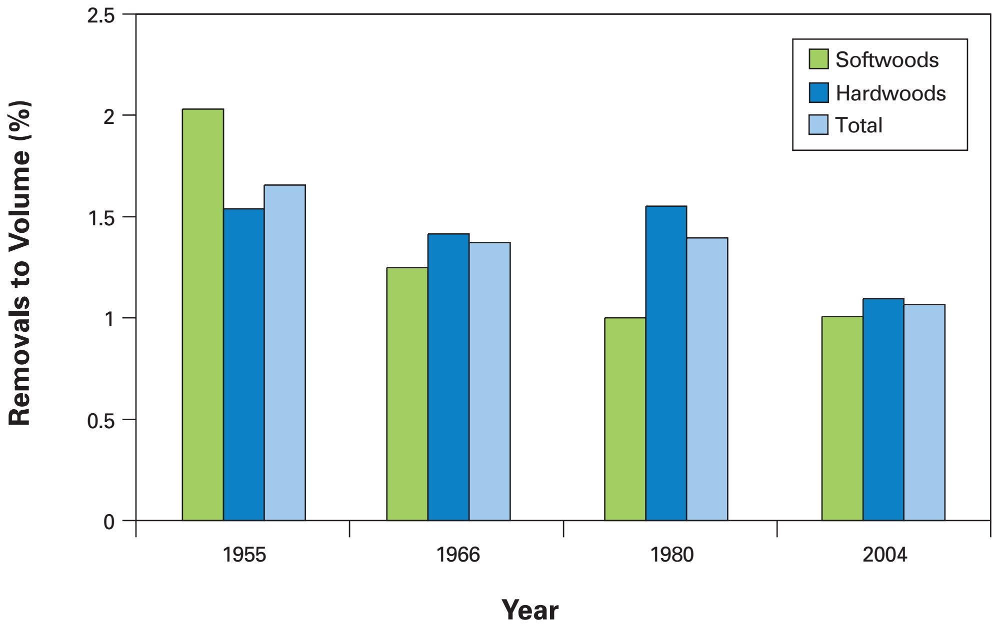
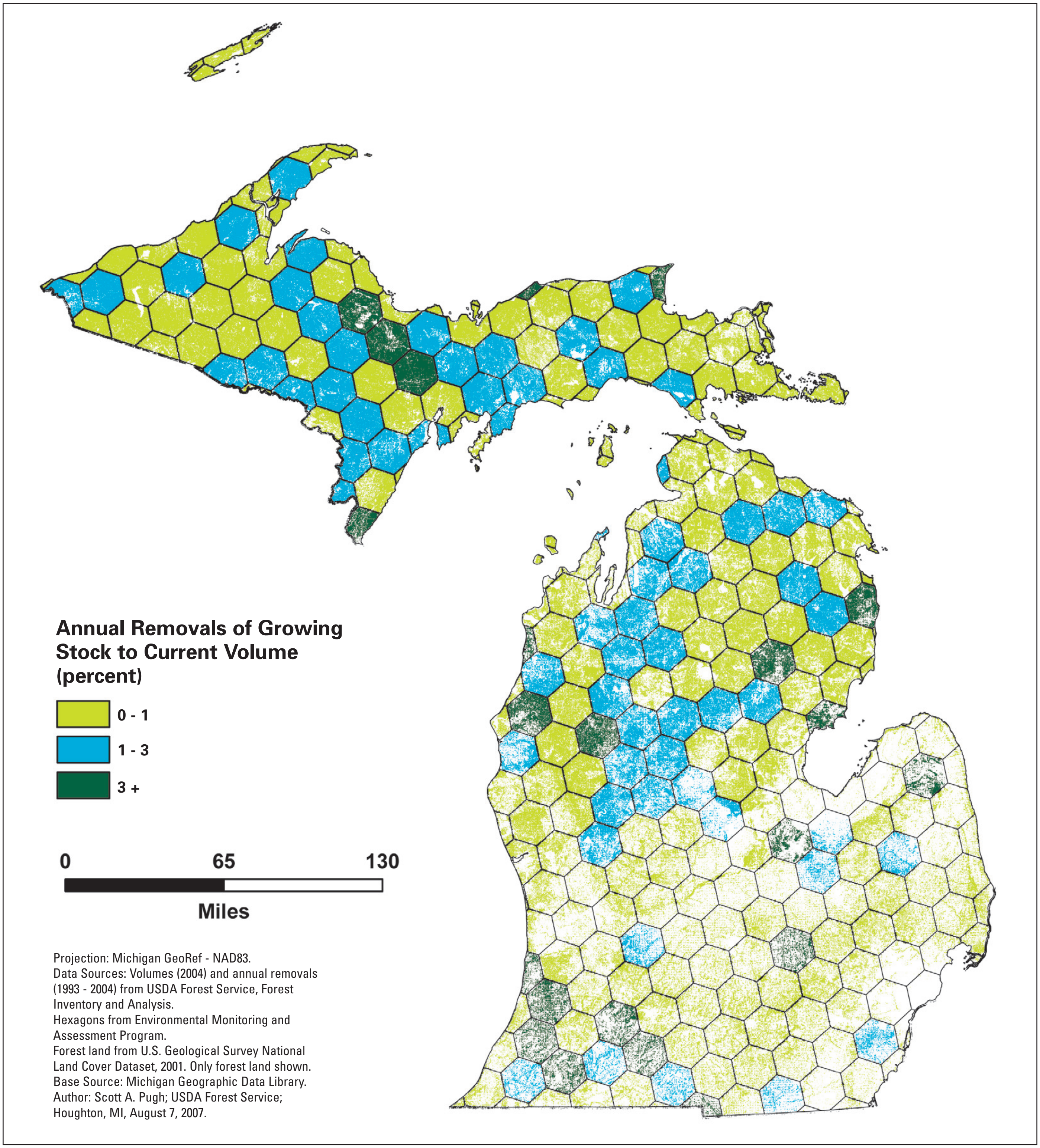


Figure 43.—Removals of growing stock on timberland as a percentage of volume by species group and total, Michigan, 1955-2004 (estimates before 2004 are for a single year versus an average over an inventory period for this most recent inventory).

The TPO estimates of removals (growing stock on timberland) have ranged from 168 million ft^3 in 1965 to 354 million ft^3 in 1994 (see page 164). TPO estimates generally have been higher than estimates of average annual removals from the 1993 and 2004 FIA plot inventories. It is difficult to determine which estimate more accurately reflects actual removals because the estimates are based on different designs measuring related but different variables.

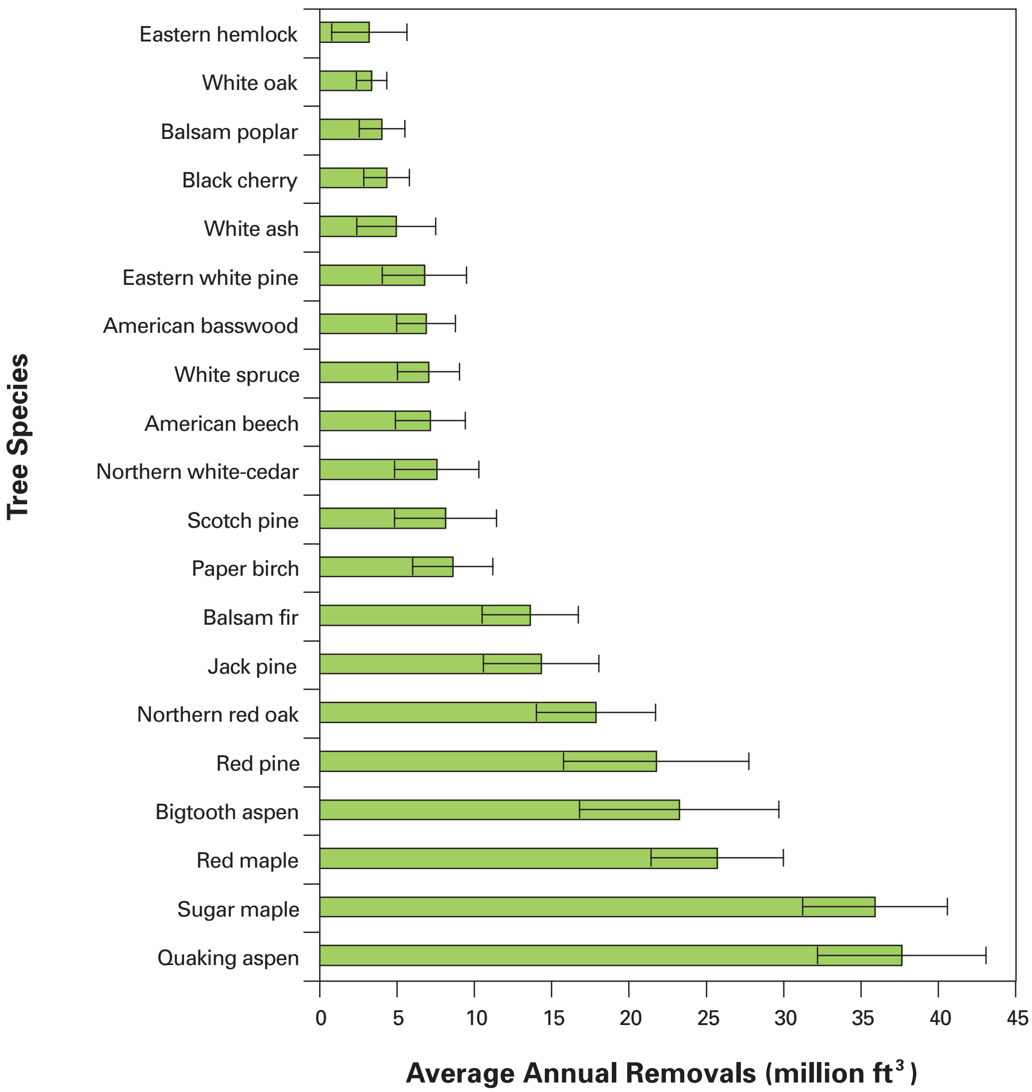
Average annual removals of growing stock to current volume varies spatially but there is no significant difference among the regional estimates (Fig. 44). Average annual removals of growing stock per acre on timberland were 18, 14, 16, and 13 ft^3 for the western Upper Peninsula, eastern Upper Peninsula, northern Lower Peninsula, and southern Lower Peninsula, respectively. Removals in the northern Lower Peninsula (114.3 million ft^3) were greater than in other regions. The western Upper Peninsula (81.3 million ft^3) has the next highest removals followed by the eastern Upper Peninsula (56.7 million ft^3) and southern Lower Peninsula (39.0 million ft^3).

Figure 44.—Average annual removals of growing stock on timberland as a percentage of current volume (2004) by EMAP hex, Michigan, 1993-2004.



The top 20 species in Figures 45 and 46 accounted for 90 percent of the average annual removals of growing stock on timberland from 1993 to 2004. Quaking aspen and sugar maple had the most average annual removals but they differ in rates of average annual removals to volume. Quaking aspen has a moderate rate of 2.5 percent. By contrast, sugar maple has a rate of 0.9 percent. Jack pine, quaking aspen, balsam fir, bigtooth aspen, balsam poplar, American beech, paper birch, white spruce, northern red oak, white ash, and red pine have moderate rates of removals to volume. In general, the more intolerant and fast growing, pioneer species have higher rates of removals to volume.

Figure 45.—Average annual removals of growing stock on timberland by species, Michigan, 1993-2004; error bars represent 68-percent confidence interval around estimate (top 20 species by average annual removals).



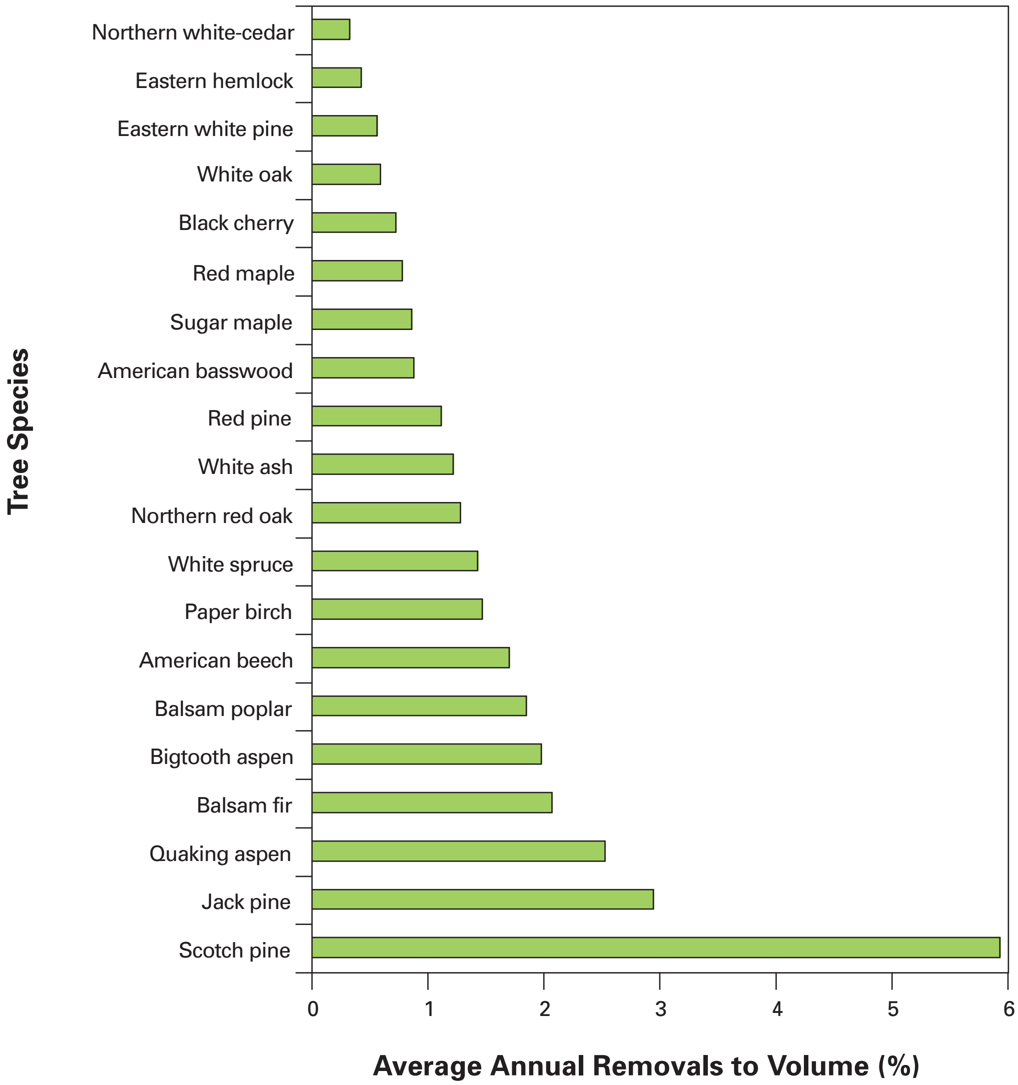


Figure 46.—Average annual removals of growing stock on timberland as a percentage of current volume (2004) by species, Michigan, 1993-2004 (top 20 species by average annual removals).

Average annual removals to current volume changes with ownership group. Private (1.1 percent) and State and local government (1.2 percent) owners have significantly higher rates than the U.S. Forest Service (0.7 percent). Private and State and local governments do not differ significantly from each other.

As mentioned previously, removals not only count what was actually removed off site but also include land-use change and mortality due to harvesting (Fig. 47). Eighty-nine percent of the average annual removals were due to harvesting and removal from the site. Five percent were left standing but the land was diverted to nonforest. Likewise, diversion to unproductive and or reserved forest land was 5 percent. On average from 1993 to 2004, only one-twentieth of a percent of the removals was killed due to harvesting and left on site.

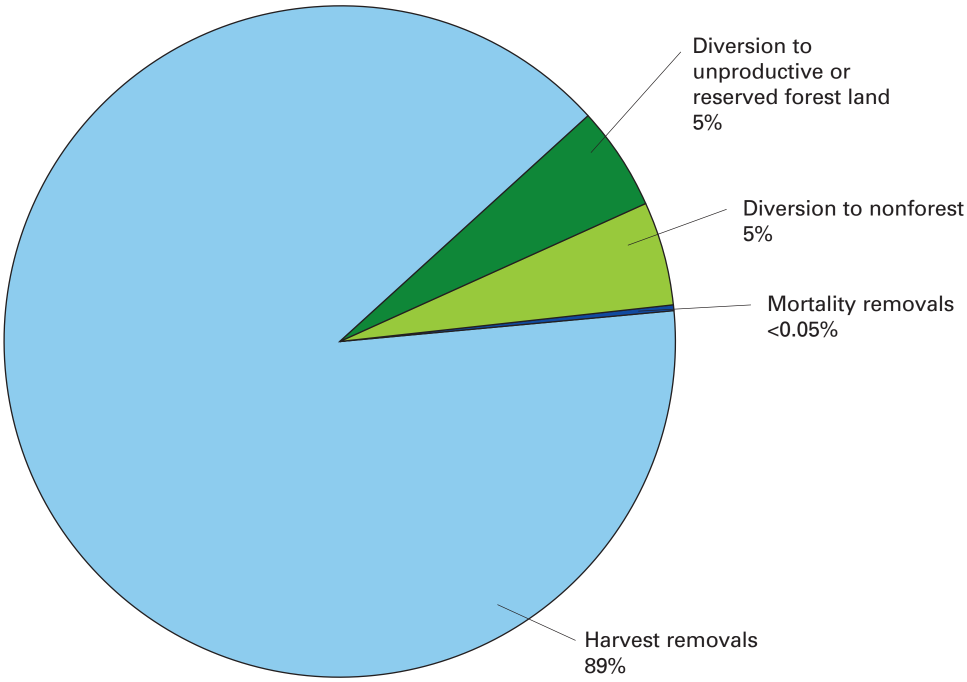


Figure 47.—Percentage of average annual removals for growing stock on timberland, Michigan, 1993-2004.

What this means

Removals are affected by biological factors and the needs and aspirations of society. Harvesting is not a top priority for some private owners (see Fig. 54) or for public owners like the U.S. Forest Service. Since the 1950s, the percentage of removals to volume has been low for Michigan. Currently, Minnesota (1990-2003) and Wisconsin (1996-2004) have percentages of 1.6 and 1.8, respectively compared to 1.1 percent for Michigan. Average annual removals have leveled since 1980 while net growth has held steady (see Fig. 34). By comparison, TPO estimates of removals did not level until 1988 (see Fig. 96).

At the species level, the percentage of average annual removals to current volume indicates sustainable practices. Many of the estimates reflect different species attributes and management practices associated with the species. Shade-tolerant species like sugar maple are expected to have lower rates for removals to volume than intolerant pioneer species like quaking aspen. Intolerant species do not live as long so the rotation cycle for harvesting these species is shorter. Also, the species attributes lend themselves to practices that remove more or all of the basal area when harvesting to promote regeneration. Species like balsam poplar, balsam fir, jack pine, and paper birch also have moderate rates of mortality. Some of the removals for these species could be an attempt to "capture mortality" or harvest the trees before they die.

Net Growth to Removals

Background

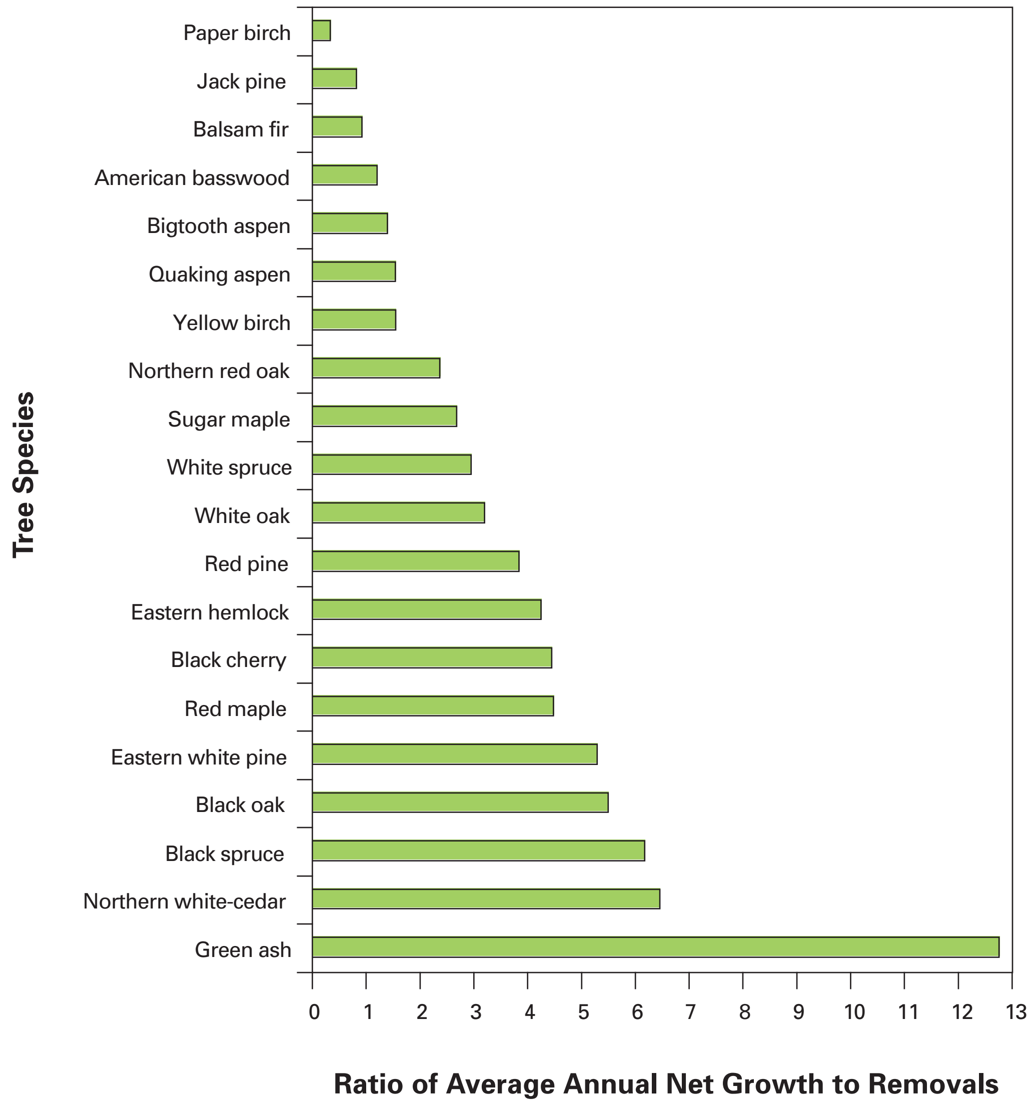
One measure of sustainability is the ratio of net growth to removals. A number greater than 1 indicates the volume of the species is increasing; a number less than 1 indicates the volume is decreasing. It is not always beneficial to maintain high ratios of net growth to removals. Over long periods, forest health issues could arise and it may be appropriate to increase removals even when the ratio of net growth to removals is less than 1 or the volume is decreasing. For example, an older forest may be experiencing little growth and high mortality. In such cases, it may be necessary to increase removals in the short term to improve long term growth. Land management objectives also will help determine an appropriate ratio of net growth to removals. As stated previously, new methods were used to calculate net growth for the current inventory of Michigan and inventories of other states mentioned in comparisons (see page 70).

What we found

The ratio of net growth to removals from 1993 to 2004 was 2.7, indicating that volume is increasing at a moderate to high rate as compared to other states. For the current inventory, only several species had ratios of net growth to removals less than 1 (Fig. 48). Moderate to high mortality and removal rates contribute to the low ratios for balsam fir, jack pine, and paper birch (see Figs. 42 and 46). Balsam poplar, not shown, has a ratio of 0.7. Some species have high to very high ratios. In turn, increases in volume for these species have been significantly greater since the 1980 inventory (see Fig. 29).

Red pine stand next to a clearcut. Photo by Scott A. Pugh, U.S. Forest Service.

Figure 48—Ratio of average annual net growth to removals for growing stock on timberland, Michigan, 1993-2004 (top 20 species by growing-stock volume on timberland).



Since 1955, the overall net growth to removals ratio has remained almost constant from 2.7 to 2.8 (Fig. 49). From 1993 to 2004, net growth increased by an average of 2.3 million ft^3 per year (0.3 percent). Removals increased by 1.5 million ft^3 per year (0.6 percent) on average during the same time period. Except for 1980, the ratio of net growth to removals for softwoods and hardwoods was relatively constant (Fig. 49).

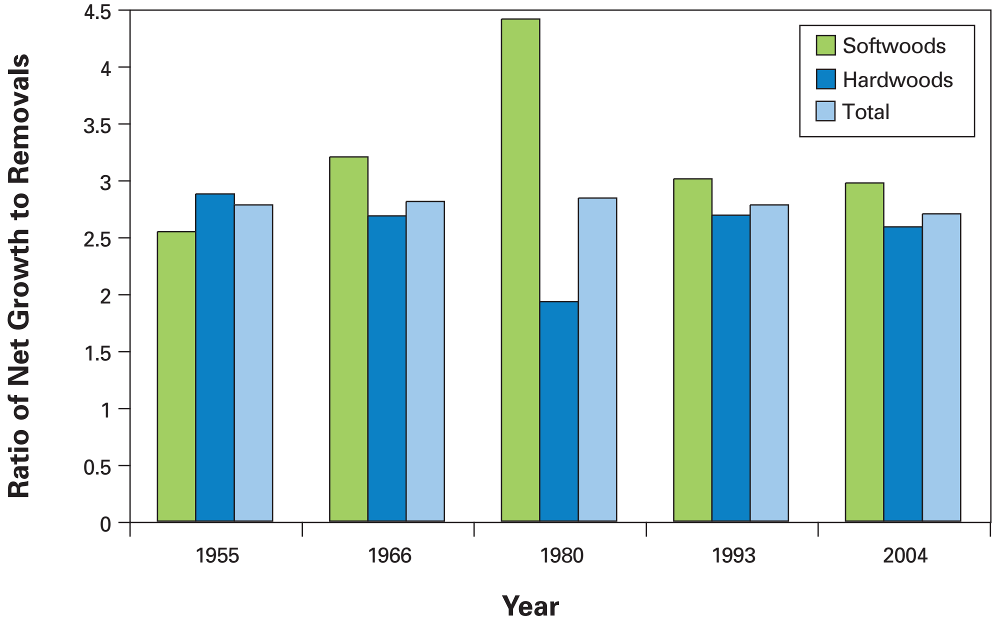


Figure 49.—Ratio of net growth to removals on timberland by species group and total, Michigan, 1955-2004.

Ratios of net growth to removals for the western Upper Peninsula, eastern Upper Peninsula, and northern Lower Peninsula were 2.1, 2.4, and 2.6, respectively; these ratios were not significantly different. The southern Lower Peninsula contributes to the high ratio of net growth to removals for Michigan at 4.8. This region also has the greatest net growth to volume (4.0 percent). Since 1980, increases in net growth to volume have been greatest in the southern Lower Peninsula.

There were no significant differences in ratios of net growth to removals among ownership groups. Rates were 3.2, 2.3, and 2.2 for the U.S. Forest Service, State and local government, and private lands, respectively. Similar ratios of net growth to removals can mean different things. Given equal ratios, one group could have high net growth and removals and another could have low net growth and removals. The ratio for the U.S. Forest Service equals that for the other ownership groups. However, the U.S. Forest Service has much lower ratios of net growth to volume and of removals to volume.

Again, equivalent ratios of net growth to removals can be based on various conditions. Compared to more recent years, 1955 had the highest percentages of net growth to volume and removals to volume (see Figs. 35 and 43). 1955 was also associated with the least amount of growing-stock volume (see Fig. 25) on the most forest land (see Fig. 7), and mortality was relatively low (see Fig. 39). Although these factors have changed over time, the overall ratio has remained virtually the same.

What this means

Historically, the ratio of net growth to removals for Michigan has been moderate to high. Minnesota (1990-2003) and Wisconsin (1996-2004) have ratios of 1.5 and 1.7, respectively. Other states have had higher ratios. For example, New York and West Virginia had ratios of 3.0 and 3.5, respectively (Smith et al. 2004). Michigan has had relatively low removals and mortality rates but high growth rates.

Low mortality and high growth rates are helpful in maintaining a sustained yield, and a high ratio is generally better than a low one. This is only one indicator of a sustained yield as it can be beneficial to lower the ratio of net growth to removals. A high ratio of net growth to removals could result in forest health issues over time, especially for certain species. For example, forest health might be improved if removals were increased in some jack pine stands even though they might already be experiencing low ratios of net growth to removals (see page 156). The objectives of land managers also determine the appropriate ratio of net growth to removals. If the primary objective is timber production, a long-term ratio of about 1 is more appropriate than a high ratio.

Many of the species with low ratios of net growth to removals are in greater demand by the wood-products industry. For example, jack pine, aspen, and northern red oak are in high demand for the manufacture of paper, oriented strand board, and furniture, respectively, while there is relatively little demand for green ash, eastern hemlock, and black oak. Also, nonmarket factors such as wildlife concerns can constrain the supply of species such as northern white-cedar.

The increase in net growth to volume was markedly higher in the southern Lower Peninsula, than in other regions. Part of this was due to agricultural land reverting to forest land. This region has the most productive sites and thus the highest growth but it also has the least timber volume and few primary wood-manufacturing facilities.

Mortality rates increase as drought and other forest-health factors increase. Insect outbreaks, disease, and succession can result in low ratios of net growth to removals. This is typically the case for species such as jack pine, paper birch, balsam fir, and balsam poplar. The high mortality rate for balsam fir is the largest contributor to the low ratio of net growth to removals for this species. This high mortality most likely is due to both spruce budworm infestations and drought (see page 82).

Jack pine, paper birch, and balsam poplar are influenced more by the combination of removals and mortality. As mentioned previously, much of the removals probably represents an attempt to harvest trees before they die of old age. Jack pine, paper birch, and balsam poplar are early successional species that are intolerant to shade. They need fire or other site preparation treatments to regenerate. Also, the jack pine budworm is affecting older jack pine. The volume of jack pine, paper birch, and balsam poplar has decreased significantly (see Fig. 29), and jack pine and paper birch have been losing significant numbers of trees of sapling and pole size (see Table 3). The large number of sapling-size balsam fir has been increasing. Balsam poplar also has increased significantly in the number of saplings and maintains a steady number of poletimber-size trees.

Forests in Flux

Farm and forest land. Photo by Scott A. Pugh, U.S. Forest Service.

Who Owns Michigan's Forests?

Background

As diverse as Michigan's forests are, so are the State's forest owners. From the Michigan Department of Natural Resources to large, forestry corporations, to families with several acres, the characteristics and objectives of these owners vary dramatically. These economic, political, and social factors will interact with biophysical factors to determine the future of the State's forest resources. Forests and forest-land owners will continue to change. By monitoring both of these, we can help assure that the needs of both landowners and the rest of society are met.

Unless stated otherwise, the information presented here is based on the 2004 FIA inventory and the 2006 National Woodland Owner Survey (NWOS, see page 180). On an annual basis, the NWOS contacts randomly selected private landowners and asks them to complete a self-administered, mailed questionnaire. Between 2002 and 2006, 3,709 private landowners were contacted in Michigan and 2,238 of them (60 percent) completed and returned questionnaires. This is a high rate of response.

Although similar methods were used in previous landowner surveys (Birch 1996), most direct comparisons to past surveys are not possible due to different methodologies. Research is being conducted on trends over time and will be available in future publications. Recently, the NWOS has been modified to make future comparisons easier.

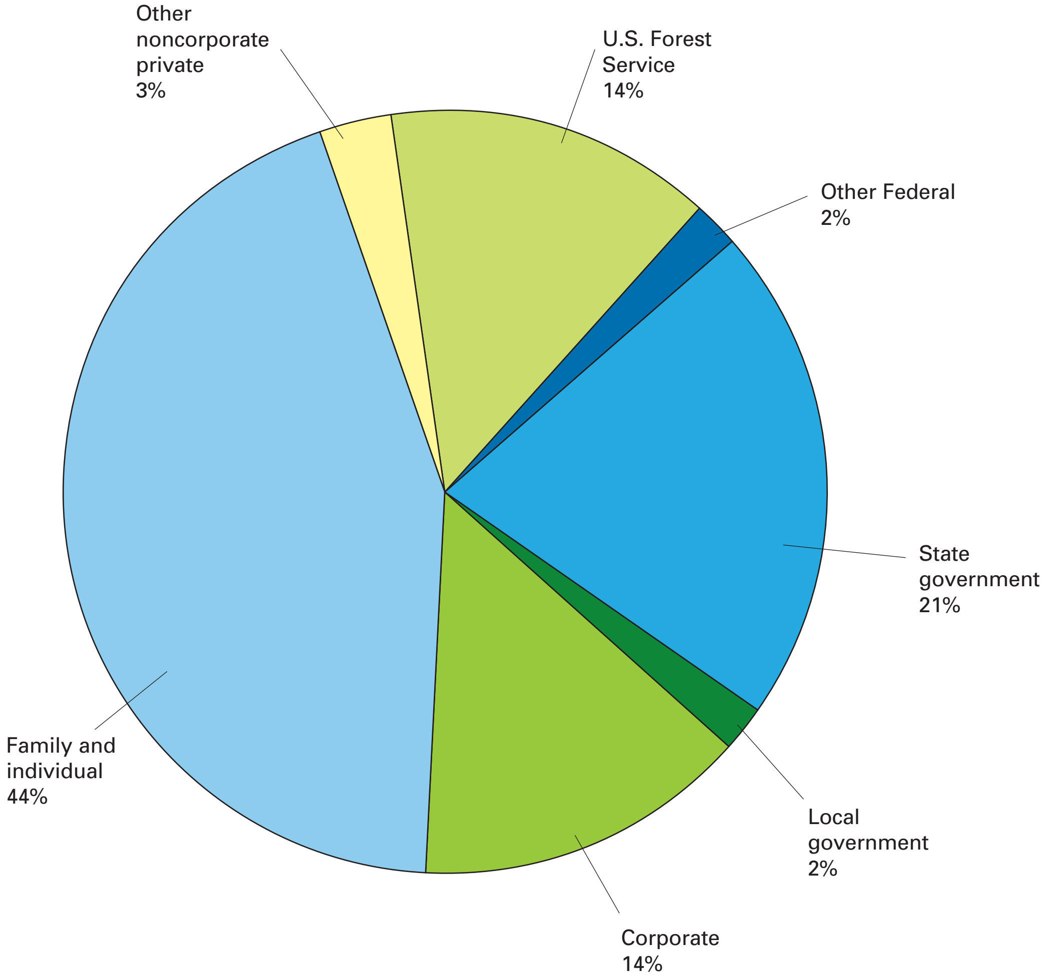
What we found

General ownership patterns

The majority (62 percent or 11.9 million acres) of Michigan's forest land is owned by families, individuals, private corporations, and other noncorporate private groups (Fig. 50). The latter groups include nongovernmental conservation and natural resource organizations; unincorporated local partnerships, associations, and clubs; and Native American communities. The remaining 38 percent (7.4 million acres) is managed by Federal, State, and local government agencies.

Family forest owners. Photo by Scott A. Pugh, U.S. Forest Service.

Figure 50.—Percentage of forest land by ownership class, Michigan, 2004.



These broad ownership patterns vary across the State (Figs. 51-52). The eastern and western portions of the Upper Peninsula and the northern Lower Peninsula have relativity high concentrations of public ownership, 49, 39, and 41 percent, respectively, compared to the more fragmented forests of the southern Lower Peninsula (15 percent). These differences affect not only the forest resources (e.g., management practices) but also recreation and other services for the general public.

Figure 51.—Private and public forest-land ownership, Michigan, 2000, 2004, and 2008.

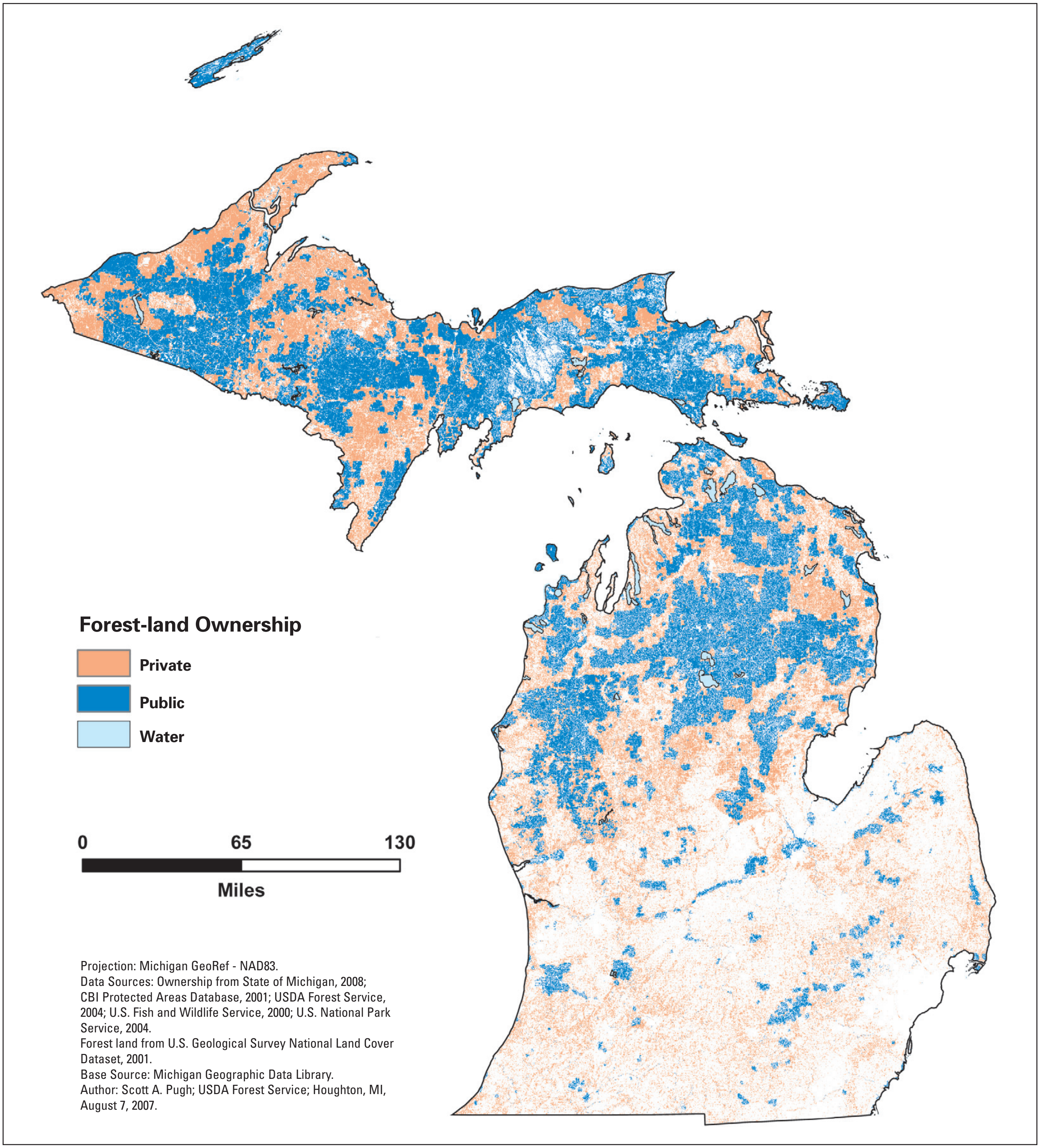
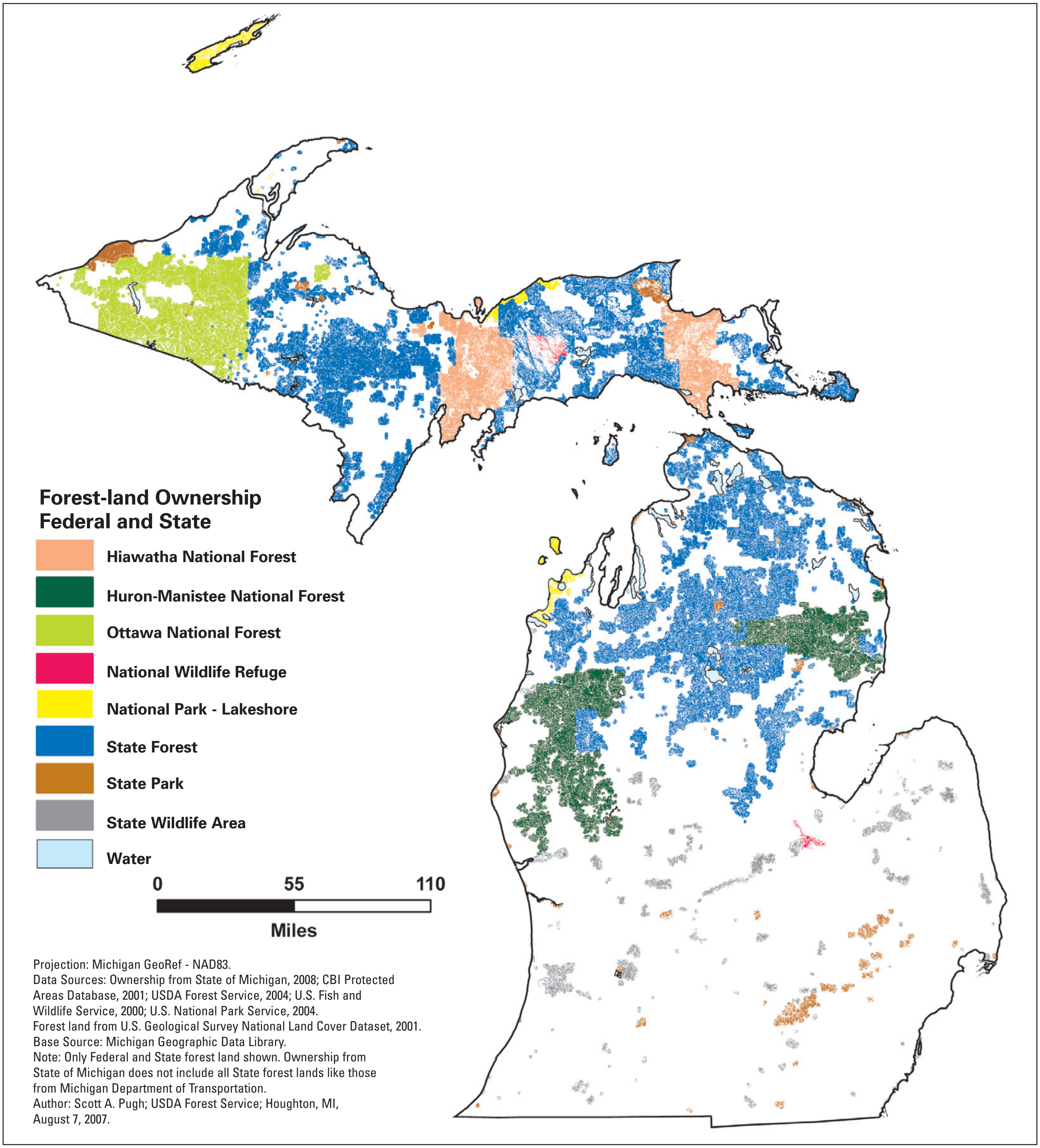


Figure 52.—Federal and State ownership of forest land, Michigan, 2000, 2004, and 2008.



Public ownership

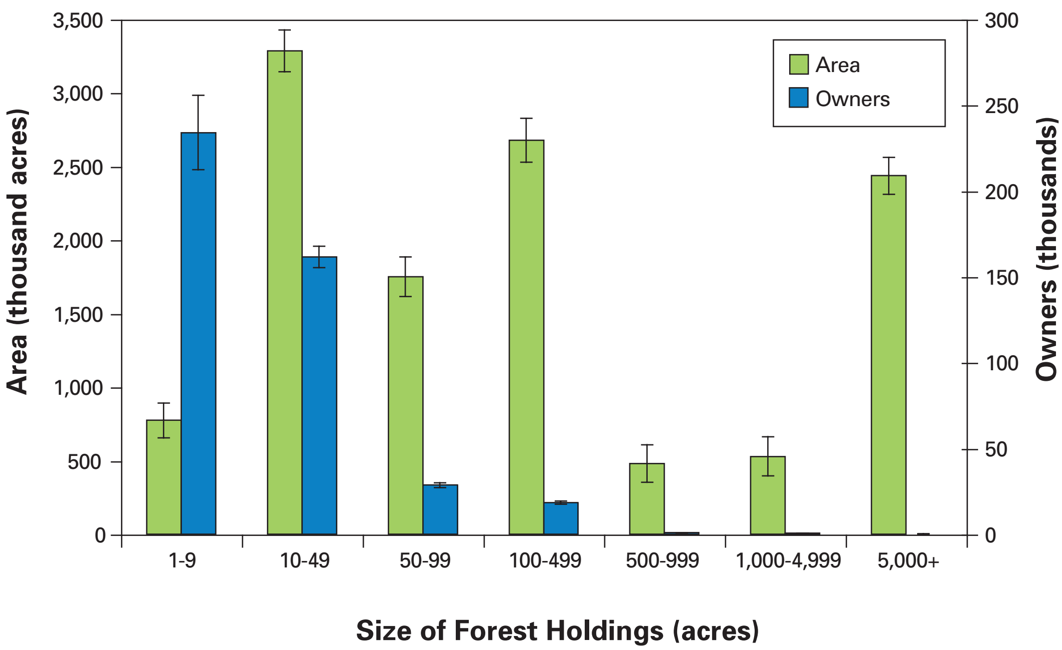
Fifty-six percent of public forest land is managed by State agencies such as the Michigan Department of Natural Resources. The Hiawatha, Huron-Manistee, and Ottawa National Forests comprise about 90 percent of Federal forest-land ownership, or 39 percent of public ownership. The remaining 4 percent is managed by county and municipal or local governments. Depending on the specific tract of land, these forests may be managed for water protection, nature preservation, timber production, recreation, other uses, or, more commonly, a combination thereof.

Public forest land has been increasing gradually. Between 1993 and 2004, the area of public forest land increased by 4 percent, due almost entirely to increases in State lands.

Private ownership

There are about 444,000 private landowners in Michigan who collectively own 11.9 million acres of forest land. Fifty-three percent of private owners hold fewer than 10 acres but collectively control only 7 percent of the State's private forest land (Fig. 53). By contrast, 20 percent own large holdings (5,000 or more acres), 31 percent own medium holdings (100 to 4,999 acres), and 42 percent own small (10 to 99 acres) tracts. The average size of forest holdings increases from south to north and east to west, from 13 to 25 to 52 to 100 acres in the southern Lower Peninsula, northern Lower Peninsula, eastern Upper Peninsula, and western Upper Peninsula, respectively.

Figure 53.—Size of private forest holdings, Michigan, 2006 (error bars represent 68-percent confidence interval around estimate).



Many large holdings, particularly in the Upper Peninsula, are owned by corporations. Traditionally, these consisted primarily of vertically integrated companies that used their forest lands to feed the sawmills and/or paper mills that they owned. Over the past two decades, these companies have been separating their land from other assets and divesting much, if not all, of their forest holdings. A high proportion of these lands has been acquired by timber investment management organizations (TIMO), real estate investment trusts (REIT), and other individuals and organizations as an investment for their clients or themselves. TIMOs and REITs are in the corporate private landowner category. In Michigan, there were large land transactions to TIMOs and REITs in 2005 and 2006.

Three-fourths of private land in Michigan is owned by families, individuals, estates, trusts, and other groups of unincorporated individuals who collectively are called family forest owners. The U.S. Forest Service conducts the NWOS to better understand this important and dynamic group.

Family forests are owned for numerous reasons and many of these center around amenity values such as aesthetics, privacy, and nature protection (Fig. 54). Although these values are fairly consistent across the State, there are strong regional patterns. For example, timber production is relatively more important in the Upper Peninsula than in the Lower Peninsula. And in the southern Lower Peninsula, a higher proportion of forest land is associated with farms and recreation is relatively less important.

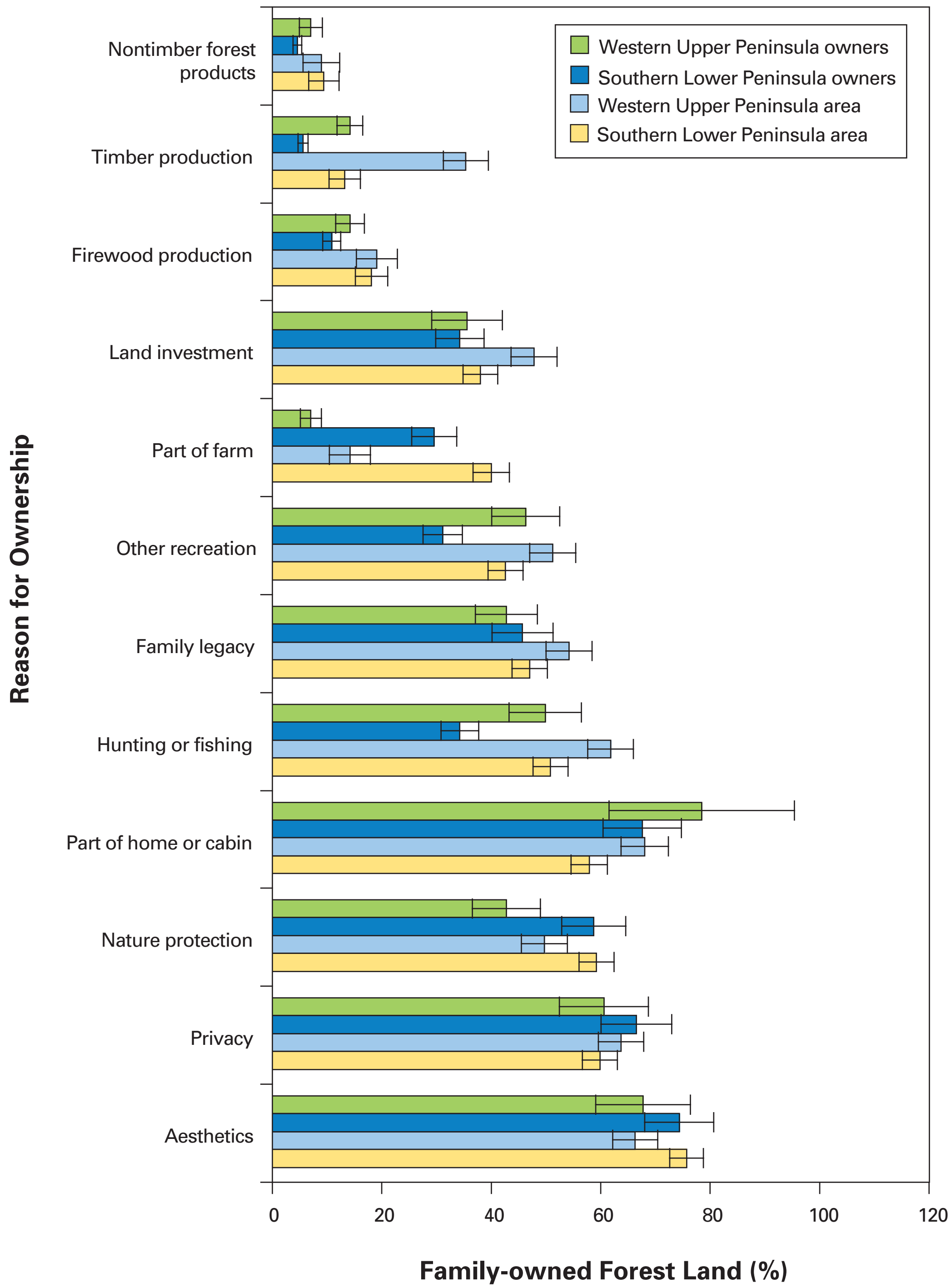
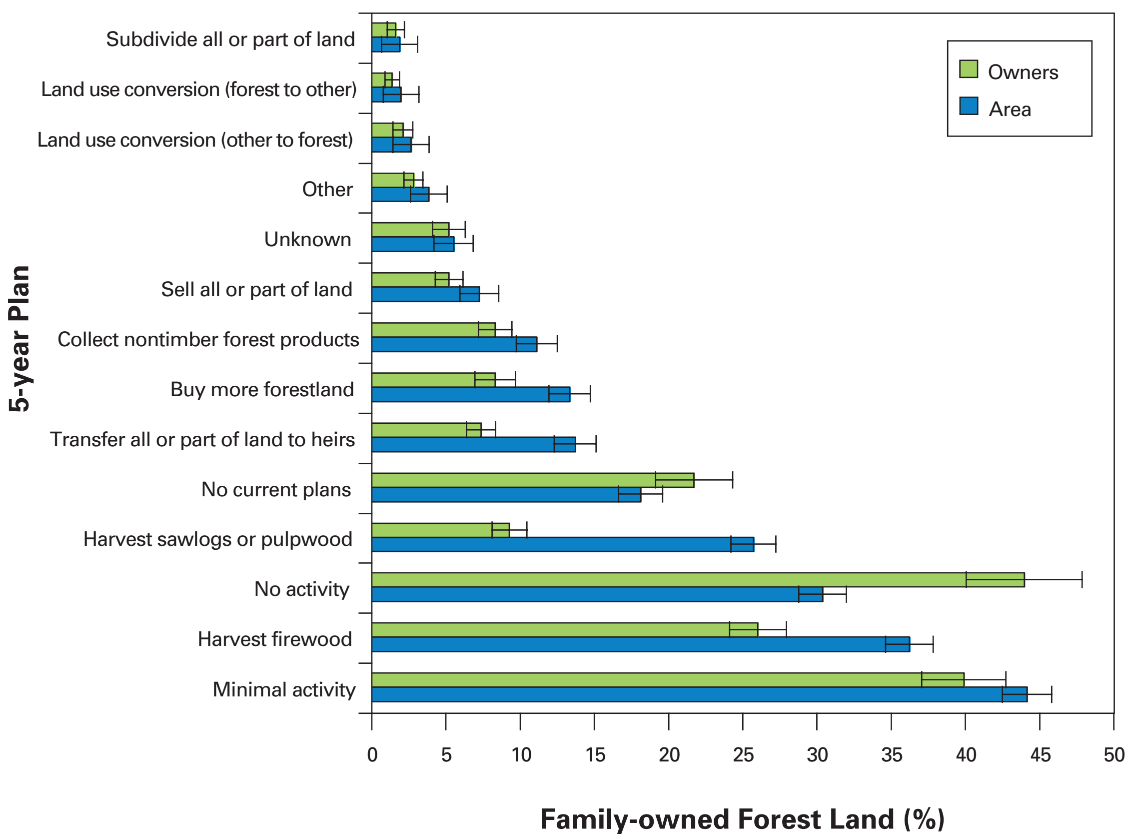


Figure 54.—Primary reasons for owning family forests in the southern Lower Peninsula and western Upper Peninsula of Michigan, 2006; error bars represent 68-percent confidence interval around estimate. Numbers include landowners who ranked each reason as very important (1) or important (2) on a seven-point Likert scale (reasons are not mutually exclusive).

Although timber harvesting is not ranked by most owners as a primary objective, few owners are averse to receiving extra income from their land. For example, 52 percent of forest land is owned by people who have commercially harvested trees. Again, there is a general south to north and east to west pattern: commercial harvesting percentage ranges from 42 in the southern Lower Peninsula to 65 in the western Upper Peninsula. Statewide, only 18 percent of family forest land is owned by people who reported having a written forest management plan. This compares to 17 percent in Minnesota and 7 percent in Wisconsin.

Although most family forest owners did not report having a management plan for their land over the next 5 years, 19 percent (1.7 million acres) of the family forest land is owned by people who plan to sell or pass on their forest land (Fig. 55). This percentage is highest in the western Upper Peninsula and lowest in southern Lower Peninsula. Legacy is important to many of these owners but many are worried about their ability to pass on their land to the next generation (Fig. 56). These findings coupled with the fact that 39 percent of family forest land is owned by people who are at least 65 years old indicate that a large intergenerational shift of land will occur soon.

Figure 55.—Future (next 5 years) plans for landowners of family-owned forests, Michigan, 2006; error bars represent 68-percent confidence interval around estimate (plans are not mutually exclusive).



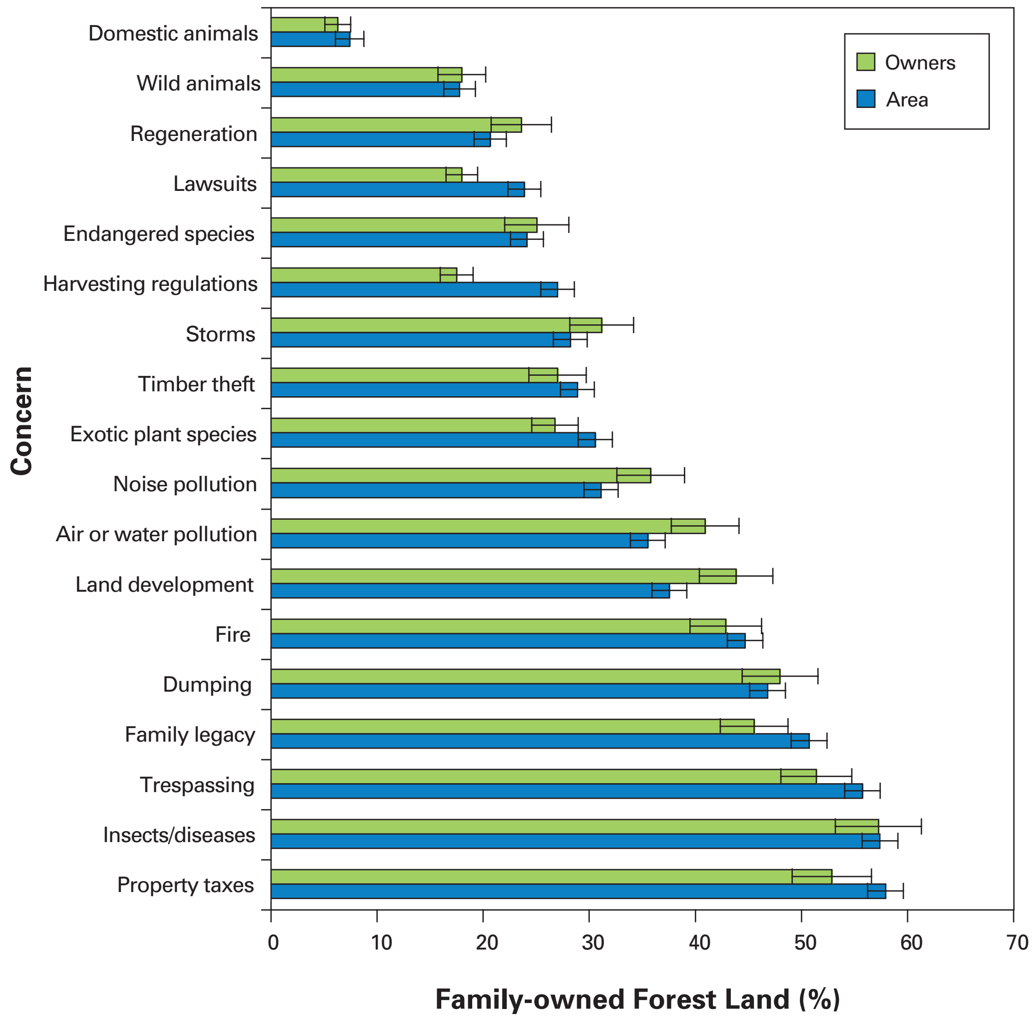


Figure 56.—Primary concerns of owners of family-owned forests, Michigan 2006; error bars represent 68-percent confidence interval around estimate. Numbers include landowners who ranked each concern as very important (1) or important (2) on a seven-point Likert scale (concerns are not mutually exclusive).

What this means

The forest-land owners of Michigan are diverse and their objectives vary across the State. Many people are open to timber harvesting, especially in the northern parts of the State. In addition, many landholdings are larger in these areas. As mentioned, there will be an intergenerational shift. Who will be the next generation of landowners and what will be their relationship with the land? Answers to these questions will have important ramifications for the future of the State's forests. The NWOS is one tool for monitoring changes in landowners and their needs, and the types of products obtained from private lands.

Land-use Change

Background

Forest conditions and trends are affected by changes in land use. Before European settlement, about 90 percent of the southern Lower Peninsula and nearly all of northern Michigan were covered by forests (Dickmann and Leefers 2003). Land change was greatest prior to the first statewide FIA forest inventory in the 1930s. Here, the focus is on forest-land change between 1993 and 2004.

The results are based on observations at the centers of 11,601 plots. The 1993 data include 7,188 modeled plots (see Table 1). However, land-use classes on these plots were assigned using aerial photo interpretation and field checks. Aerial photo interpretation works well when land-use classes are not detailed.

For this section, all land-use definitions from 1993 were updated to the 2004 definitions for comparisons. In 1993, wide windbreaks, wooded pasture, and urban forest land were considered nonforest. Here, wide windbreaks, wooded pasture, and urban forest land are included in the forest-land category for 1993 and 2004. Christmas tree plantations were forest land in the 1993 inventory but nonforest in the 2004 inventory. We consider Christmas tree plantations as nonforest land in 1993 and 2004.

What we found

About 53 percent of the land in Michigan is forested. Between 1993 and 2004, 3 percent of the nonforest land and water (Great Lakes waters excluded) converted to forest land. Land that converts to forest land typically is referred to as reversions since it is assumed that at presettlement times, the land had been forested and is now reverting to its original use. Forty-seven percent of land in Michigan is classified as nonforest. From 1993 to 2004 there was a 2-percent change in the land and water base (Great Lakes waters excluded) from forest land to nonforest land and water. Land that converts from forest land to nonforest typically is referred to as diversions.

After reclassifying 1993 land uses to 2004 definitions, the total forest land for 1993 is about 19,425,900 acres (19,280,800 by the 1993 definition) versus 19,311,946 acres for 2004. Even after this adjustment, there is no significant change in forest land from 1993 to 2004 over all types of land ownership.

Most of the reversions came from, in decreasing order, pasture and rangeland, urban, farmland, and marsh and water (Fig. 57). Most of the diversions were due to development (42 percent urban, Fig. 58). Marsh and water was another major diversion source.

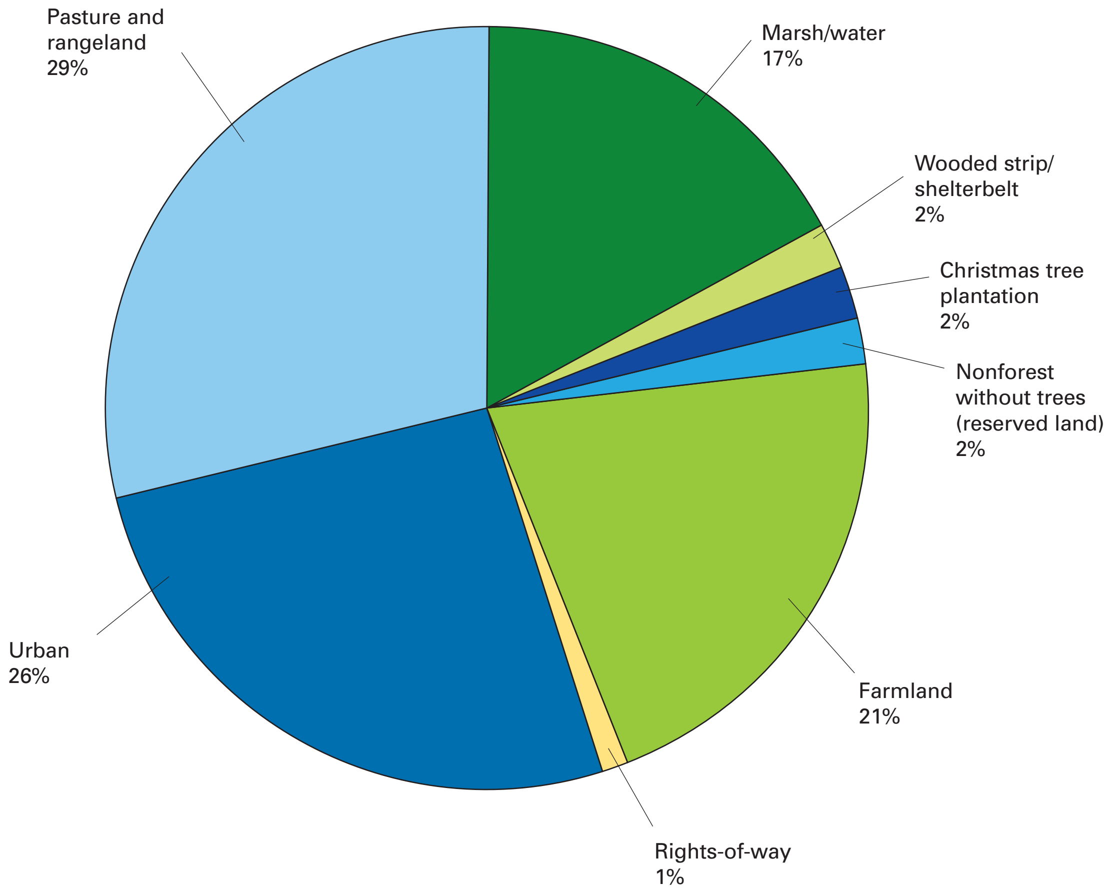


Figure 57.—Percentage of forest-land reversion by previous land use, Michigan, 1993-2004.

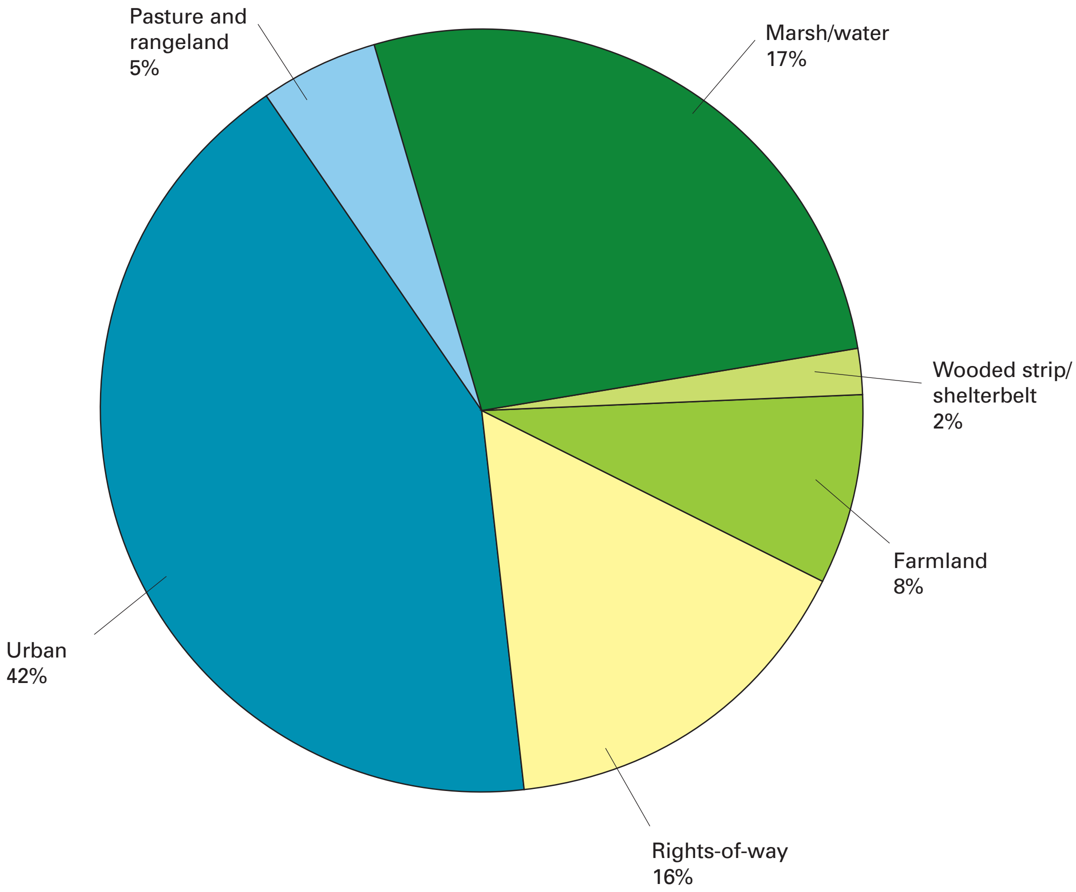


Figure 58.—Percentage of forest-land diversion by current land use, Michigan, 1993-2004.

What this means

Forest land area in Michigan generally held steady between 1993 and 2004. Nearly 97 percent of forest land in 1993 remained so in 2004 as diversions from forest land were offset by reversions to forest land. Nevertheless, land-use change is occurring within the land base. Both urban development and low wet areas contribute substantially to reversions and diversions and this probably will continue. Low wet areas move in and out of forest land based on natural forces. Development is controlled primarily by socioeconomic factors. Also influenced by socioeconomic factors, farmland and pasture left over from the farming boom of the 1960s and 1970s continues to revert to forest land, though this is expected to slow.

Forest Fragmentation

Background

Forest fragmentation has been called "the most serious threat to biological diversity" (Wilcox and Murphy 1985). Forman (1995) defined it as the breaking up of large habitat or land areas into smaller pieces. This results in a loss of interior forest and an increase in edge habitat, which has many negative effects on the remaining vegetation and wildlife. Some of the harmful consequences of fragmentation are a loss of biodiversity, increased populations of invasive and nonnative species, and changes in biotic and abiotic conditions (Haynes 2003). Another concern is the loss of interior species.

Fragmentation occurs naturally from disturbances such as wildfire, wind, and flooding, or as the result of human activities such as conversion to agriculture or urban development and sprawl (Haynes 2003). The latter causes have more severe impacts on the remaining forest because they typically occur more frequently and result in more permanent land-use changes than those caused by natural disturbance events (Haynes 2003). For example, in the United States, urbanization is a primary cause of population declines in more than half of all Federally listed threatened and endangered species (Czech et al. 2000), and housing development plays a central role in species endangerment (Radeloff et al. 2005).

Many factors contribute to patterns of housing and other development. Public works infrastructure (e.g., roads and airports) along with accompanying procedures and policies (e.g., zoning and tax incentives) have facilitated housing development. The economy is one of the most important factors affecting these infrastructures and development. In the Midwest, including Michigan, the preference to live in a rural setting has led to a substantial growth in housing, primarily in the form of suburban and rural sprawl (Radeloff et al. 2005). This rural sprawl has led to heavily fragmented forest conditions in the northern portion of the Lower Peninsula. According to Radeloff et al. (2005), "There is substantial forest cover in the Lower Peninsula of Michigan but it is all within close vicinity of housing." They also state that this is worse than suburban sprawl because "much larger areas are affected and rural sprawl occurs in relatively less altered landscapes."

Rural homes in Keweenaw County, Michigan. Photo used with permission by Neil Harri, neilharriphotos.com.

The imagery used in this analysis was obtained from the National Land Cover Dataset (NLCD) 2001, which has a spatial resolution of 30 m (Vogelmann et al. 2001; see page 180). This means that each pixel in the map represents a square area of 30 m by 30 m on the ground, or 0.2 acre. This imagery was used to create a fragmentation map of Michigan using techniques adapted from Riitters et al. (2002). This technique first used the NLCD imagery to produce maps of forest versus nonforest cover, forest density, and forest connectivity. The corresponding pixel values from each map were then analyzed to create the final fragmentation map. During the analysis, an output pixel was assigned to one of five classes:

- Interior forest—continuous forest canopy (minimum of 5.6 acres or at least 60 m from the nearest edge).
- Edge—junction between forest and nonforest areas (forest density is greater than 60 but less than 100 percent within a 5.6-acre block).
- Patch—small forest area surrounded mostly or entirely by nonforest area (forest density is at least 4 but less than 60 percent within a 5.6-acre block).
- Nonforest—nonforest-land cover.
- Water/barren land—open water or naturally barren land.

Forested pixels from the forest versus nonforest cover map were assigned to one of the three forest classes (interior, edge, or patch); nonforested pixels were assigned to a nonforest class. Pixels classified as open water or bare rock/sand/clay in the original NLCD imagery were placed in the water/barren land class and were not considered to be a cause of fragmentation.

What we found

The fragmentation map of Michigan indicated that 53 percent fell into one of the forest classes, 44 percent were classified as nonforest, and 3 percent were in the water/barren land class (Fig. 59). A further breakdown of the pixels shows that 31 percent were classified as interior forest, 18 percent were in the edge class, and 4 percent were classified as patch. The resulting map (Fig. 60) shows that forest land in the Lower Peninsula is fragmented. The northern Lower Peninsula contains the most forest land but a considerable amount is classified as edge. Forest land in the southern Lower Peninsula contains little interior forest and is nearly entirely as edge or in small, isolated patches. The Upper Peninsula contains much more interior forest but much of the landscape is dissected by roads.

Figure 59.—Percentage of land by forest-fragmentation class, Michigan, 2001.

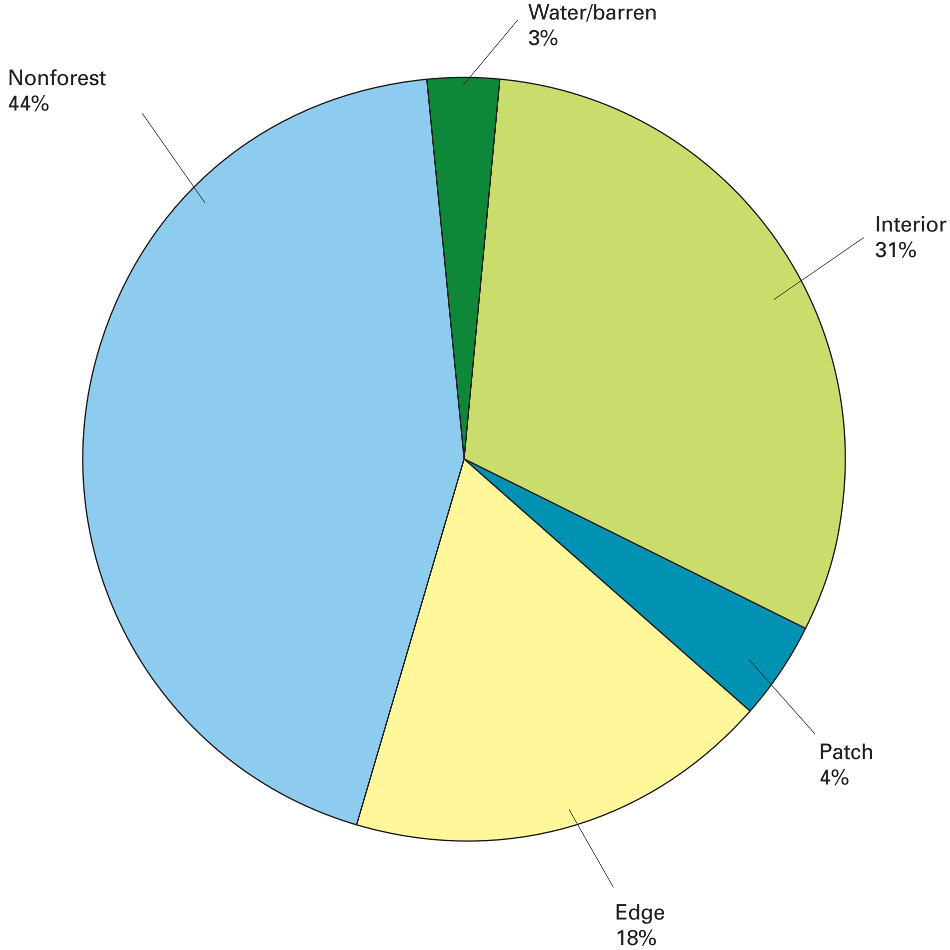
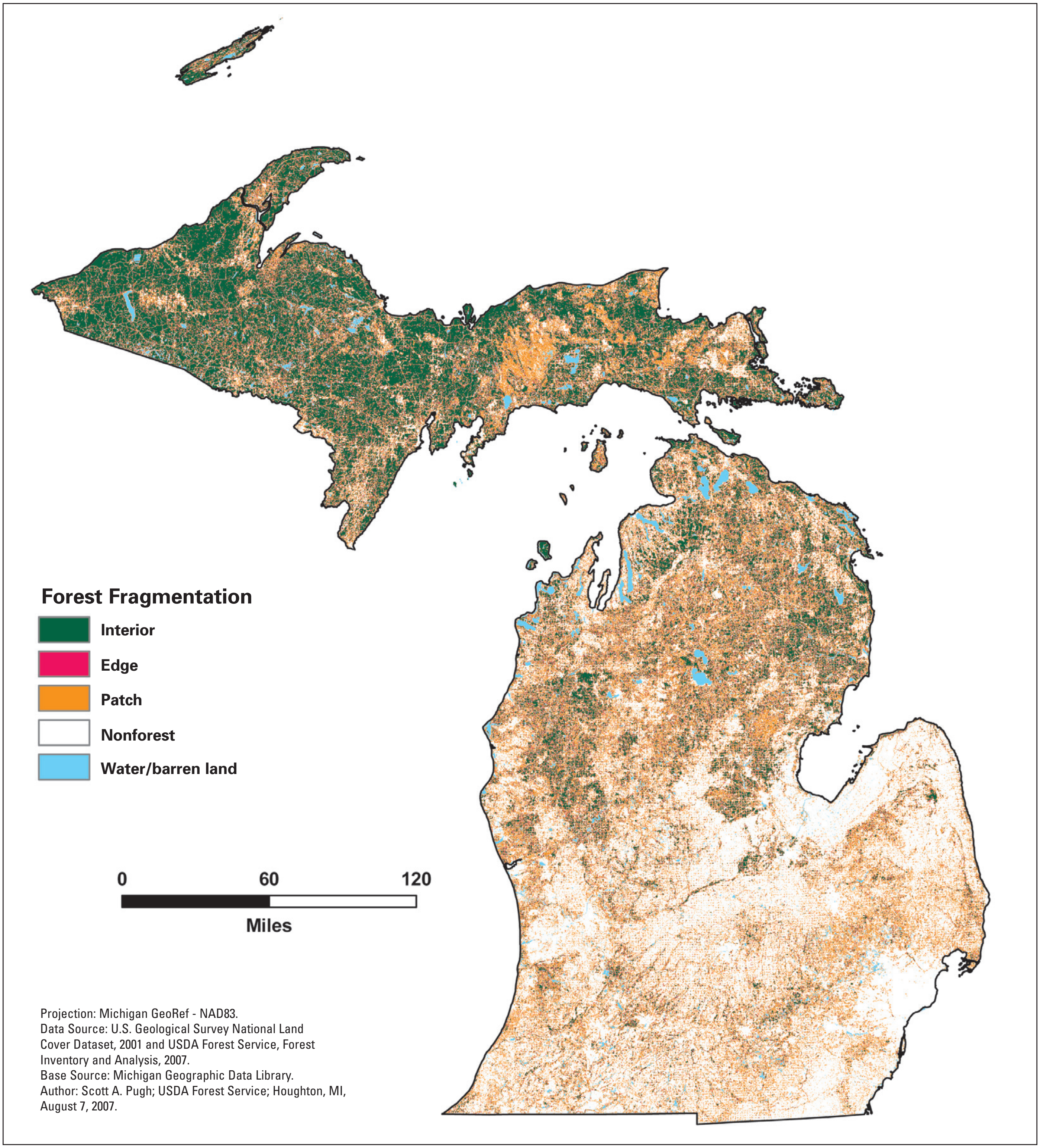


Figure 60.—Forest fragmentation based on NLCD imagery, Michigan, 2001.



Unfortunately, consistent image data are not available from previous years to identify trends in fragmentation. The land classification methods used in the 1992 NLCD differ from those used in 2001, so a true comparison of the fragmentation results obtained from the methods used in this analysis is not possible.

What this means

Much of the forest land in Michigan is relatively fragmented as indicated by the large proportion of edge pixels. Most of this occurs in the Lower Peninsula. The high occurrence of forest edge in the northern Lower Peninsula is primarily due to roads, agriculture, and urban development. Some of the fragmentation is a result of natural causes, mainly nonforest wetland and shrubland (see Fig. 5).

The fragmented landscape in the southern Lower Peninsula is due almost entirely to agriculture and urban development (see Fig. 5). This type of landscape lacks the continuous forest habitat required by many species of wildlife and plants and can result in a loss of biodiversity and even extinction (Forman 1995). In addition, many of the negative effects of fragmentation occur in edge habitat, for example, increased predation of bird nests and prey species (Heske et al. 1999) and population declines of native plant and wildlife species (Collinge 1996). There seems to be a correspondence between the relatively higher amounts of nonnative and invasive species and the heavily fragmented areas of Michigan (see Fig. 80).

Large tracts of public land impede or slow the overall pace of fragmentation in the State, though, the level of fragmentation varies within the State and the long-term trend is that large tracts of private forest land will be developed. Some of this development is the result of parcelization where tracts of land are subdivided. Parcelization does not mean that increased fragmentation is inevitable but it does increase the likelihood. Many other parts of the country have experienced this trend besides Michigan.

Although we were unable to directly compare the results of this study with previous ones, future comparisons should be possible, and research is being conducted to determine whether FIA plot data can be incorporated into the fragmentation analysis.

Forest Health

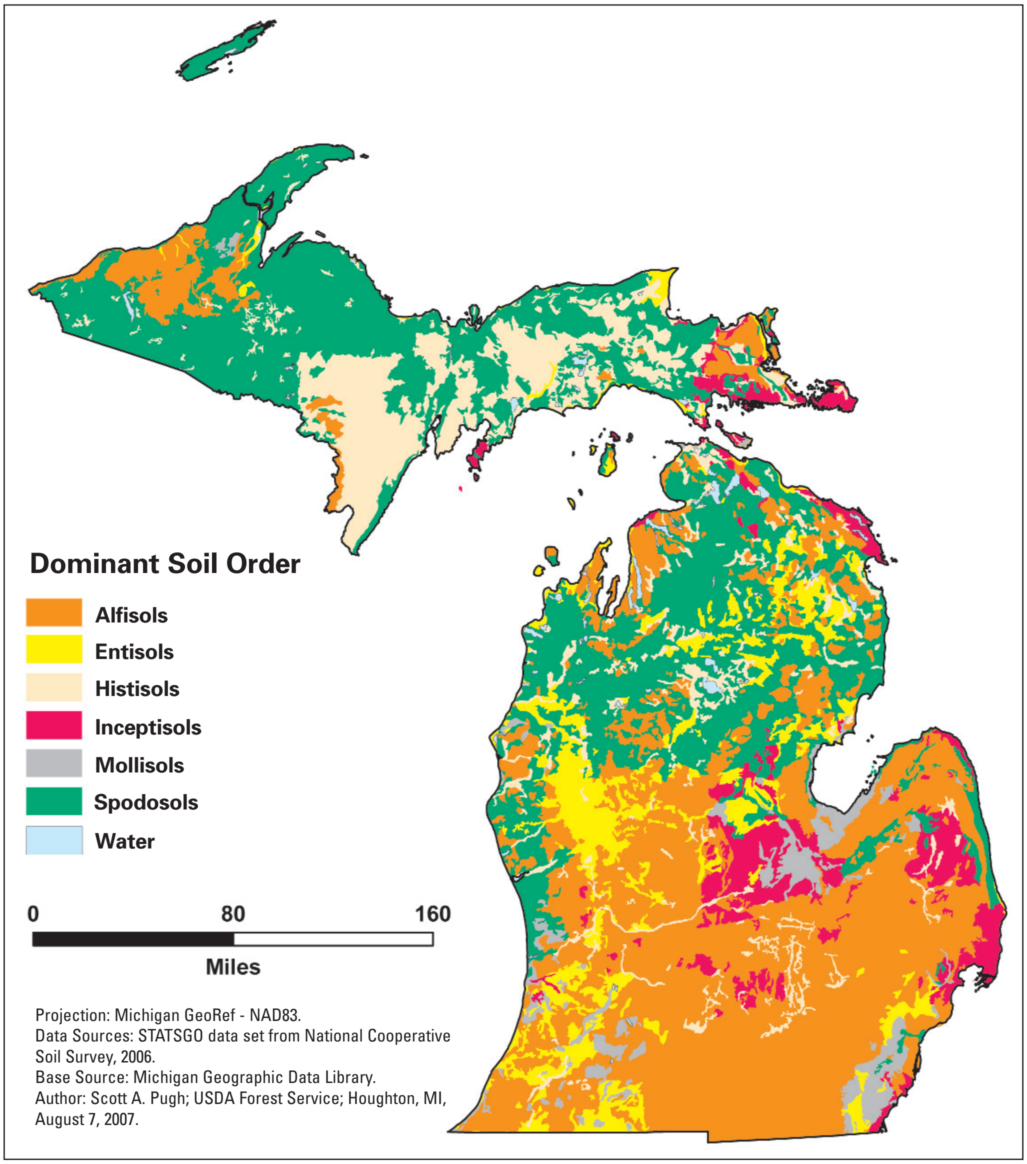
Male Kirtland's warbler perched on jack pine in the Huron-Manistee National Forest. Photo used with permission by photographer Ron Austing, https://wwwnotes.fs.fed.us/wo/wfrp/find_a_photo.nsf

Forest Soils

Background

Rich soils are the foundation of productive forest land and also one of the major carbon banks. Soils develop in response to factors such as climate, local vegetation, topography, parent material, and time. These factors, in turn, provide unique conditions that influence the distribution of forest types. This is seen in the correspondence between the spatial distribution of dominant soil orders (a soil taxon or class, Fig. 61) and land-cover types around 1800 (see Fig. 4). Today, the forest-soil inventory illustrates the unique niches that different forests occupy. As an initial inventory, the collected data also provide critical baseline information for documenting changes in forest health from natural or human influences (see page 178). For additional information and maps, visit the Web Soil Survey maintained by the USDA Natural Resources Conservation Service (http://websoilsurvey.nrcs.usda.gov/app/).

Figure 61.—Soil regions underlying the forests of Michigan based on the U.S. General Soil Map (Soil Survey Staff 2006).



The soil holds more carbon than the aboveground vegetation (Lal 2004). Therefore, it is a major contributor in the carbon cycle. The study of soil carbon is in its infancy, so additional measurements are needed to quantify the soil carbon pool across different land types and to quantify soil carbon flux over time. Annual inventories of FIA soil plots provide this type of information. The results presented here are based on observations on 160 forested plots throughout Michigan. The data generally are presented with associated forest-type groups. At times, the data are broken down at the finer forest type level for better understanding. The data in this report focus on the more noteworthy findings.

The forest floor develops from the slow accumulation of organic matter. Carbon is the primary component of soil organic matter, which increases water-holding capacity, retains certain nutrients by cation exchange (e.g., Ca^{2+}, Mg^{2+}, and K^{+}), releases other nutrients as it decays (e.g., available forms of N and P), and captures potential toxic agents (McBride 1994). Effective cation-exchange capacity (ECEC) is the sum of five key cations: Na^{+}, K^{+}, Ca^{2+}, Mg^{2+}, and Al^{3+}. High ECEC values are associated with higher fertility.

Carbon also is inventoried to track the sequestration of certain greenhouse gases. Thicker forest floors contribute to greater carbon storage. Wet sites tend to accumulate carbon; draining them can lead to increased emissions as material decays. Thick forest-floor material can be viewed as a fire threat in some settings but the mesic conditions of these stands mitigate this threat. Direct measurements of carbon and its functions are essential in better understanding the carbon cycle.

Bulk density is an important physical property of soil measuring the mass of dry soil in a fixed volume. Trees have greater difficulty rooting in soils with higher bulk densities and less pore space is available for air and water exchange. Soil texture affects bulk density; sandy soils tend to have higher bulk densities than finer textured soils like silts, clays, and loams.

Sandy soils can be xeric with normally low or deficient moisture and relatively lower cation exchange capacity. Fine-textured soils can be hydric with abundant or overabundant moisture all year. Mesic sites generally have moderate and adequate available moisture. Although certain species and associated forest types have competitive advantages over others on these sites, trees on xeric and hydric sites are at a higher level of health risk when adverse environmental conditions prevail.

What we found

There is substantial variety within Michigan's soil regions as trees compete for specialized niches. For example, spruce/fir and elm/ash/cottonwood stands accumulate more forest floor material than any other forest-type group (Fig. 62). Northern white-cedar is the most abundant forest type within the spruce/fir forest-type group. Northern white-cedar, the predominate species within this forest type, tends to grow in moist landscapes. Seventy-seven percent of timberland acreage occupied by the northern white-cedar forest type is hydric. Black ash/American elm/red maple is the most prevalent forest type within the elm/ash/cottonwood forest-type group. This type typically is found in bogs or seasonally flooded landscapes. Sixty-seven percent of timberland acreage occupied by the black ash/American elm/red maple forest type is hydric.

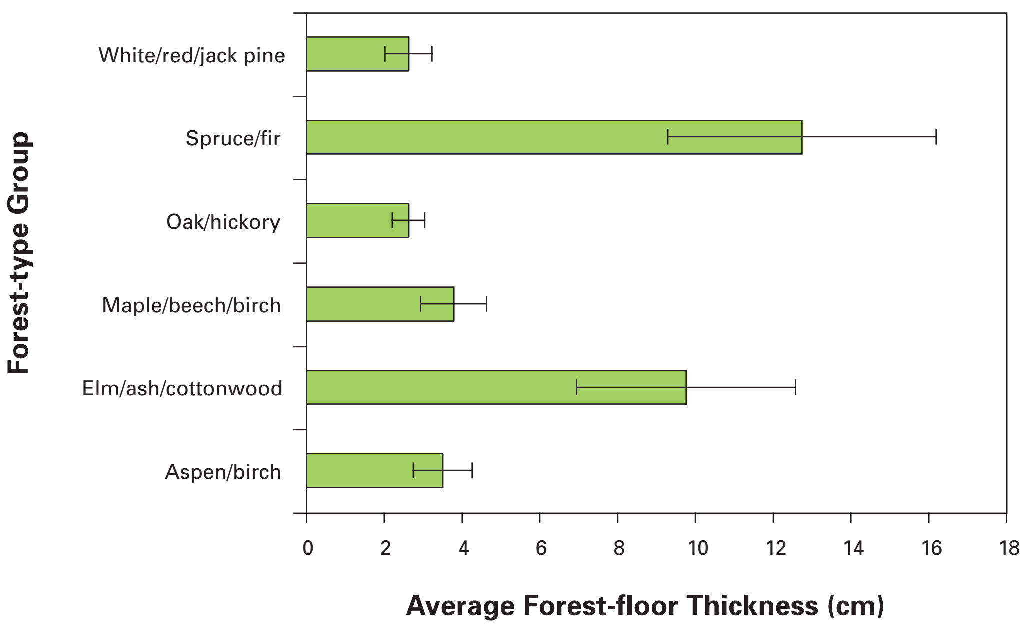


Figure 62.—Average forest-floor thickness (centimeters) by forest-type group, Michigan, 2004 (error bars represent 68-percent confidence interval around estimate).

Estimates of forest-floor carbon are greater in the spruce/fir and elm/ash/cottonwood forest-type groups but the variability also is greater, making it difficult to identify significant differences in carbon (Fig. 63). Carbon in the first 10 cm of mineral soil is greater in the spruce/fir stands than in most of the other stand types (Fig. 64).

Figure 63.—Average forest-floor carbon (megagrams/ha) by forest-type group, Michigan, 2004 (error bars represent 68-percent confidence interval around estimate).

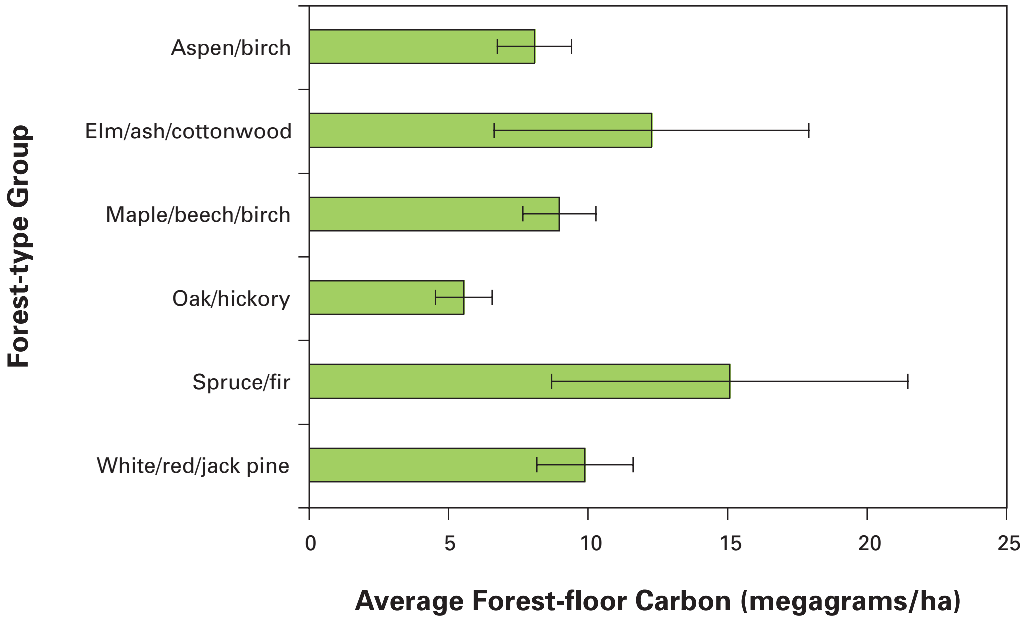
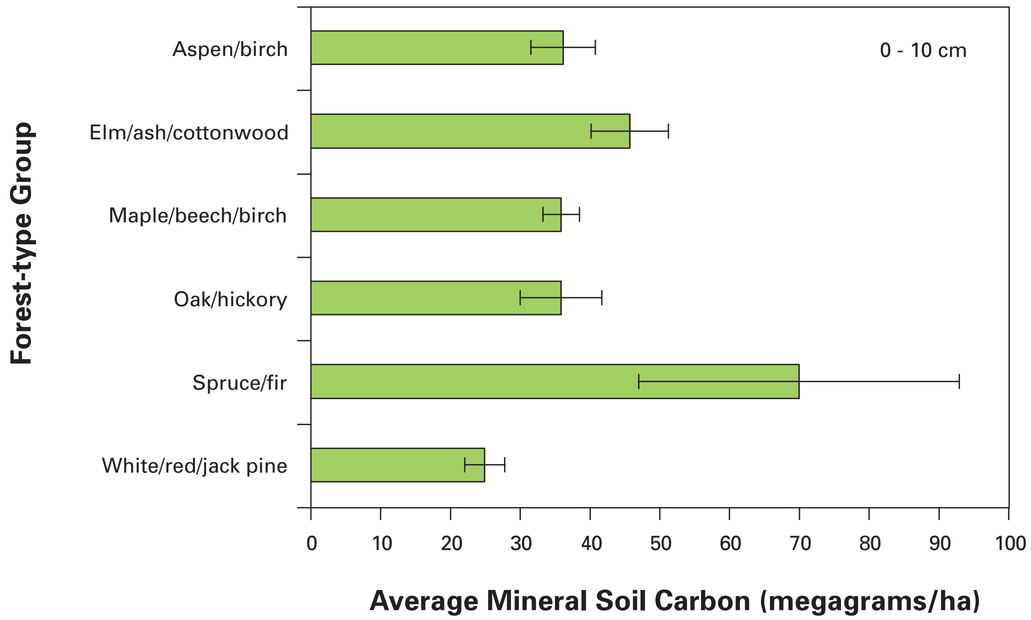


Figure 64.—Average mineral soil carbon (megagrams/ha) for the 0-10 centimeter soil layer by forest-type group, Michigan, 2004 (error bars represent 68-percent confidence interval around estimate).



Pines and oaks are found on soils with higher bulk densities and fewer coarse fragments in the surface soil (Figs. 65-66). Seventy percent of the samples in the white/red/jack pine forest-type group and 55 percent of the samples in the oak/hickory forest-type group were collected on sandy sites but the other groups are found much more commonly on loamy and clayey sites.

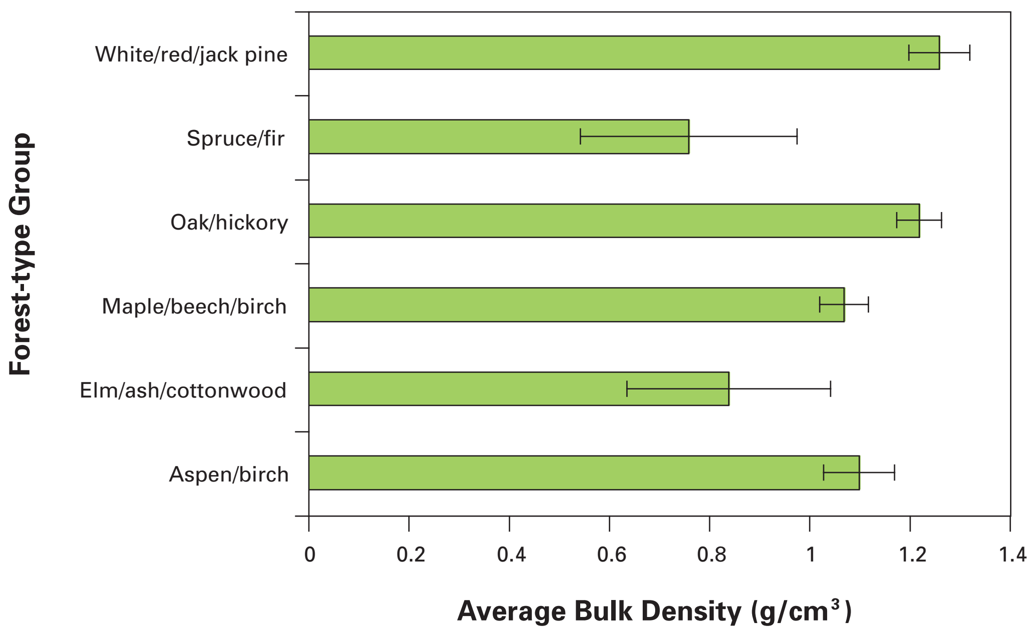


Figure 65.—Average bulk density (g/cm^3) for the 0-10 centimeter soil layer by forest-type group, Michigan, 2004 (error bars represent 68-percent confidence interval around estimate).

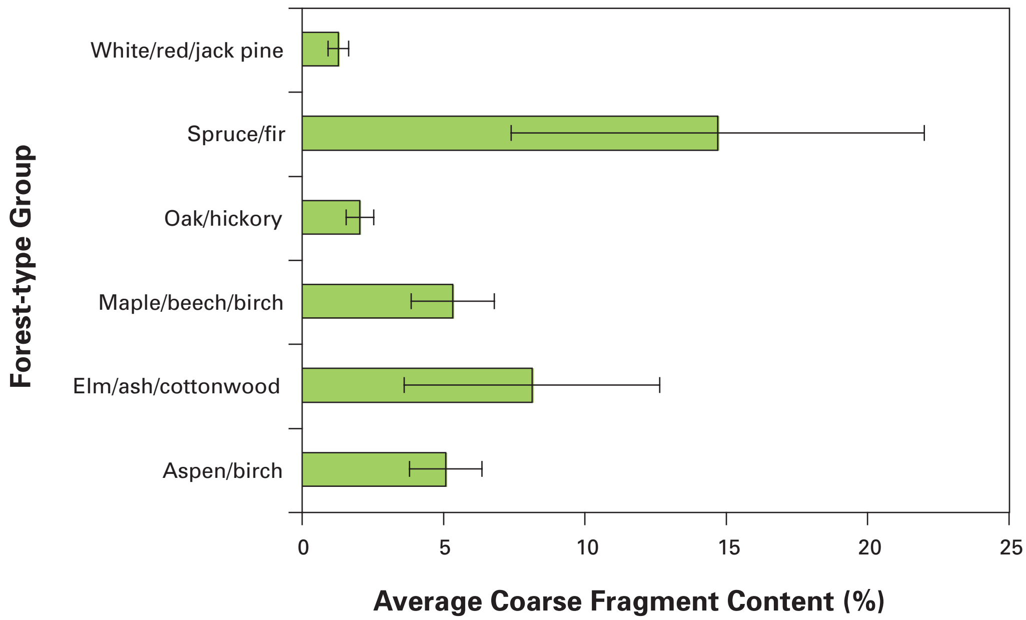
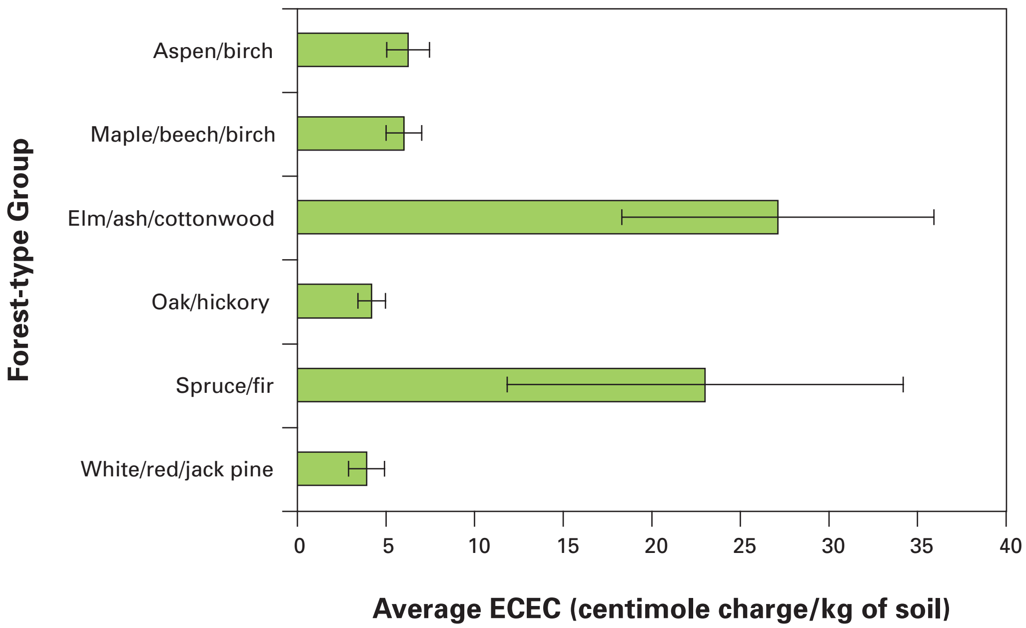


Figure 66.—Average coarse fragment content (percent) for the 0-10 centimeter soil layer by forest-type group, Michigan, 2004 (error bars represent 68-percent confidence interval around estimate).

Many sandy sites are xeric. For example, 66 percent of the jack pine, 25 percent of northern red oak, and 19 percent of white oak/red oak/hickory forest types are on xeric sites. When comparing xeric to mesic sites on timberland, the rates of growing-stock average annual mortality to current volume for the jack pine, northern red oak, and white oak/red oak/hickory forest types are higher on xeric sites. Rates for the jack pine, northern red oak, and white oak/red oak/hickory forest types are 1.1 versus 0.7, 0.8 versus 0.3, and 1.7 versus 0.8 percent, respectively, on xeric versus mesic sites. Although there are differences in mortality among mesic and xeric sites for these forest types, mortality rates are low on xeric sites.

Elm/ash/cottonwood and spruce/fir forest-type groups are on landscapes with greater ECEC (more available mineral nutrients, Fig. 67). The northern white-cedars in the spruce/fir forest-type group often are found in rich fens where mineral-rich water flows through the soil. The white/red/jack pine and oak/hickory forest-type groups are on sites with the lowest relative fertility.

Figure 67.—Average ECEC (centimole charge per kilogram of soil) for the 0-10 centimeter soil layer by forest-type group, Michigan, 2004 (error bars represent 68-percent confidence interval around estimate).



What this means

There are correlations between forests and soil properties. Forest-floor depth, soil carbon, bulk density, coarse fragment content, and cation exchange capacities varied by forest-type group. These findings were not based on a large sample. Additional samples could reduce variability (i.e., shorten error bars) and help identify factors contributing to variability in soil estimates. Soil properties presented here and possibly others could help identify sites associated with greater forest health risks. Further, this inventory could contribute to a better accounting of carbon in soil with additional data. In the future, such data along with other forest attributes could be used to model important variables and indices at the landscape level.

Down Woody Materials

Background

Down woody materials (DWM) in the form of fallen trees, branches, litterfall, and duff fill a critical ecological component of Michigan's forests. They provide valuable wildlife habitat such as dens for black bears and shelter for small mammals (Harmon et al. 1986). Flora use the microclimate of moisture, shade, and nutrients provided by DWM to establish regeneration (Harmon et al. 1986). DWM are important carbon stocks (Woodall and Liknes 2008), and also can constitute a fire hazard and should be monitored during extreme fire weather (Woodall et al. 2005). Carbon pools, fuels, forest structure, and wildlife habitat can be measured to some degree with estimates of DWM (Woodall 2007, Woodall and Monleon 2008). As part of forest health monitoring and the new Phase 3 inventory, FIA began tallying DWM in 2001. Since then, Michigan has been collecting data on DWM. The results for Michigan are based on observations on 166 plots (see page 178).

What we found

The fuel loadings of DWM (tons/acre) are not exceedingly high in Michigan, Wisconsin, and Minnesota (Fig. 68). Compared to Wisconsin and Minnesota, Michigan's loadings of 1-hr, 10-hr, and 100-hr fuels are not significantly different. The loadings of the largest fuels (1,000+-hr) are between those in Minnesota and Wisconsin. There is no apparent trend in total down woody fuel biomass (fine woody debris, coarse woody debris, duff, and litter) among classes of live-tree density, though the lowest down woody biomass is in stands with little standing live-tree density (Fig. 69). The distribution of coarse woody debris by size class is skewed heavily (83 percent) toward pieces less than 8 inches in diameter at point of intersection with plot sampling planes (Fig. 70). Apparently, the stages of coarse woody decay across the State are fairly uniform (Fig. 71). The spatial distribution of coarse woody debris carbon stocks indicates that coarse woody debris carbon is highest in the Upper Peninsula and scattered areas of the southern Lower Peninsula (Fig. 72).

Down woody materials. Photo by Scott A. Pugh, U.S. Forest Service.

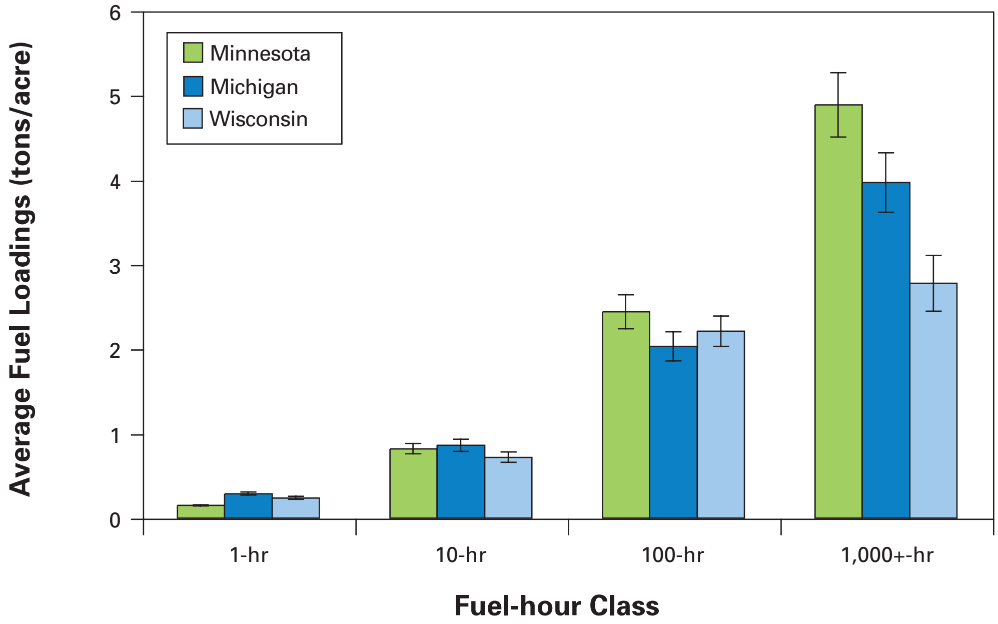


Figure 68.—Average fuel loadings (tons/acre) by fuel-hour class for Michigan, Minnesota, and Wisconsin, 2001-2005 (error bars represent 68-percent confidence interval around estimate).

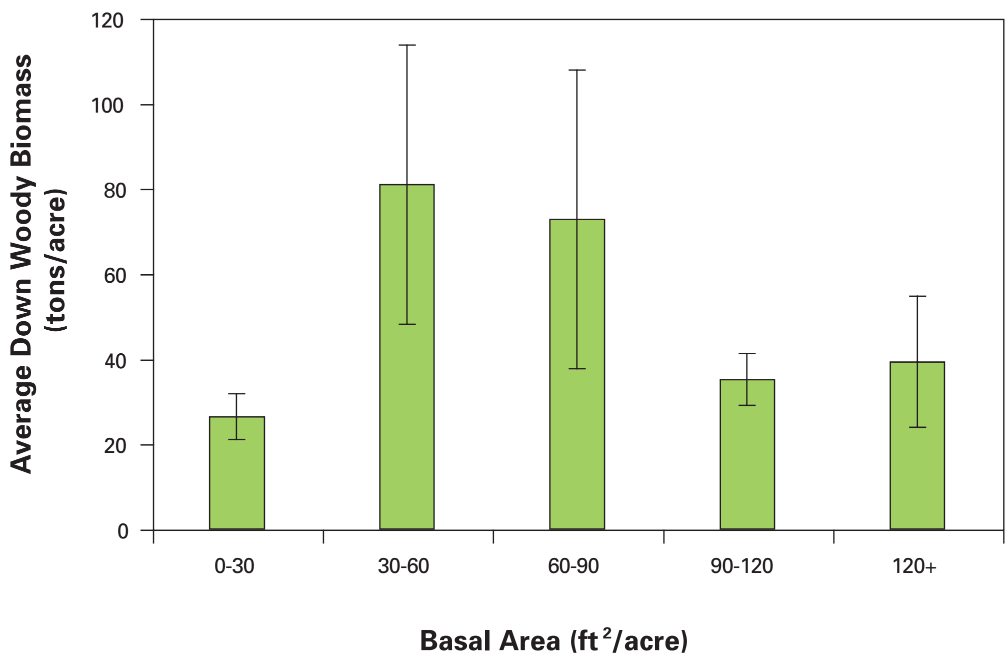


Figure 69.—Average down woody material biomass (woody debris, duff, and litter) by stand density, Michigan, 2004 (error bars represent 68-percent confidence interval around estimate).

Figure 70.—Percentage of coarse woody debris (pieces/acre) by size class (diameter in inches), Michigan, 2004.

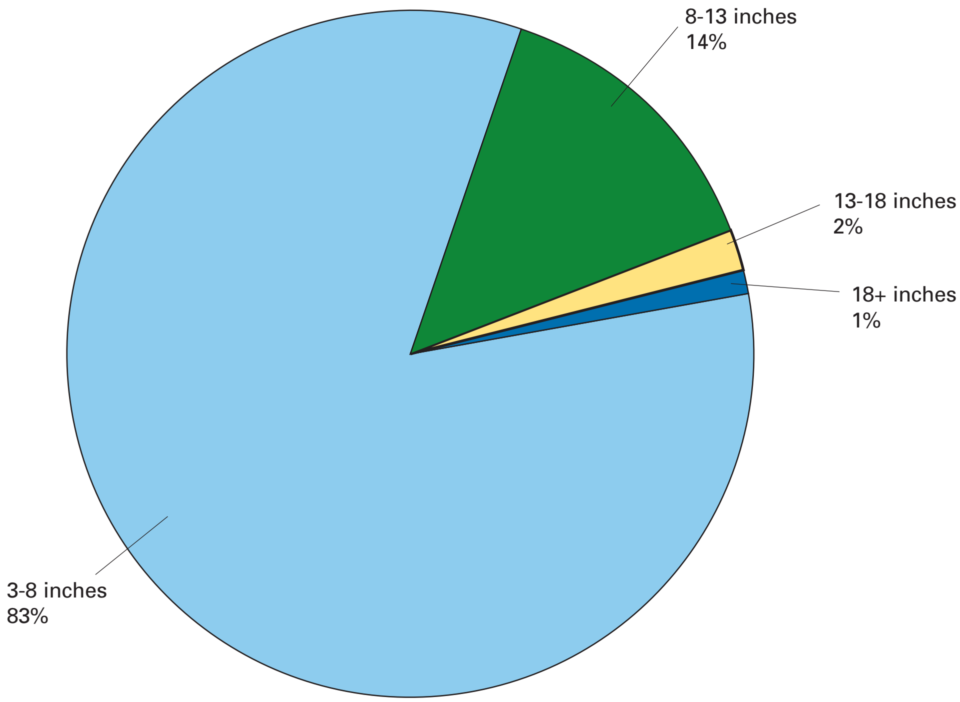


Figure 71.—Percentage of coarse woody debris (pieces/acre) by decay class (1 to 5 equals least to most decayed), Michigan, 2004.

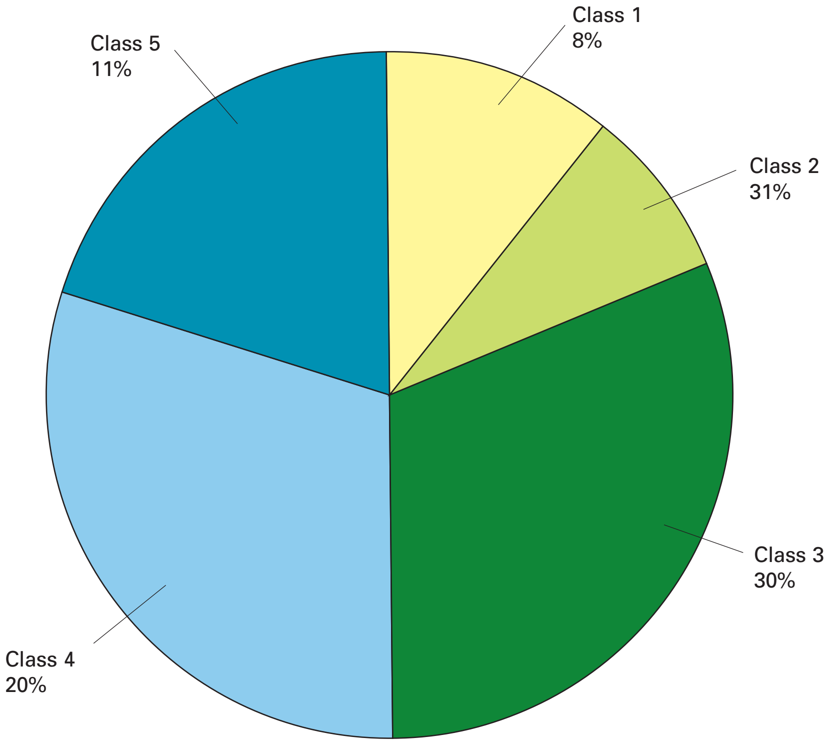
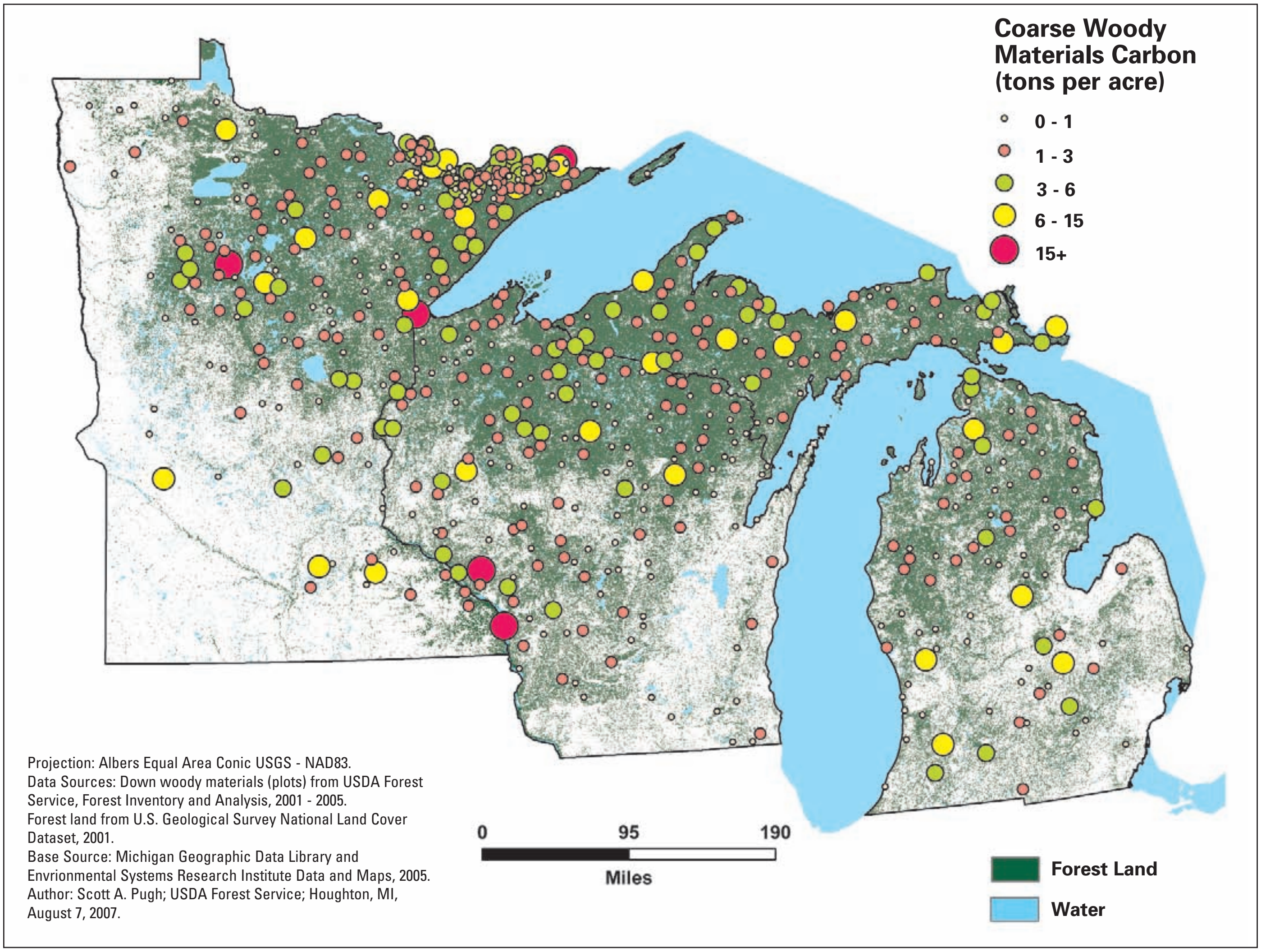


Figure 72.—Distribution of coarse woody materials (carbon from plot estimates) for Michigan, Wisconsin, and Minnesota, 2001-2005.



What this means

Down woody fuel loadings in Michigan's forests differ little from those in neighboring states. Generally, they pose a hazard only in certain areas and only in times of extreme drought across the State. Among the woody components, duff comprises the majority of biomass. Although there is an appreciable amount of coarse woody debris habitat in Michigan's forests, most pieces are small and represent a forest resource that may decay rapidly. In fact, 61 percent of coarse woody pieces are in advanced stages of decay. Typically, fuel loadings are not exceedingly high across Michigan, so fire danger is low or moderate. Michigan's total woody fuel loadings (fine and coarse woody) are less than 8 tons/acre on average. By contrast, a wind-disturbed area of northern Minnesota averaged nearly 18 tons/acre (Woodall and Nagel 2007). It is in this context that the wildlife habitat and carbon sequestration benefits provided by Michigan's down woody materials are considered.

Tree Crowns and Standing Dead Trees

Background

The status of tree crowns can indicate the health of the forest. Dieback, uncompacted crown ratio, and transparency characterize the status of crowns. Like mortality, dieback is a natural part of forest-stand development. Dieback (live trees at least 5 inches d.b.h) is measured as the percent of branch tips in the crown that are dead. Several categories for dieback were created to indicate the severity: none (0-5 percent), light (6-20), moderate (21-50), and severe (51-100). The uncompacted crown ratio of a tree (live trees at least 1 inch d.b.h.) is defined as the portion of the tree height supporting live foliage. Crown transparency (live trees at least 5 inches d.b.h.) is a measure of the proportion of the crown through which the sky is visible. High amounts of dieback, low crown ratios, and high transparency signal the potential for higher mortality. The degree to which these variables vary for a healthy tree depends on species and light exposure (e.g., open grown to overtopped). As part of forest health monitoring and the new Phase 3 inventory, detailed crown information has been collected since 2000 (see page 178). The following analysis is based on information from 214 plots and 5,583 trees.

The percentage of standing dead basal area to live basal area on forest land provides more information on forest health. Some standing dead trees are a natural part of forest-stand development and provide wildlife habitat. Any tree at least 5 inches d.b.h. and at least 4.5 feet tall that died from one inventory to the next and still standing is recorded as standing dead. Estimates of standing dead trees are based on information from all timberland plots (7,998 and 10,224 timberland plots for 1980 and 2004, respectively). Due to issues with modeled plots in the 1993 inventory (see Table 1), only 1980 to 2004 comparisons are presented.

What we found

Dieback is not pronounced overall (Fig. 73). Ninety percent of the trees have no dieback, 8 percent have light dieback, and 2 percent have moderate or severe dieback. Black ash, northern white-cedar, paper birch, silver maple, and yellow birch have notably higher percentages of trees with moderate or severe dieback (Fig. 74). Paper birch and black ash have the highest percentages of severe dieback (both at 4 percent). American elm (7 percent) and balsam poplar (8 percent) are not shown in Figure 74 but also have higher percentages of moderate to severe dieback.

Figure 73.—Average dieback, transparency, and uncompacted crown ratio by species, Michigan, 2004 (top 20 by number sampled).

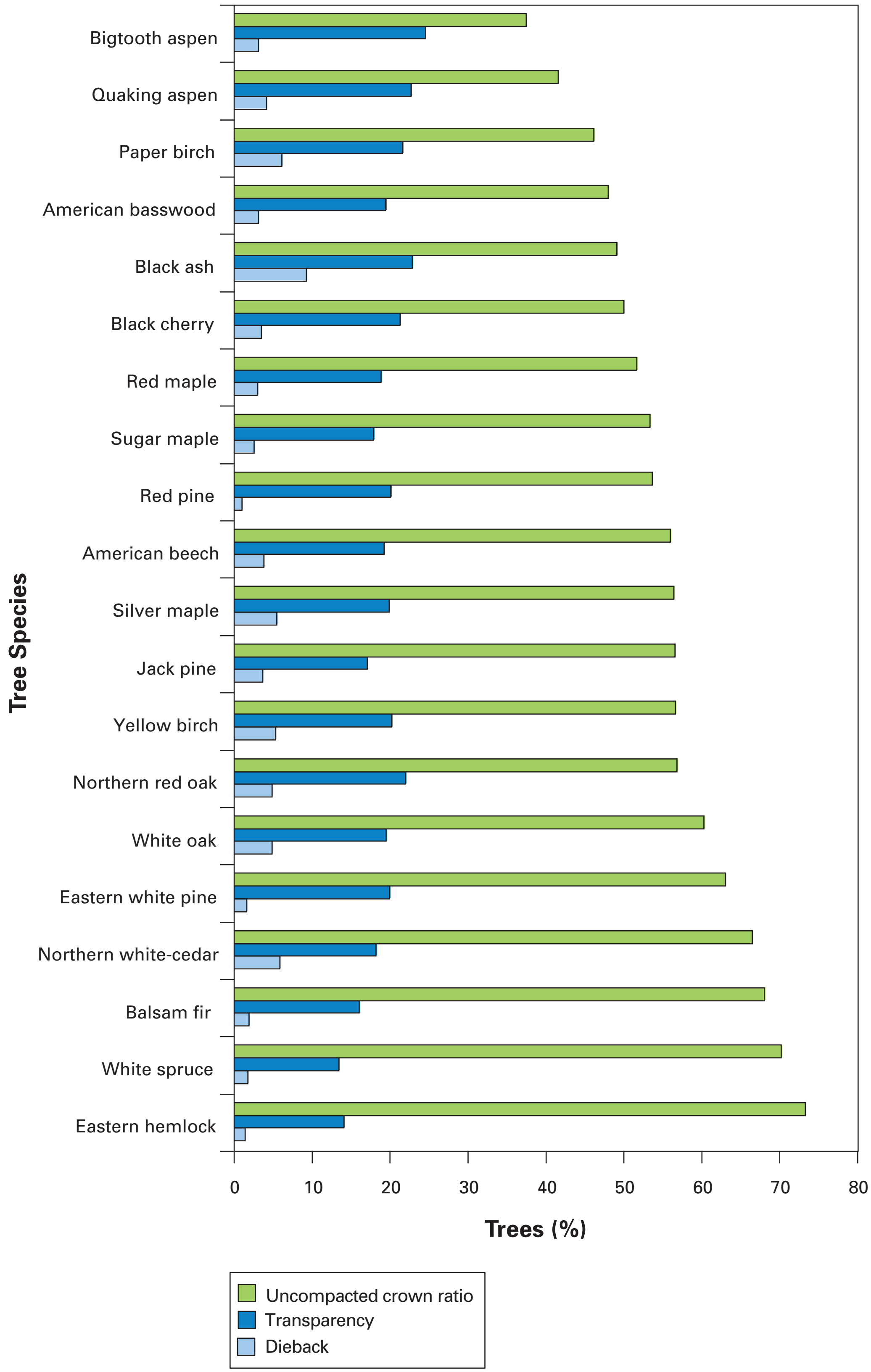
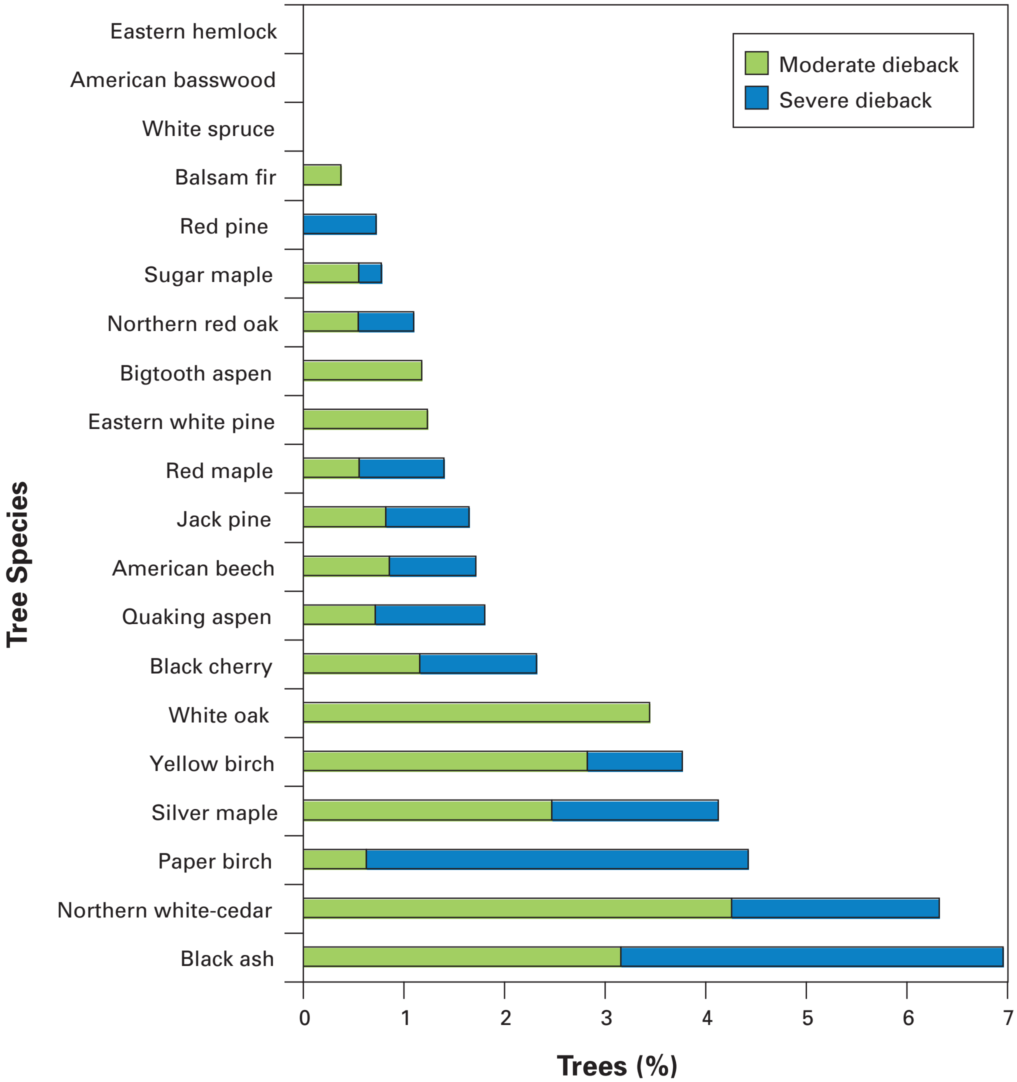


Figure 74.—Percentage of trees with moderate and severe dieback by species, Michigan, 2004 (top 20 by number sampled).



Softwood species have the higher uncompacted crown ratios while the aspen and birch have the lower ratios (Fig. 73). Generally, transparency seems to be inversely related to uncompacted crown ratio.

Most species with known issues related to succession and health (e.g., balsam fir, quaking aspen, jack pine, balsam poplar, paper birch, and American elm) have higher percentages of standing dead to live basal area (Fig. 75). In most cases, standing dead to live basal area increased from 1980 to 2004. American elm is the only species that showed a decrease in standing dead to live basal area from 1980 to 2004. By 1980, many American elm trees were killed by Dutch elm disease and those standing dead trees have since fallen. The percentage of mortality to volume for American elm (growing stock on timberland) fell from 10 to 8.5 percent during the same period.

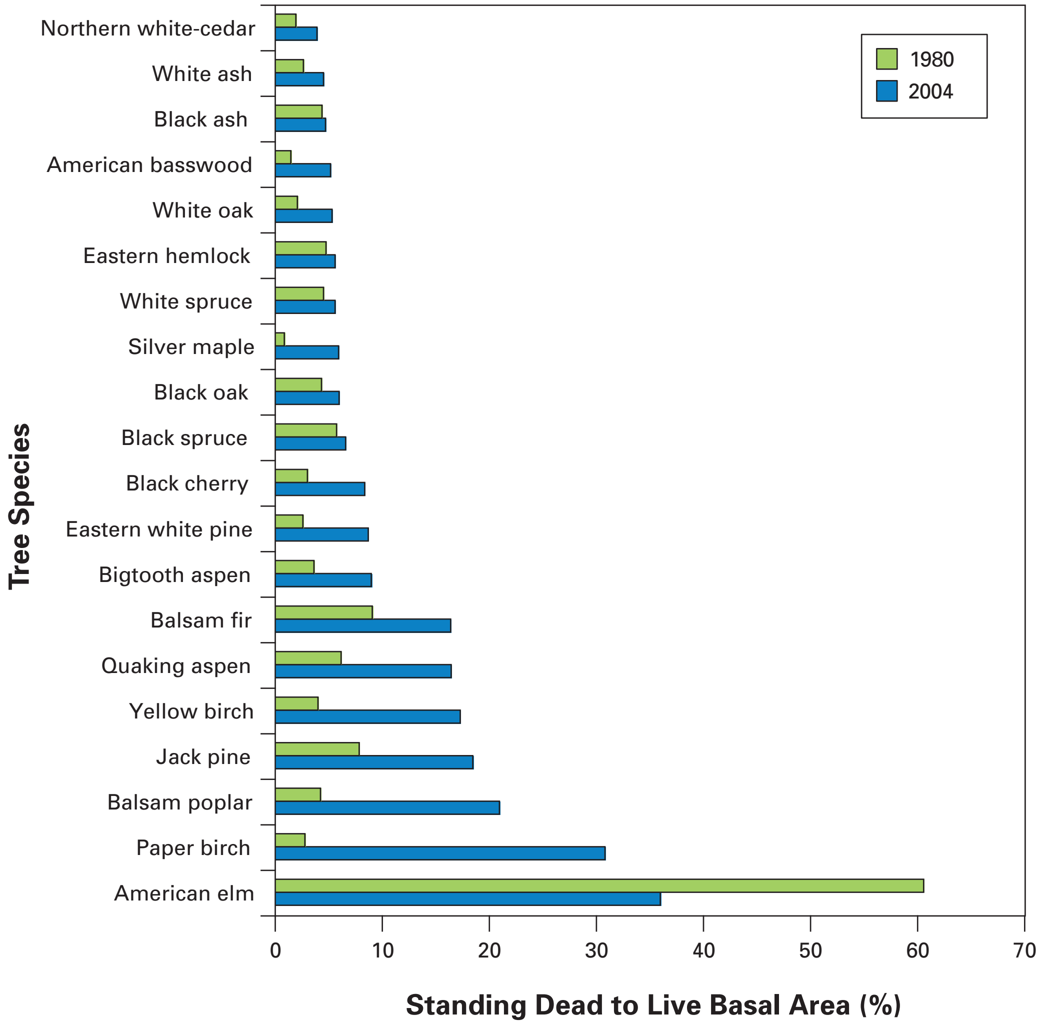


Figure 75.—Percentage of standing dead to live basal area (trees at least 1 inch d.b.h.) for select species on timberland, Michigan, 1980-2004.

What this means

No major health problems are indicated in the crown information and some crown dieback and standing dead trees are natural and desirable for wildlife habitat. Additional samples are needed for a more thorough assessment of crowns. Species like black ash and northern white-cedar will have higher numbers with moderate to severe crown dieback due to the poorer, hydric sites they occupy. Species like black ash and northern white-cedar had more crown dieback but low percentages of standing dead to live basal area and low mortality to volume rates (see Fig. 42). As expected, some of the early successional species and others with known health issues (see pages 92 and 156) have more standing dead to live basal area than other species.

Ozone Damage

Background

Ozone (O_3) is a natural part of the atmosphere produced primarily through sunlight-driven chemical reactions of nitrogen oxides (byproduct of combustion) and volatile organic compounds (e.g., petroleum products). In the upper atmosphere, O_3 is beneficial in limiting ultraviolet radiation. By contrast, O_3 at the ground level can interact with forest ecosystems causing visible injury, decreased growth (Karnosky et al. 1996, Peterson et al. 1987), and changes in structure and function (Karnosky et al. 2005, Awmack et al. 2004, Holton et al. 2003). O_3 is the most prevalent phytotoxic compound in the ambient air and O_3 injures more ecosystems and native vegetation than any other air pollutant (Environ. Prot. Agency 1996a, b, 2007). The severity of ground level-induced foliar injury is indicated by the biosite index (Coulston et al. 2003, Smith et al. 2003, 2007).

O_3 levels are higher within and downwind of major urban and industrialized areas. Hot summers often produce significant exposures while cool wet summers result in low O_3 exposure. Nonetheless, foliar damage depends on a number of factors. For example, foliar injury remains low even at high O_3 exposures during drought. O_3 causes damage when it enters plants through stomates. Stomates often are closed during drought, so injury can remain low in hot weather when O_3 levels are high. The amount of damage also varies by plant species. Most tree species are relatively tolerant of O_3 while species like quaking aspen, black cherry, white ash, green ash, and yellow-poplar are more sensitive. Sensitive species may have lower productivity that can result in changes to forest structure and function.

FIA has collected O_3 bioindicator data in Michigan since 1994. Although the number of biosites has varied over time, a base grid of 45 biosites was established when the national O_3 grid was implemented in 2002. The FIA O_3 biomonitoring indicator is unique because of its national scale and standardized implementation. FIA incorporated the O_3 biomonitoring indicator into its Phase 3 inventory (see page 178).

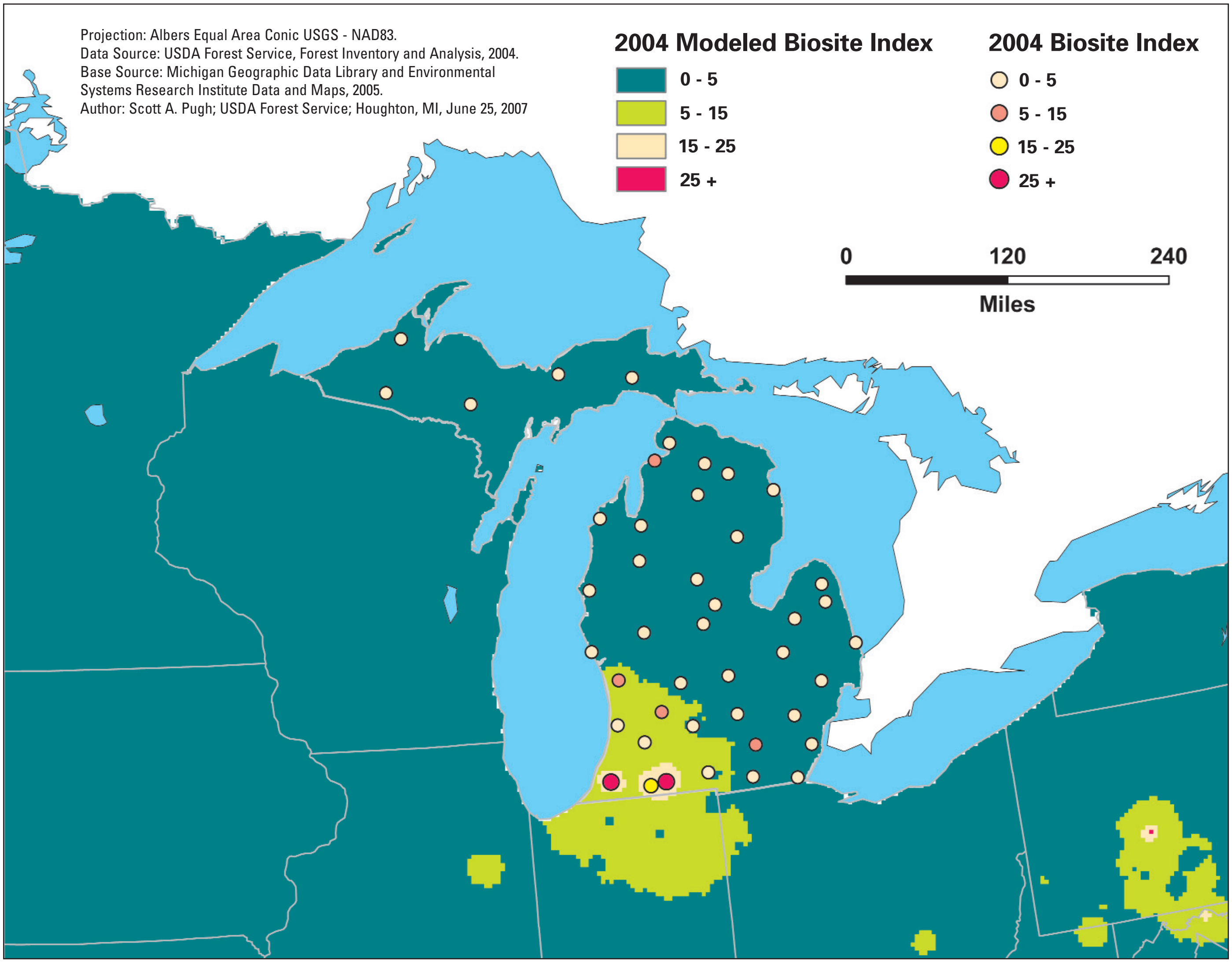
What we found

Most of Michigan is at low risk to O_3 damage. Visible foliar injury on bioindicator species is low to absent in the Upper Peninsula and the northern Lower Peninsula. O_3 exposures in these areas typically are below thresholds that would result in even light to moderate foliar injury, growth loss, or adverse long-term consequences on most forests. By contrast, forests in southern Michigan often are exposed to peak hour O_3 concentrations and seasonal cumulative exposures sufficiently above background levels to cause visual injury and potentially affect growth and productivity. To indicate intensity and risk, a qualitative categorization of the biosite index value is provided in Table 6. The number of injured species, plants, and the intensity of the injury is greatest in southwestern Michigan (Fig. 76).

Table 6.—Biosite index.

Bioindicator response	Assumption of risk	Biosite value
Little or no injury	None	0 - 5
Light to moderate injury	Low	5 - 25
Moderate to severe injury	Moderate	15 - 25
Severe injury	High	25+

Figure 76.—Observed biosite index for Michigan and modeled biosite index for the region, 2004.



O_3 induced foliar injury has been verified every year since surveys were initiated. The results for 2004 inventory are presented in Table 7. More than 2 percent of the surveyed specimens of yellow-poplar, black cherry, and common milkweed were injured each year. During this same time, the most commonly sampled bioindicator species in rank order were black cherry, common milkweed, spreading dogbane, blackberry, and white ash. Nine bioindicator species are routinely evaluated for foliar injury and seven species (black cherry, blackberry, common milkweed, white ash, spreading dogbane, sassafras, and yellow-poplar) exhibited O_3 injury.

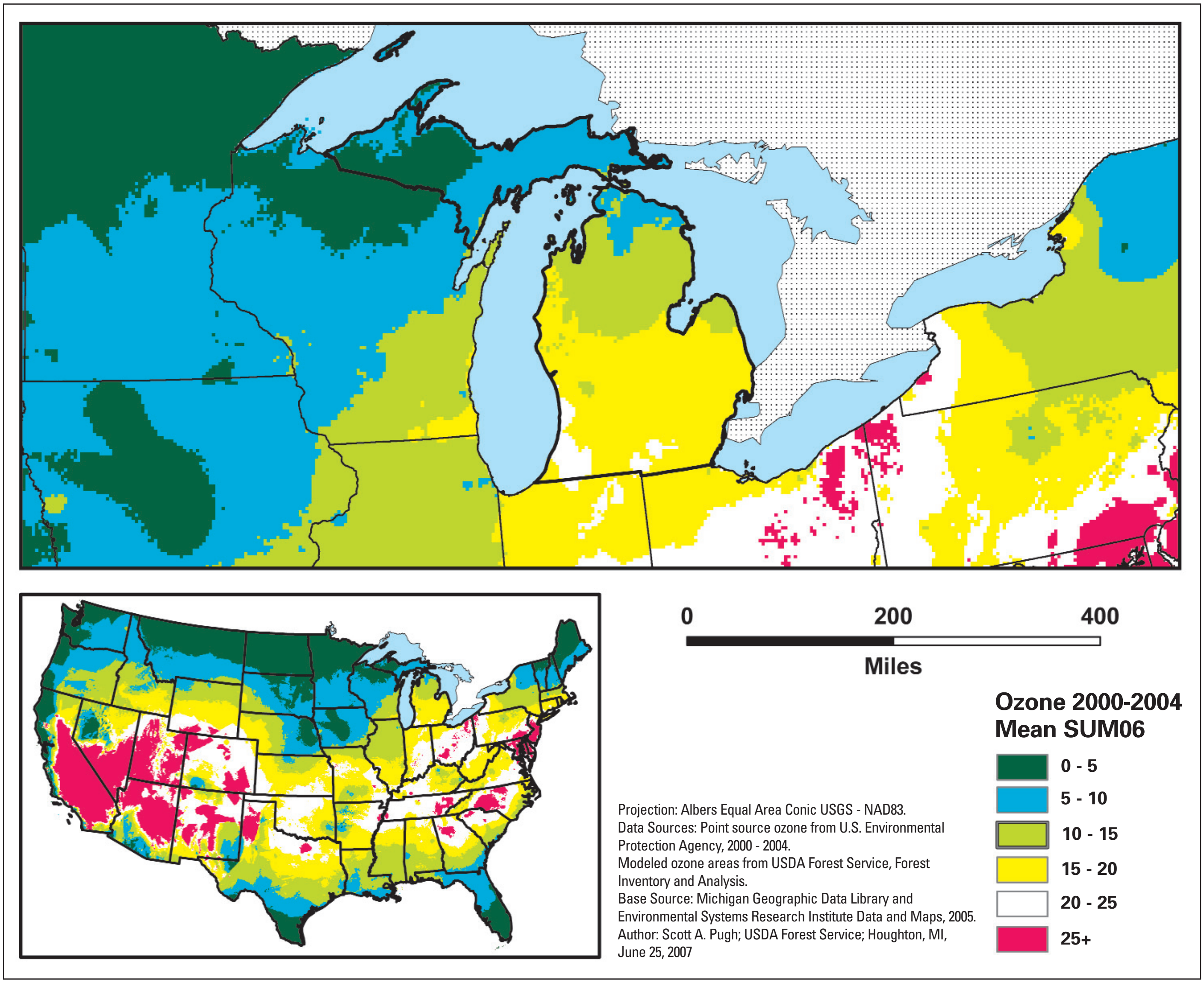
Table 7.—Bioindicator O_3 injury information, Michigan, 2000-2004.

Parameter	2000	2001	2002	2003	2004
Biosites	54	49	45	45	45
Biosites with ozone injury (%)	56	61	40	16	29
Plants evaluated	4,238	4,271	4,649	4,467	4,648
Plants with injury	195	163	62	30	50
Plants with injury / plants evaluated (%)	4.6	3.8	1.3	0.7	1.1

The severity and duration of O_3 exposures across the State exhibit notable year-to-year variability. Peak hourly O_3 values exceed 0.100 parts per million (ppm) along Lake Michigan in southwest Michigan. This exceeds the threshold required to cause injury. The EPA's O_3 attainment standard (0.084 ppm averaged over 8 hours) has been routinely exceeded in southwest and southeast Michigan. For more information, visit http://www.michigan.gov/deq/0,1607,7-135-3310---,00.html.

Foliar injury can be related to seasonal exposures as well as peak concentrations. Seasonal exposures measure O_3 stress by summing hourly concentrations above a threshold concentration over several months. For example, a common growing season exposure index (SUM06) is the sum of all daylight hourly O_3 concentrations greater than 0.060 ppm from June 1 through August 31. SUM06 values in Michigan for these summer months ranged from about 3 to the 24 ppm-hours during the 2004 inventory period (Fig. 77). Presettlement seasonal SUM06 values probably would have been in the 0.5 to 2.0 range (Environ. Prot. Agency 2007). A SUM06 value of 8 to 12 has been considered as constituting protection from visible foliar injury in natural ecosystems (Heck and Cowling 1997).

Figure 77.—Ozone (average SUM06) in Michigan and the United States, 2000-04.



What this means

The O_3 exposures, biosite index values, and foliar injury indicate that O_3 is a stress agent for some forests in southern Michigan. Ground-level O_3 exposures in Michigan are influenced by both local and regional pollution sources. Northern forests are at low risk of O_3-induced visible foliar injury because sources are limited, though regional transport events occur from the urban areas in the southern Lake Michigan basin.

O_3 sensitive species like quaking aspen, black cherry, yellow-poplar, white ash, and green ash are at low to moderate risk of injury, particularly in the southwestern region of the southern Lower Peninsula. Quaking aspen, the only major species on this list, has only 5 percent of its live volume on forest land in the southern Lower Peninsula. Yellow-poplar (nearly 100 percent), green ash (64), and black cherry (56) have most of their live volume on forest land in the southern Lower Peninsula. Yellow-poplar has little live volume at 57 million ft^3 on forest land. White ash (35 percent) has a moderate amount of live volume on forest land in the southern Lower Peninsula.

Although numerous studies have identified the effects of O_3 on forest ecosystems, the extent to which O_3 affects Michigan's forests is unclear due to factors such as drought, pests, disease, and competition.

Ozone damage on quaking aspen. Photo used with permission by David Karnosky, Michigan Technological University

Insects and Diseases (2004)

Background

Forest health, structure, and composition are influenced by the interaction of various biotic and abiotic elements. Limiting factors such as insects, disease, deer herbivory, invasive plants, and abiotic stressors such as drought can have negative effects on individual trees and forests. Monitoring the status of these limiting factors provides a measure of forest health and is crucial in assessing conditions and trends in Michigan's forests. A list of insects and diseases is included in the Appendix.

Changes to our forest ecosystems often are observed when pests, disease, and other adverse environmental conditions combine. Abiotic environmental factors like drought, extreme wetness, windstorms, late spring frosts, pollution, and soil properties that affect nutrient availability, moisture content, and aeration can play a role in facilitating or increasing the adverse effects of pests and disease.

Frequent drought events since the 1980s have contributed to declines in some susceptible tree species. Trees on xeric and hydric sites (see page 119) and short-lived species that are at or past maturity are most susceptible. For example, drought in the late 1980s contributed to mortality and dieback in northern pin oak and paper birch during the 1990s. Effects on northern pin oak and paper birch were more pronounced in older forest stands and on sites with poorer soils. Trees show decline when they start loosing branches, leaves, and roots. Pests that otherwise would not pose a threat to healthy trees can become a serious threat to declining trees. Some of these pests include defoliators, wood-boring insects, and root rot fungi. A number of pests contribute to increases in tree mortality during drought. Oak is affected by the two-lined chestnut borer, paper birch by the bronze birch borer, larch by the eastern larch beetle, balsam fir by the spruce budworm and Armillaria root rot, jack pine by the jack pine budworm, and jack and red pine saplings by diplodia blight and Armillaria root rot. Drought also can increase populations of forest defoliators like gypsy moth, linden looper, fall cankerworm, forest tent caterpillar, jack pine budworm, and spruce budworm.

In addition to many insects and diseases that have evolved over time as part of the natural life cycle of trees, there is a continuing threat from nonnative species. Nonnative species have not evolved with our forest ecosystems and may have no biological control agents. Consequently, these species can have adverse effects on the health, structure, and composition of native forest communities (Parker et al. 1999, Mack et al. 2000, Mooney and Cleland 2001). Michigan has been affected by nonnative insects and diseases such as Dutch elm disease, chestnut blight, gypsy moth, and, more recently, emerald ash borer and beech bark disease.

There has been increased interest in the effects of deer and other cervid herbivory on the regeneration and survival of herbaceous and woody plants in forest ecosystems (Cook

2008, Cote et al. 2004). This is a particular concern when local populations of cervids are high. Determining how many deer are too many depends on many factors.

There are a number of programs that focus on monitoring forest health. Information presented in this section is derived from data from the FIA, National Forest Health Monitoring (FHM) program, U.S. Forest Service's Northeastern Area, State and Private Forestry, and Michigan Department of Natural Resources' Forest Health, Inventory, and Monitoring Program. An overview of noteworthy insects and diseases is presented here. Detailed information on the emerald ash borer, beech bark disease, gypsy moth, and jack pine budworm is presented elsewhere in this report.

What we found

A number of insects and disease pathogens were active in Michigan from 2000 through 2004 (Table 8). Widespread defoliation was caused by the native forest tent caterpillar, which began a 4-year outbreak in 2000 and reached peak defoliation in 2001 (Fig. 78). The most notable impact from this insect is on aesthetics. Growth loss is usually of short duration, especially when rainfall is at least average. The native jack pine budworm (Fig. 79), nonnative emerald ash borer, and nonnative beech bark disease also caused substantial damage. The emerald ash borer and beech bark disease were first discovered in Michigan during this inventory.

Table 8.—Insects and diseases that have caused notable damage to forests, Michigan, 2000-04 (in descending order by amount of damage).

2000	2001	2002	2003	2004
Forest tent caterpillar	Forest tent caterpillar	Emerald ash borer	Emerald ash borer	Emerald ash borer
Larch casebearer	Jack pine budworm	Forest tent caterpillar	Jack pine budworm	Beech bark disease
Gypsy moth	Beech bark disease	Jack pine budworm	Beech bark disease	Jack pine budworm
Jack pine budworm	Large aspen tortrix	Beech bark disease	Forest tent caterpillar	Gypsy moth
Beech bark disease	Larch casebearer	Larch casebearer	Oak skeletonizer	Eastern larch beetle
Oak wilt	Spruce budworm	Spruce budworm	Gypsy moth	Spruce budworm
Large aspen tortrix	Oak wilt	Cherry scallop shell moth	Maple trumpet skeletonizer	Oak wilt
Diplodia blight	Diplodia blight	Pine needleminer	Eastern spruce budworm	Large aspen tortrix
	Fall webworm	Larch casebearer	Black ash decline	
	Oak wilt	Oak wilt	Annosus root disease	
	Eastern larch beetle	Annosus root disease	Oak decline	
	Red-headed pine sawfly	Fall webworm		
		Red-headed pine sawfly		
		Oak decline		

Figure 78.—Area defoliated by forest tent caterpillar during a peak year of outbreak, Michigan, 2001.

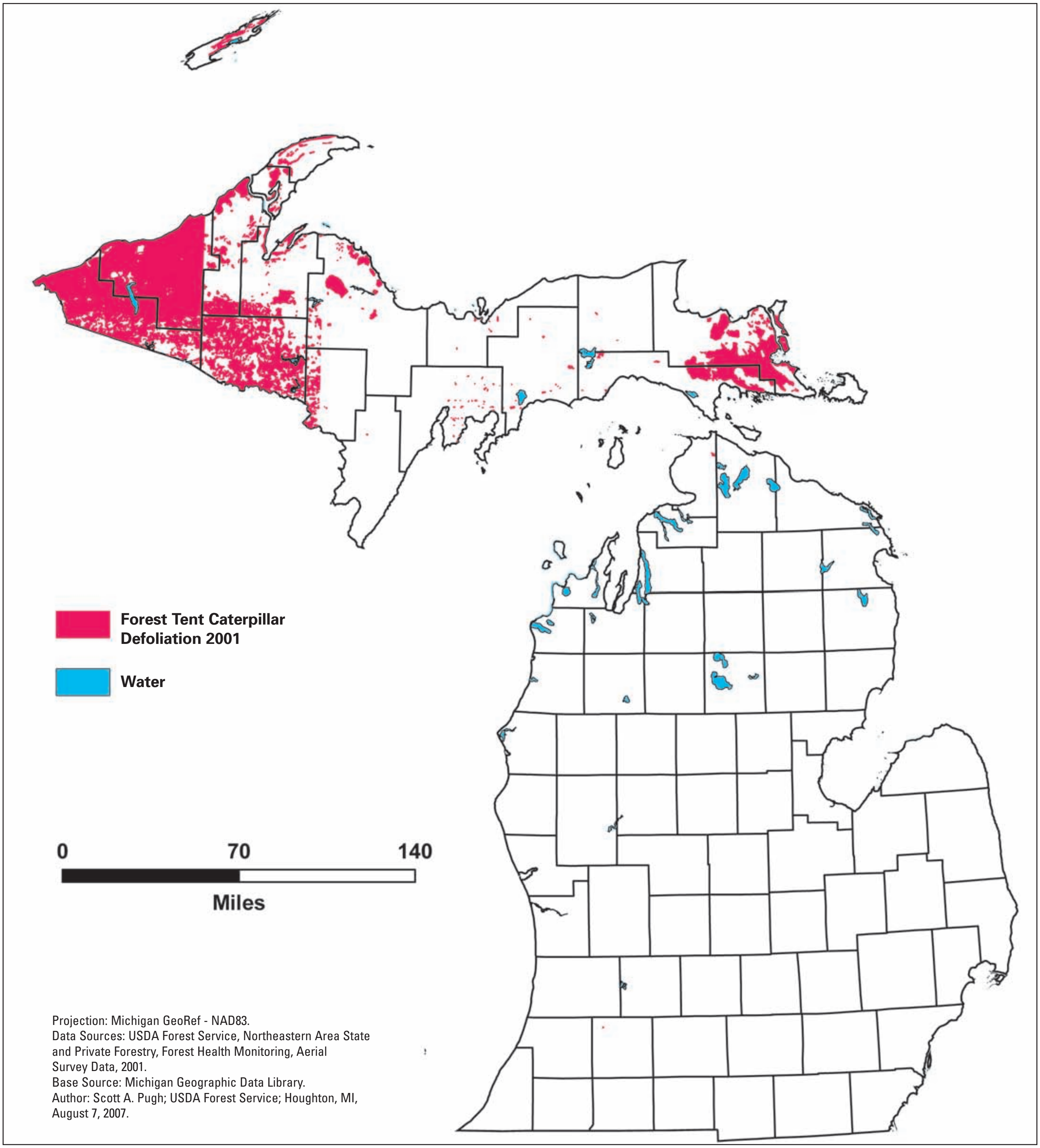
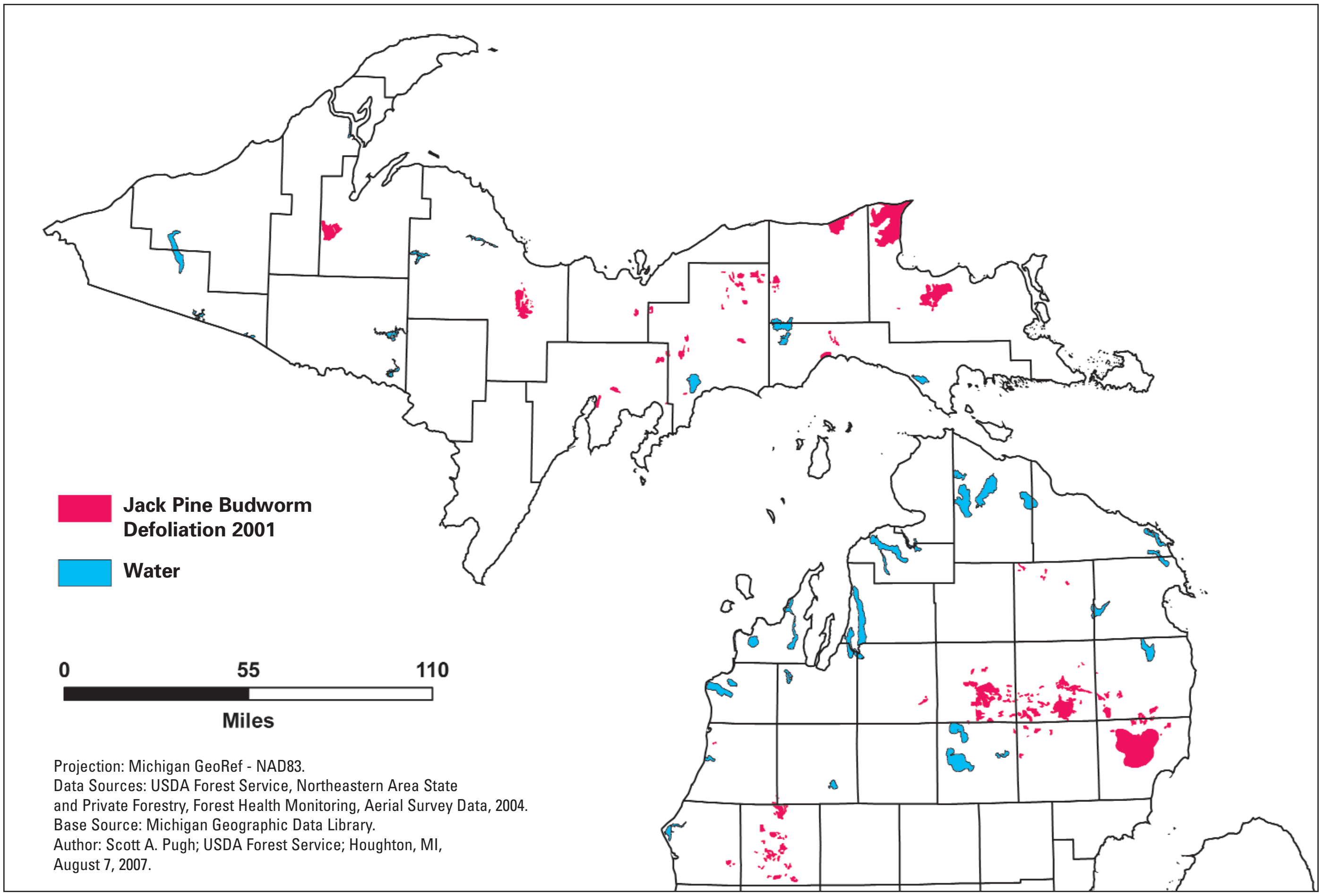


Figure 79.—Area defoliated by jack pine budworm, Michigan, 2004.



Gypsy moth, larch casebearer, eastern larch beetle, spruce budworm (see page 82), oak wilt, large aspen tortrix, red-headed pine sawfly, red oak and black ash decline, and environmental elements such as drought and late frost also caused considerable damage. Gypsy moth, larch casebearer, and oak wilt are nonnative.

Oak wilt, which causes considerable oak mortality, has been present in Michigan for many years and continued to increase throughout the survey period. It has been identified in 33 counties throughout the Lower Peninsula and two counties in the Upper Peninsula. A vascular wilt fungus, oak wilt is transmitted by insects or through root grafts. The movement of firewood or logs cut from diseased trees also increases the spread of this disease. An infected tree never recovers and usually dies. To slow the overland spread of oak wilt, harvesting is being restricted on land owned by the State of Michigan. Forest stands with oak trees are not cut between April 15 and July 15 in areas where the risk of oak wilt is high. These dates mark the period when the sap-feeding beetles responsible for spreading oak wilt are most active. These small (1/4-inch long) beetles are attracted to fresh tree wounds and transmit spores to oak trees that have been damaged during logging.

Larch casebearer is a needle-mining insect and a major defoliator of tamarack. This insect defoliated areas in the central and eastern Upper Peninsula and northern Lower Peninsula from 2000 through 2002 (at peak in 2000 exceeded 100,000 acres). Defoliation for 2 or more consecutive years can cause tree decline and mortality. Populations generally collapse after a single year of damage due to two parasites imported from Europe. Repeated defoliations by larch casebearer combined with stress from drought in 2000-01 contributed to a major epidemic of native eastern larch beetles. Outbreaks of this beetle have been extensive throughout North America since 1970. The eastern larch beetle has killed tamarack in stands ranging in size from a cluster of several trees to stands of 100 acres. Healthy trees can be killed once beetle populations build on stressed trees. Populations of eastern larch beetle rose in the central and eastern Upper Peninsula and northern Lower Peninsula. Some larch mortality occurred in 2004 in the eastern Upper Peninsula, where 29,439 acres were affected. Both native tamarack and nonnative larch species are susceptible to damage by the eastern larch beetle. Populations of eastern larch beetle and larch casebearer declined sharply after 2004 with little defoliation and associated mortality reported in 2005.

What this means

Michigan's forest land is host to a variety of native and nonnative insects and diseases. While varying in the degree of severity, these organisms affect forest resources across the State. Adverse environmental conditions interact with these pathogens in various ways with weather playing a major role. In some cases, trees on poorer soils with higher bulk densities and lower nutrients are at greater risk (see Fig. 65).

Nonnative species such as the emerald ash borer and beech bark disease are playing a larger role in affecting Michigan's forest health. Because of the lack of natural enemies and specific plant defense mechanisms, they often cause considerable decline and mortality that could alter forest structure and composition. The State's forests also face serious potential risk from the introduction of the Asian longhorned beetle, sudden oak death (SOD), balsam woolly adelgid, hemlock wooly adelgid, and sirex wooodwasp. In fact, since this survey period ended in 2004, hemlock woolly adelgid and the sirex woodwasp have been detected in Michigan.

Nonnative and Invasive Plants

Background

Nonnative plants are a major concern in forested ecosystems because many species spread and become noxious or invasive. For example, garlic mustard (*Alliaria petiolata*), an invasive weed found in moist, shaded forests of Michigan, directly threatens a number of native wildflowers through competition. Many species of wildlife depend on these wildflowers. Changes in diversity and abundance of native and nonnative species are a major concern. About 42 percent of the species currently listed as threatened or endangered under the U.S. Federal Endangered Species Act are at risk from nonnative plants (Pimentel et al. 2005). The cost of damage and control measures has been estimated at $120 billion annually (Pimentel et al. 2005). For additional information, visit the Michigan Invasive Plant Council (http://invasiveplantsmi.org/) and the National Invasive Species Information Center (http://www.invasivespeciesinfo.gov).

The data analyzed in this section are from the Vegetation Diversity and Structure Indicator (VEG) and standard FIA plots. The primary purpose of VEG is to provide a base for species richness, species abundance, spatial distribution, and forest structure at regional and national scales. Michigan is fortunate to have 125 VEG plots, the most in the region, upon which trees and understory data were collected. Due to resource limitations, data was collected only from 2001 through 2003. In addition, all standard forest-land plots (10,355) were examined for nonnative tree species from 2000 through 2004.

What we found

In all, 813 species were identified on the VEG plots, 98 of which were introduced. Eighty-one (65 percent) of the 125 plots had at least one identifiable nonnative species. The most nonnative species found on a plot totaled 14. Percentages of nonnative to total species are higher in the Lower Peninsula than in the Upper Peninsula (Fig. 80). Likewise, the percentage of nonnative-species ground cover to total ground cover is higher in the Lower Peninsula. Regionally, nonnative species appear to be more pronounced in more populated and fragmented landscapes. It is difficult to compare nonnative species with average subplot species richness (Fig. 81). There is no apparent trend for the entire region.

Garlic mustard. Photo by Steven Katovich, U.S. Forest Service, www.forestryimages.org.

Figure 80.—Percentage of count and cover of nonnative species to all species sampled in Michigan, Wisconsin, and Minnesota, 2001-03.

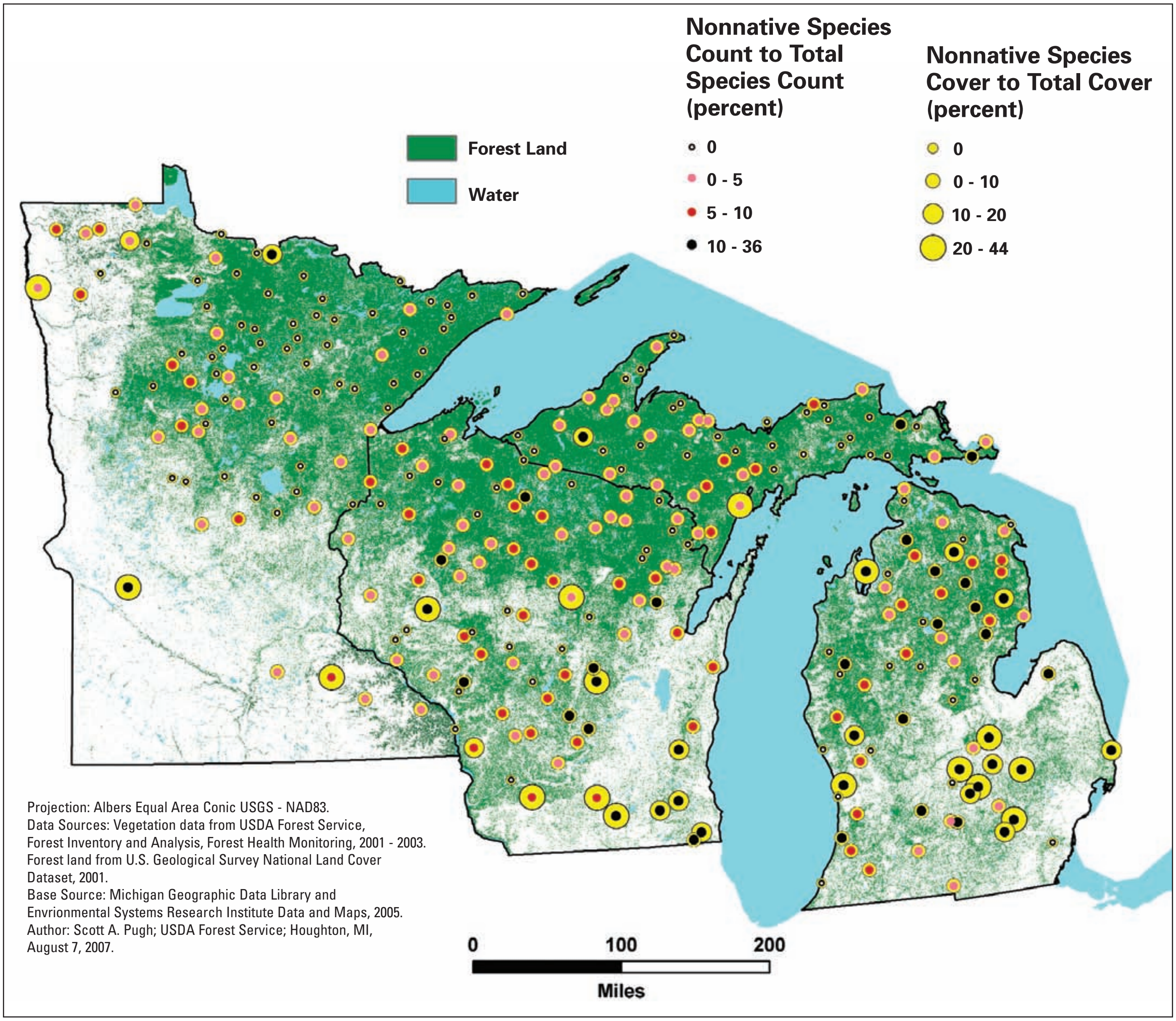


Figure 81.—Average subplot species richness in Michigan, Wisconsin, and Minnesota, 2001-03.

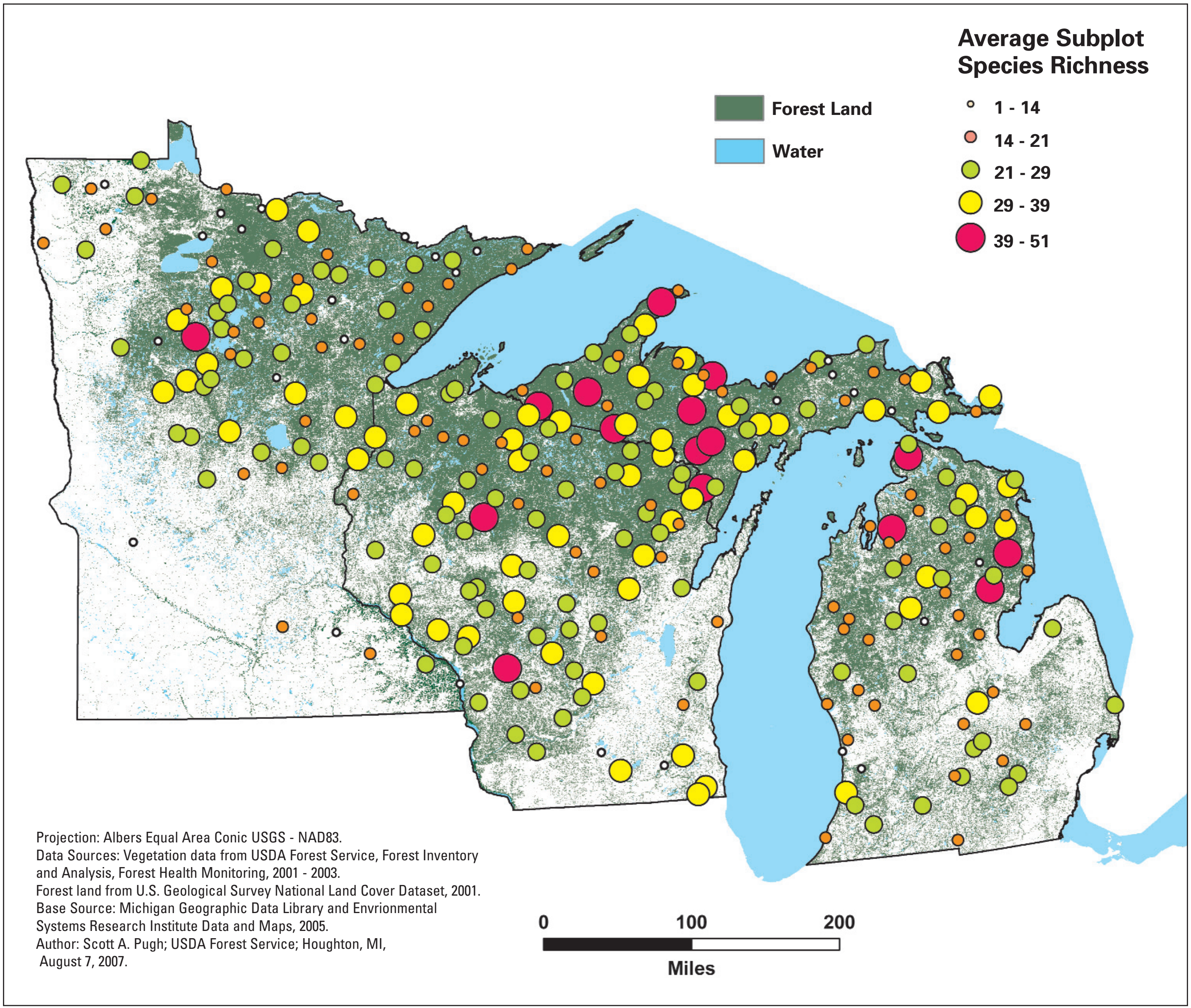


Table 9 shows the top 30 nonnative plant species. Except for paradise apple, these are not trees. Common dandelion was observed most often. Multiflora rose, autumn olive, and glossy buckthorn are the most commonly observed shrubs. Using biomass as an indicator, the most common nonnative tree species to Michigan is Scotch pine at nearly 3.5 million dry tons. There is more biomass in Scotch pine than in all of the other nonnative tree species combined. Other noteworthy nonnative tree species, in decreasing amount of biomass, are black locust, Norway spruce, apple (includes native and nonnative), Austrian pine, Colorado blue spruce, Russian-olive, white willow, Siberian elm, white mulberry, and tree-of-heaven. Many of these nonnative tree species invade forest edges and adjacent open areas, preventing native trees from establishing. Nonnative tree species comprise at least 0.7 percent of the tree biomass in Michigan's forest land (trees at least 1 inch d.b.h.). Likewise, nonnative trees species comprise at least 0.8 percent of the number of trees.

Table 9.—Count of nonnative plant species from Vegetation Diversity and Structure Indicator plots, Michigan, 2001-03 (top 30 by number sampled).

Common / scientific name	Count	Common / scientific name	Count	Common / scientific name	Count
Canada thistle *Cirsium arvense*	4	Autumn olive *Elaeagnus umbellata*	5	Redtop *Agrostis gigantea*	11
Paradise apple *Malus pumila*	4	Love-lies-bleeding *Amaranthus caudatus*	6	Narrowleaf plantain *Plantago lanceolata*	11
Black medick *Medicago lupulina*	4	Orchardgrass *Dactylis glomerata*	6	Stinging nettle *Urtica dioica*	12
Oxeye daisy *Leucanthemum vulgare*	4	Bull thistle *Cirsium vulgare*	7	Common sheep sorrel *Rumex acetosella*	13
Glossy buckthorn *Frangula alnus*	4	Timothy *Phleum pratense*	7	Common yarrow *Achillea millefolium*	13
Marsh thistle *Cirsium palustre*	4	Quackgrass *Elymus repens*	7	Canada bluegrass *Poa compressa*	14
Smooth brome *Bromus inermis*	4	Lesser burrdock *Arctium minus*	9	Kentucky bluegrass *Poa pratensis*	15
Spotted knapweed *Centaurea biebersteinii*	5	Sweet cherry *Prunus avium*	9	Orange hawkweed *Hieracium aurantiacum*	16
Common mouse-ear chickweed *Cerastium fontanum*	5	Common St. Johnswort *Hypericum perforatum*	10	Multiflora rose *Rosa multiflora*	17
White clover *Trifolium repens*	5	Climbing nightshade *Solanum dulcamara*	10	Common dandelion *Taraxacum officinale*	33

What this means

The VEG data are a baseline with which to monitor changes in species richness, species abundance, spatial distribution, and forest structure at regional and national scales. On the basis of this limited set of data, there appears to be a correspondence of invasive species richness and cover with more fragmented and heavily populated areas. With 65 percent of the VEG plots containing nonnative and invasive species, continued monitoring will allow trend analysis. These data will be linked to specific ecosystems and forest types across the Nation and changes will be observed over time. Thus, managers will have additional information for making informed decisions regarding nonnative species.

Emerald Ash Borer

Background

The emerald ash borer (EAB) (*Agrilus planipennis*) is a nonnative wood-boring beetle that was discovered near Detroit, Michigan in 2002. EAB probably found its way there on solid wood-packing material in the early 1990s. The primary cause of ash decline and mortality in southeastern Michigan, EAB has been found throughout the Lower Peninsula and in Ohio, Indiana, and Ontario, Canada (also in Maryland, Illinois, Pennsylvania, and four locations in the Upper Peninsula after 2004) (Michigan State University 2008, Poland and McCullough 2006).

All major species of ash (e.g., green, white, and black ash) and all ash cultivars found in Michigan have been attacked by EAB (Cappaert et al. 2005). Tree size and vigor apparently influence host selection only when insect density is low (Cappaert et al. 2005, Poland and McCullough 2006). The natural dispersal rate of EAB is uncertain but the human transportation of infested firewood, nursery stock, and other ash with intact bark enables the insect to spread great distances. A quarantine has been imposed, making it illegal to move from designated areas all firewood and all ash tree parts or products down to wood chips larger than 1 inch. Visit the regional EAB website for updates and additional information (http://emeraldashborer.info/). In addition, no ash firewood is allowed on State parks, State forest campgrounds, and posted State lands.

The Michigan ash resource has made gains in the last two inventories (see Table 3 and Fig. 29). Growing stock on timberland for black, green, and white ash increased from 687 to 1,273 million ft^3 (85 percent) between the 1980 and 2004 inventories. On timberland during the same period, the number of black, green, and white ash (live trees at least 1 inch d.b.h.) increased from 649 to 871 million (44 percent). EAB is expected to reverse this upward trend.

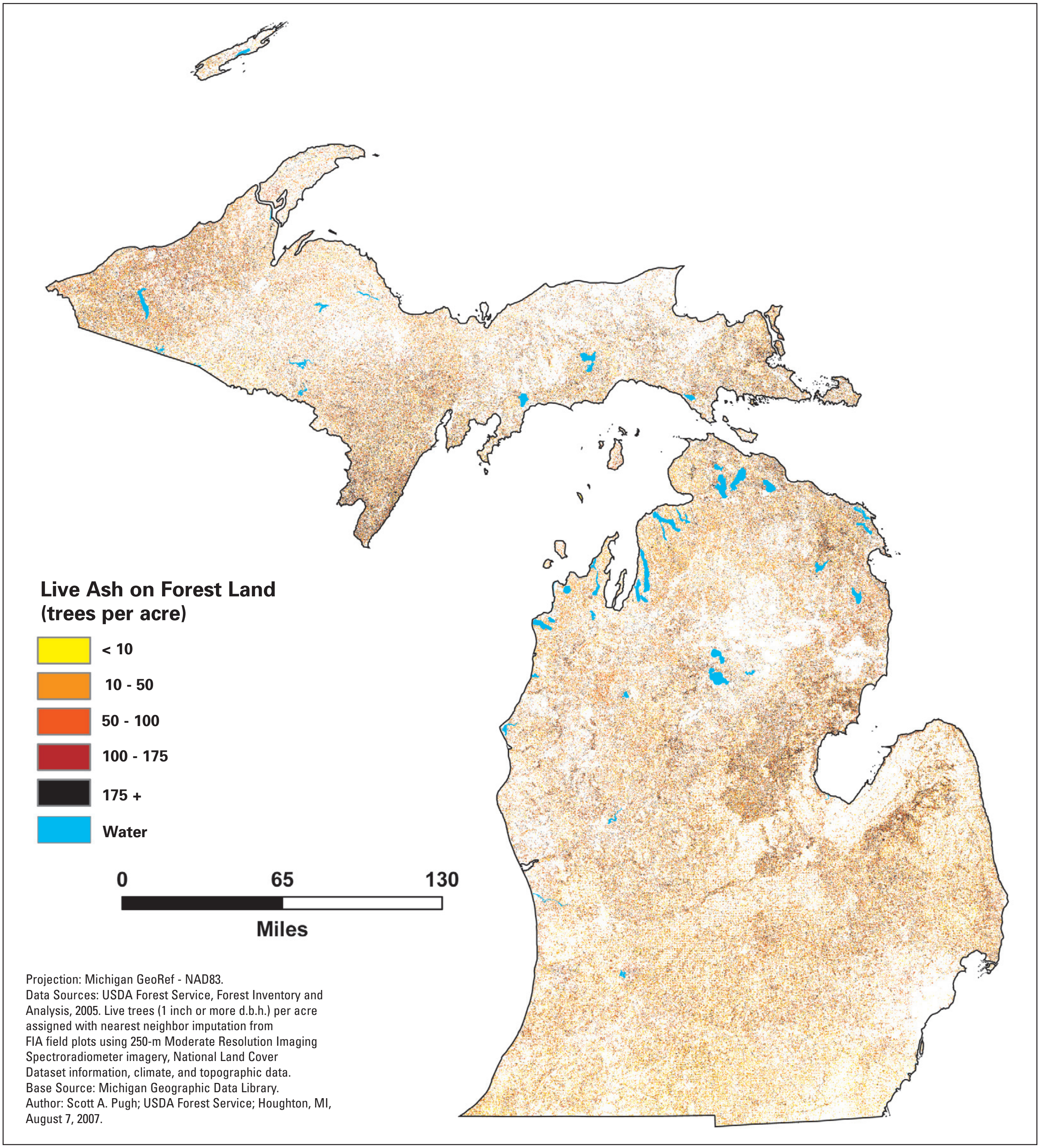
Emerald ash borer. Photo used with permission from Pennsylvania Department of Conservation and Natural Resources - Forestry Archive, www.forestryimages.org.

There also were gains in growing-stock volume and number of live trees (at least 1 inch d.b.h.) on timberland for black, green, and white ash in Wisconsin (1983 to 2004) and Minnesota (1977 to 2003). Growing-stock volume increased from 737 to 1,134 million ft^3 (54 percent) in Wisconsin and from 608 to 1,127 million ft^3 (85 percent) in Minnesota. The number of live trees increased from 404 to 716 million (77 percent) in Wisconsin and from 539 to 776 million (44 percent) in Minnesota.

What we found

Michigan's forest land contains an estimated 894.2 million live ash trees (at least 1 inch d.b.h.) that account for 1.4 billion ft^3 of volume. Ash trees are found throughout the State with high densities in the northern and central portions of the Lower Peninsula, and the eastern, western, and south-central portions of the Upper Peninsula (Fig. 82). Ash trees are present on more than 5.8 million acres of forest land. In stands where ash resides, it generally accounts for less than 25 percent of total live-tree basal area (Fig. 83). Black ash does occur as a pure or nearly pure stand in some wetlands.

Figure 82.—Number of live ash trees per acre (at least 1 inch d.b.h.) on forest land, Michigan, 2005.



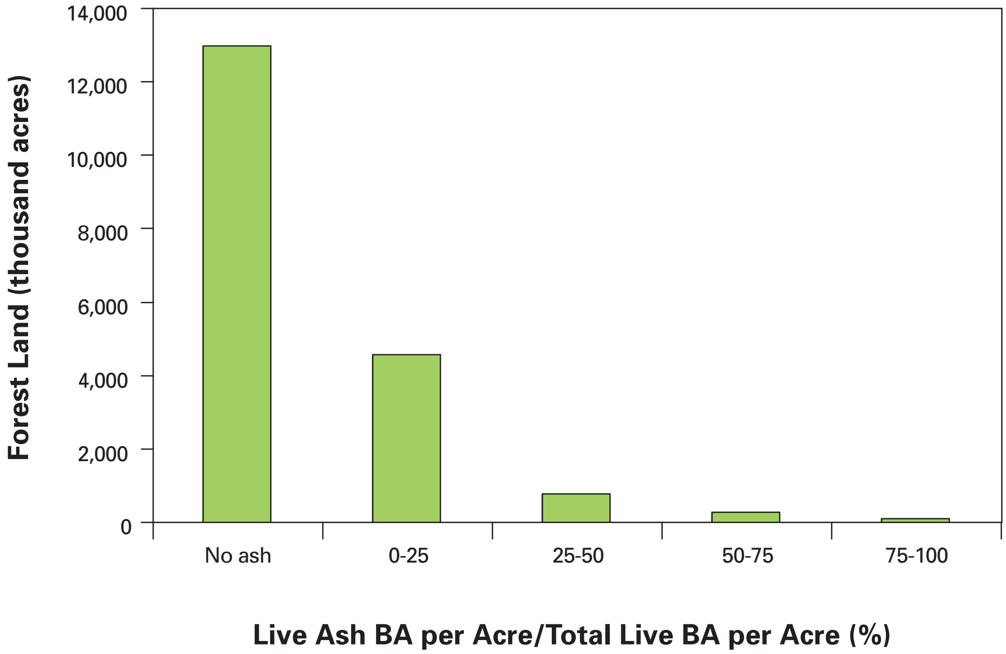
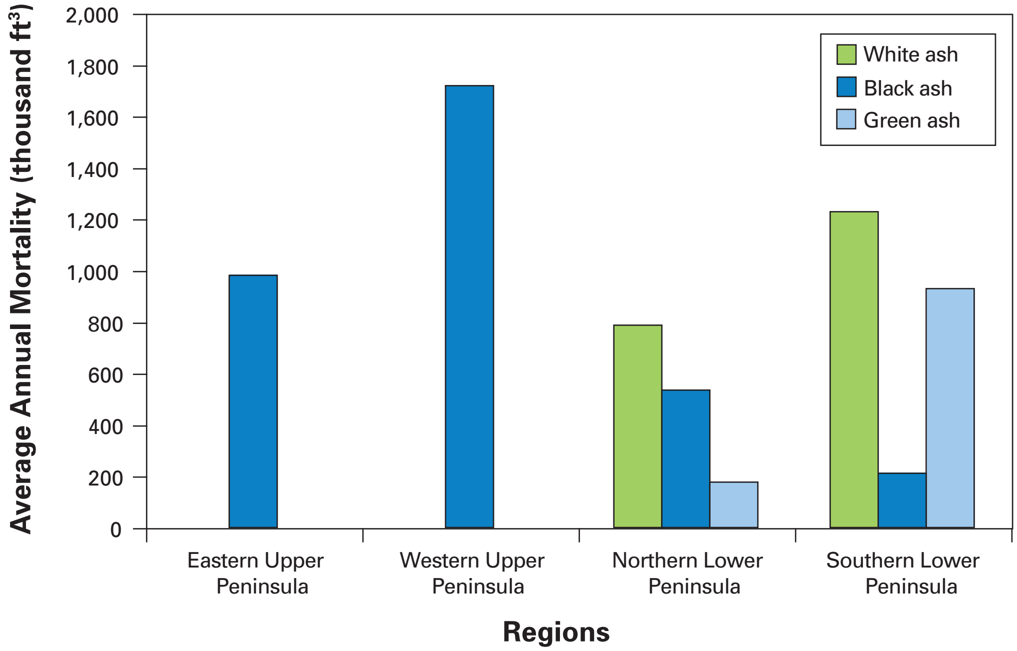


Figure 83.—Percentage of live ash basal area (BA) to total live BA (trees at least 1 inch d.b.h.) on forest land, Michigan, 2004.

Nearly 60 percent of all (not limited to EAB) ash mortality was in the Lower Peninsula (Fig. 84). Ash mortality was highest in the southern Lower Peninsula; white and green ash accounted for 91 percent of this mortality. In the Upper Peninsula, ash mortality was limited to black ash. As of 2004, EAB was not established in the Upper Peninsula; high ash mortality in that region likely was due to black ash decline. Ash yellows disease and general ash decline are present throughout the State and also contribute to ash mortality.

Figure 84.—Average annual mortality of ash growing stock on timberland by species and region, Michigan, 2004.



What this means

Michigan's entire ash resource is at risk to incur substantial mortality from EAB. With millions of ash killed in southeastern Michigan alone (Michigan State University 2008), EAB has caused considerable losses in the timber, nursery, and wood-products industries. This has resulted in high tree removal and replacement costs (Anim. Plant Health Insp. Agency 2005, Michigan State University 2008). Additionally, the loss of ash in forested ecosystems will change species composition and alter community dynamics. As ash is a major component of northern forests and urban landscapes, continued spread of EAB represents a potentially serious threat to ash resources throughout the United States. There are ongoing efforts to learn more about EAB and its future impacts.

Beech Bark Disease

Background

Beech bark disease (BBD) is the result of a small, sap-feeding insect known as beech scale (*Cryptococcus fagisuga*) and at least two species of *Nectria* fungi (one nonnative and one native species) acting together (McCullough et al. 2005). The cause of substantial defect and mortality of American beech across the Northeastern United States, BBD has been a major concern in Michigan since its discovery in 2000.

Beech scale and a nonnative species of *Nectria* fungi were initially introduced to North America via Nova Scotia in 1890 (McCullough et al. 2005). By 1932, isolated infestations of BBD were identified in eastern and south-central Maine. Since that time, the disease has spread from New England to North Carolina, Ohio, and Tennessee.

BBD is set in motion by beech scale insects that attack host trees and create feeding wounds in the bark. *Nectria* fungi then enter through the feeding wounds. Fungal growth, which often causes cankers to form along the bole and large branches, girdles the tree by killing narrow sections of bark (McCullough et al. 2005). BBD is influenced by the basal area, age, and diameter of American beech trees. Mature stands with an abundance of American beech (i.e., stands where American beech basal area is greater than 20 percent) and stands containing many trees larger than 9 inches d.b.h. are highly vulnerable to this disease (Heyd 2005).

What we found

During the current inventory period, BBD was found in the western portion of the northern Lower Peninsula (counties bordering Lake Michigan) and in the eastern Upper Peninsula. American beech grows throughout much of Michigan. It is present on 1.9 million acres or 10 percent of total forest land (Figs. 85-86). Twenty-six percent of this land occupied by this species has an American beech component greater than 20 percent by basal area. These stands are concentrated in the eastern Upper Peninsula (along the shoreline of Lake Superior) and in the northern Lower Peninsula. Michigan's forest land contains an estimated 220 million live American beech; 19.1 million American beech are more than 9 inches d.b.h. (Fig. 87).

Figure 85.—Percentage of live American beech basal to total live basal area (trees at least 1 inch d.b.h.) on forest land, Michigan, 2005.

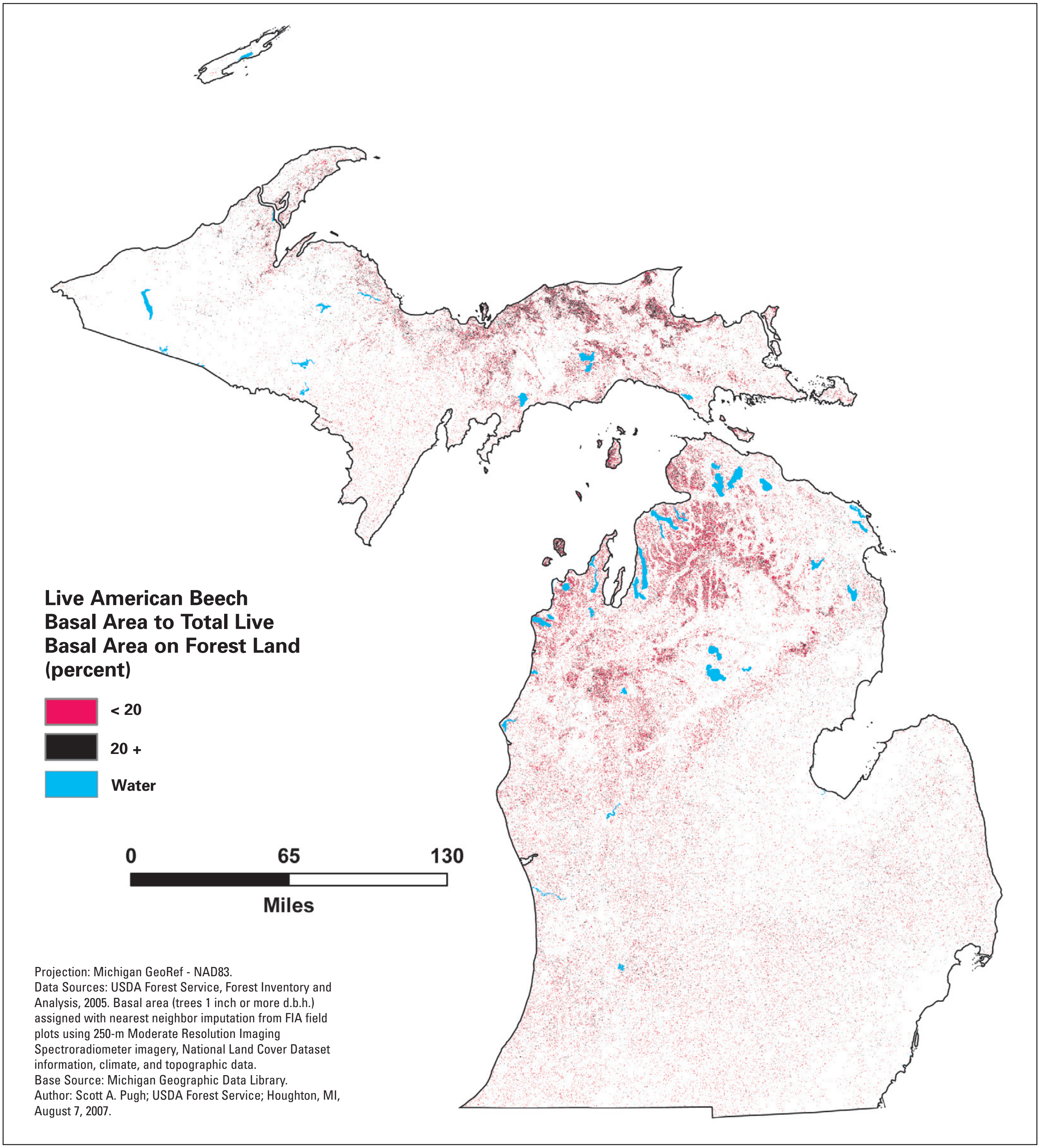


Figure 86.—Percentage of live American beech basal area (BA) to total live BA (trees at least 1 inch d.b.h.) on forest land, Michigan, 2004.

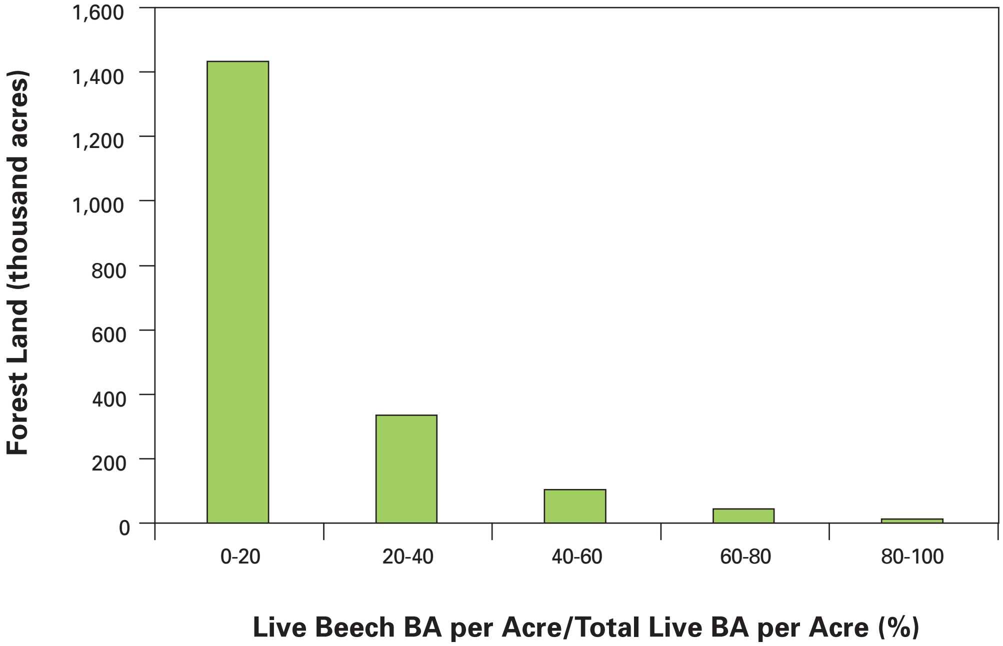
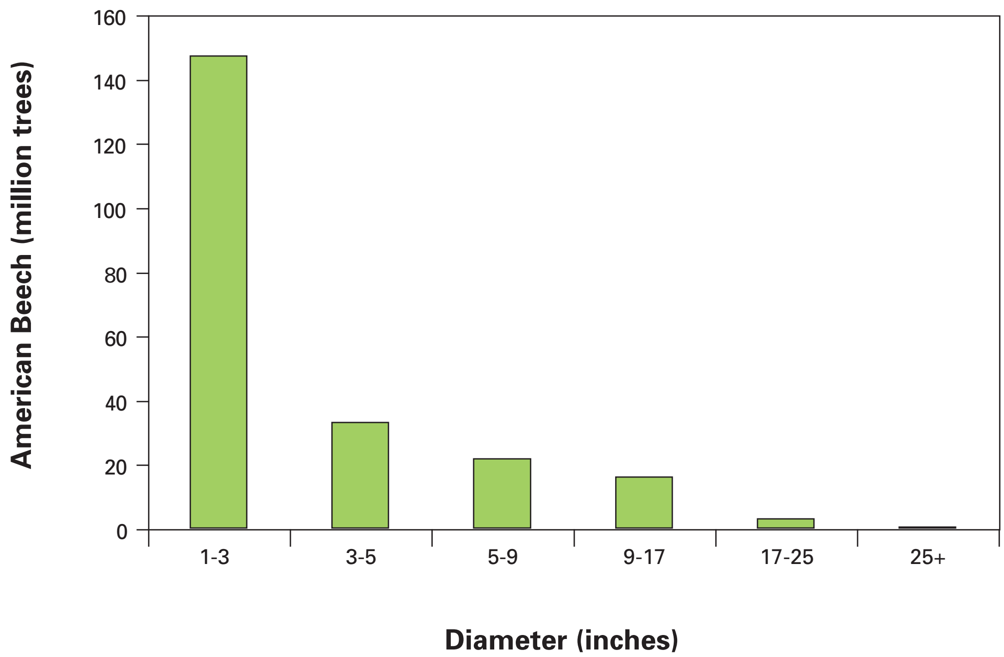


Figure 87.—Number of live American beech trees (at least 1 inch d.b.h.) on forest land by diameter class, Michigan, 2004.



What this means

Mature American beech experiences high mortality from BBD. Because this species is abundant and occupies large portions of overstory, mortality of mature American beech can create gaps in the canopy that could accelerate changes in species composition (McCullough et al. 2005). These trees also pose a hazard as the main stems and large limbs break off in wind (beech snap). Many parent trees killed by BBD have heavy sprouting at their base. Sprouting can create thickets of young American beech, which ensures disease susceptibility. Also, American beech mast is an important source of food for wildlife. As thickets of young American beech produce little mast, these stands will have a reduced value for wildlife (McCullough et al. 2005).

By studying the advancing front of this disease in Michigan and applying specific management guidelines, managers may be able to reduce its adverse effects. To aid in this process, plots have been established across the State to monitor and gather information on the impact, abundance, and rate of spread of BBD. There also are efforts to identify American beech that are resistant to BBD with the hope of propagating these resistant trees.

Beech bark disease. Photo by Linda Haugen, U.S. Forest Service, www.forestryimages.org.

Gypsy Moth

Background

A nonnative hardwood defoliator, the gypsy moth (*Lymantria dispar*) was introduced to North America in 1869 (Michigan Dep. Agric. 2007). Populations have been established from Maine to North Carolina and from the Atlantic Coast to Illinois and Wisconsin. Gypsy moth defoliation in Michigan was first reported in Lansing in 1954 and now is present throughout the Upper and Lower Peninsulas (Michigan Dep. Agric. 2007). Oaks are the primary hosts of gypsy moth but preferred species also include basswood, sweetgum, aspen, birch, and willow (South. Reg. and Northeast. Area, State and Priv. For. 2001).

Environmental conditions influence gypsy moth populations. The early 1990s saw dramatic declines in gypsy moth defoliation. A cold winter in 1993-94 reduced the gypsy moth population but defoliation rose in 1997 and 1998. Cool dry springs are not favorable to the fungus *Entomophaga maimaiga*, the natural enemy of gypsy moth. A resurgence of the gypsy moth in 1997 was partly attributed to a cool dry spring.

What we found

Defoliations declined from the resurgence in the late 1990s to the point of no detection in 2001 and 2002. After 2 years without defoliation, gypsy moth populations in Michigan began to rise in 2003. Defoliation was heavy in several northern Lower Peninsula and Upper Peninsula counties (Fig. 88). Statewide defoliation was approximately 38,000 acres in 2003 and 45,000 acres in 2004. Oak species are distributed throughout the State but oak density is highest in the northern Lower Peninsula (Fig. 89). Oak species make up 3.1 billion ft^3 of total live-tree volume and the greatest volume of preferred hosts of gypsy moth (Fig. 90). The combined volume of all preferred hosts is 25 percent of the total live-tree volume on Michigan's forest land.

Gypsy moth caterpillar. Photo by U.S. Forest Service, Archives, www.forestryimages.org.

Figure 88.—Area of gypsy moth defoliation, Michigan, 2003-2004.

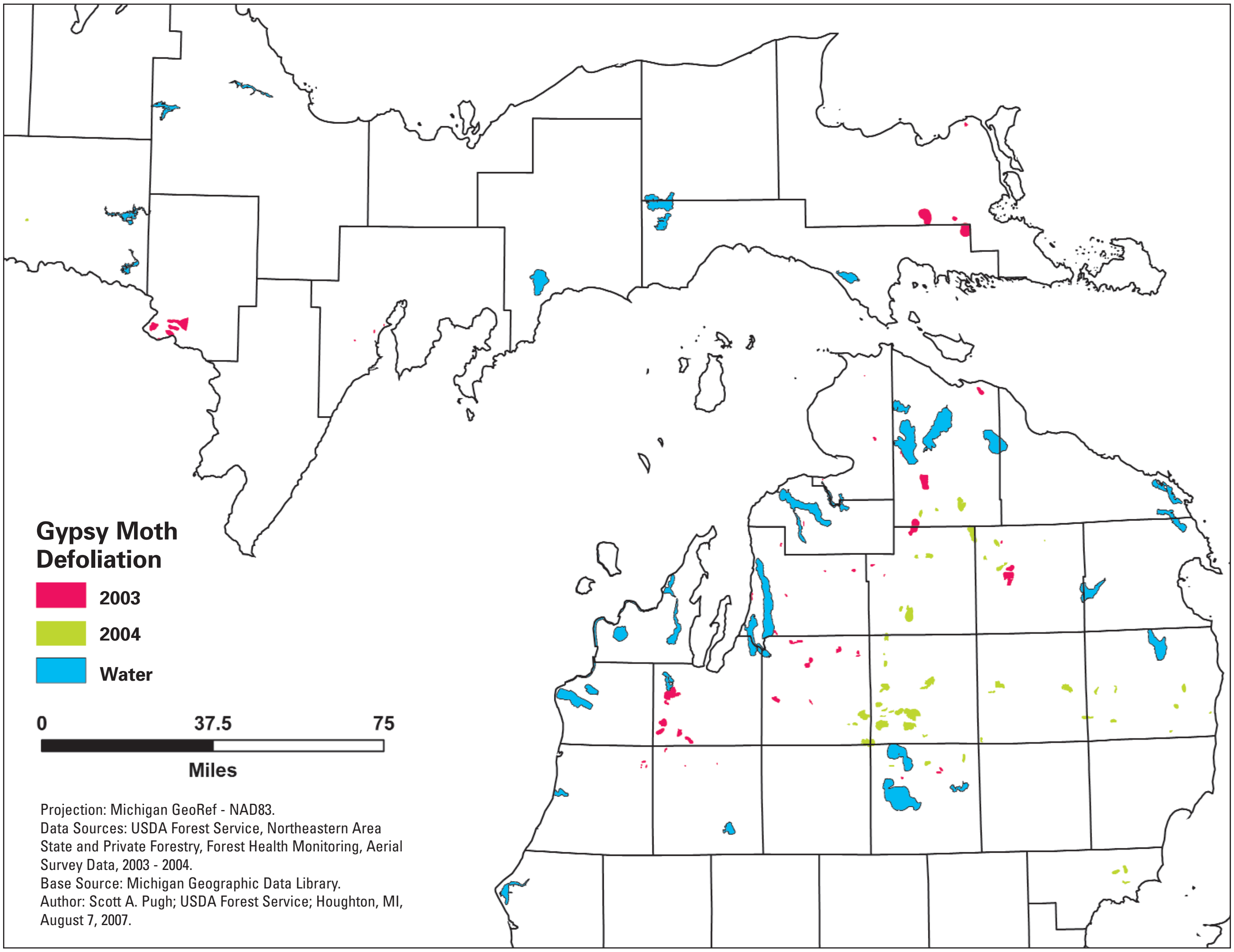


Figure 89.—Number of live oak trees per acre (at least 1 inch d.b.h.) on forest land, Michigan, 2005.

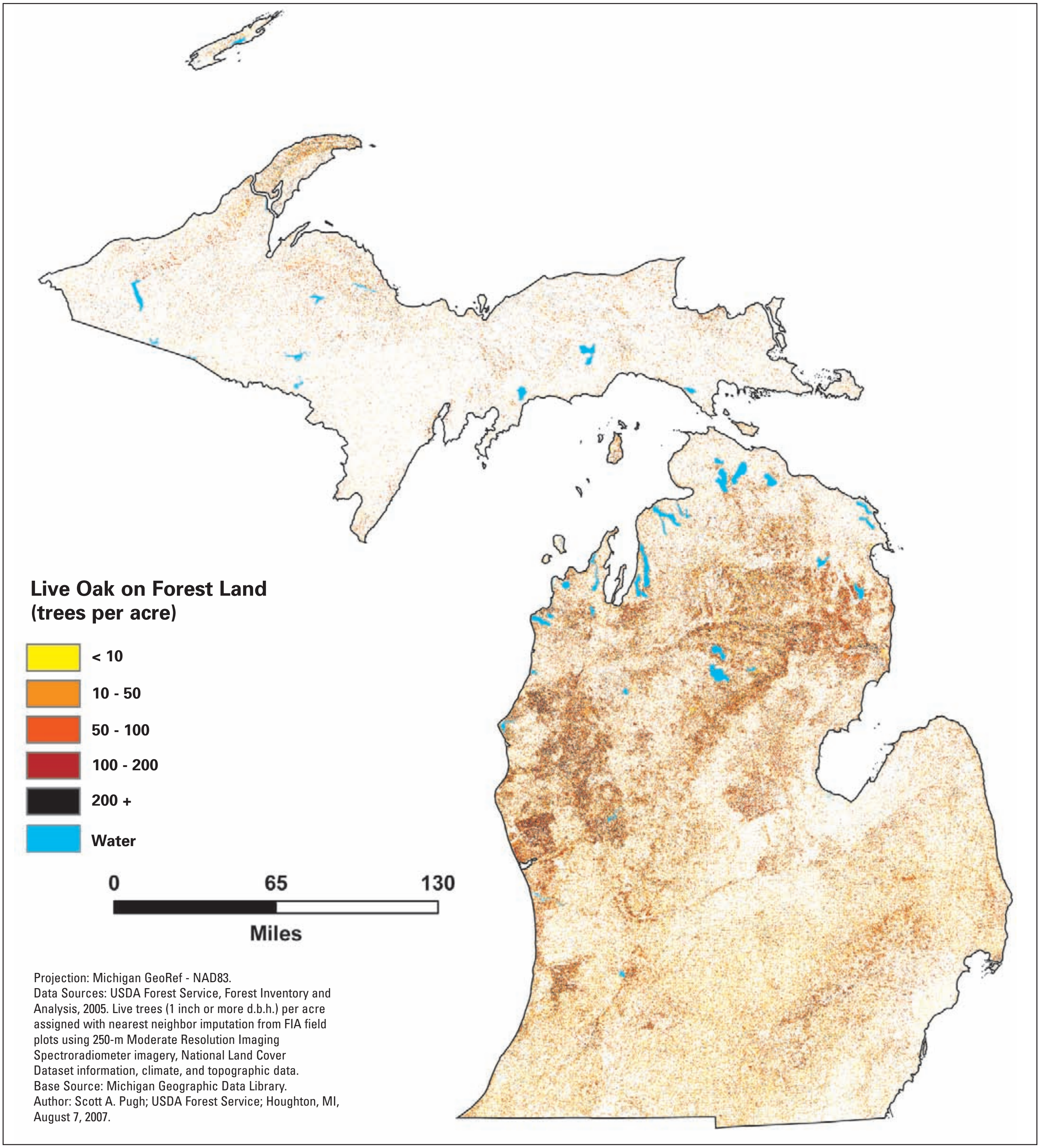
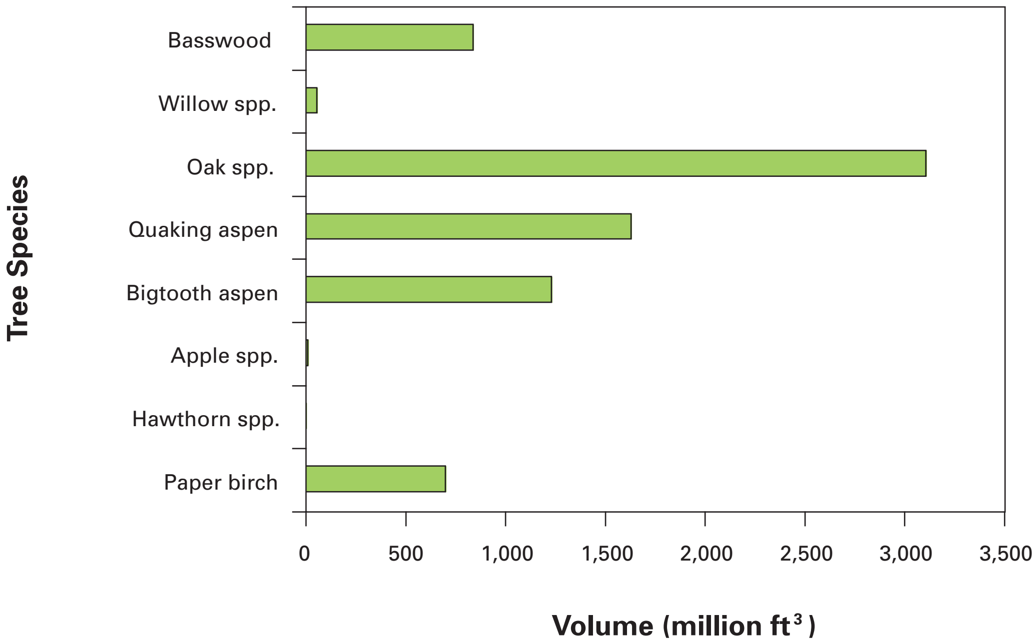


Figure 90.—Live-tree volume (trees at least 5 inches d.b.h.) of preferred gypsy moth host species on forest land, Michigan, 2004.



Oak is adapted to grow on dry sandy soils but these soil conditions are associated with higher severity of damage caused by the gypsy moth. Nineteen percent of the white oak/red oak/hickory forest type and 25 percent of the northern red oak forest type are on xeric sites.

What this means

Gypsy moth could adversely affect a large percentage of Michigan's forest land. Forests in the northern Lower Peninsula, which have the greatest density of oaks, are likely to receive the bulk of gypsy moth damage. In general, healthy trees are able to withstand one or two consecutive defoliations of greater than 50 percent of the tree canopy (McManus et al. 1992). Mortality can result after repeated defoliations weaken trees, making them vulnerable to other environmental stresses (e.g., drought, disease, or other insects) (McManus et al. 1992).

Oaks, which are dominant throughout the landscape, are economically important. Oak mortality could have a substantial effect on timber and wood-product availability. Recreation activity is also adversely impacted by gypsy moth outbreaks. The larvae annoy recreationists and degrade the natural beauty of forest stands through defoliation. Negative impacts also extend to wildlife as mast production is reduced. Over time, gypsy moth activity may lead to changes in species composition and accelerated succession to species that are less susceptible to defoliation.

Jack Pine Budworm

Background

Jack pine budworm (*Choristoneura pinus*) is a native softwood defoliator and a major pest of jack pine (McCullough et al. 1994). Caterpillars begin to feed on pollen in male flowers and later move to new shoots and consume needles. Budworm defoliation causes topkill and tree mortality. Stands more than 45 years old that are growing on low-quality sites like those with dry sandy soils are most vulnerable. Dry sandy soils tend to have higher bulk densities and lower fertility (see page 115). Stands with a basal area less than 70 ft^2/acre and stands with multiple stories or an uneven-age distribution are at high risk, as many of these stands have trees with large crowns that produce many male flowers (McCullough et al. 1994). Budworm defoliation tends to occur in a cyclical fashion, about every 6 to 10 years. However, the frequency and duration of defoliation is affected by drought.

Jack pine budworm is an integral part of the jack pine ecosystem. Jack pine is shade intolerant so it needs full sunlight to regenerate. The budworm kills trees in older unmanaged stands. Tree mortality and wildfires open stands creating an environment suitable for jack pine regeneration. Harvesting stands when they reach maturity minimizes mortality caused by the jack pine budworm and reduces the threat of damaging wildfires.

What we found

Budworm populations began to build in the eastern Upper Peninsula in 2001. Populations spread westward and defoliated roughly 226,000 acres across the Upper Peninsula by 2004. Defoliation in the Lower Peninsula rose in 2000 and remained relatively high throughout the survey period. From 2001 through 2004, about 381,000 acres were defoliated in the Lower Peninsula. Many areas were defoliated repeatedly from year to year. The jack pine forest type covers 710,000 acres in Michigan and is concentrated in the northern Lower Peninsula and the eastern Upper Peninsula (Fig. 91). There are an estimated 527.7 million ft^3 of live-tree volume on forest land (Fig. 92). Seventy percent of jack pine volume is in stands more than 45 years old; 55 percent of this volume is on xeric sites (primarily deep sandy sites). Average annual mortality of jack pine growing stock was 9.1 million ft^3/year; 64 percent of mortality occurred in stands that are more than 45 years old (Figs. 93-94).

Jack pine budworm larva. Photo used with permission from Connecticut Agricultural Experiment Station Archive, www.forestryimages.org.

Figure 91.—Live jack pine basal area per acre (trees at least 1 inch d.b.h.) on forest land, Michigan, 2005.

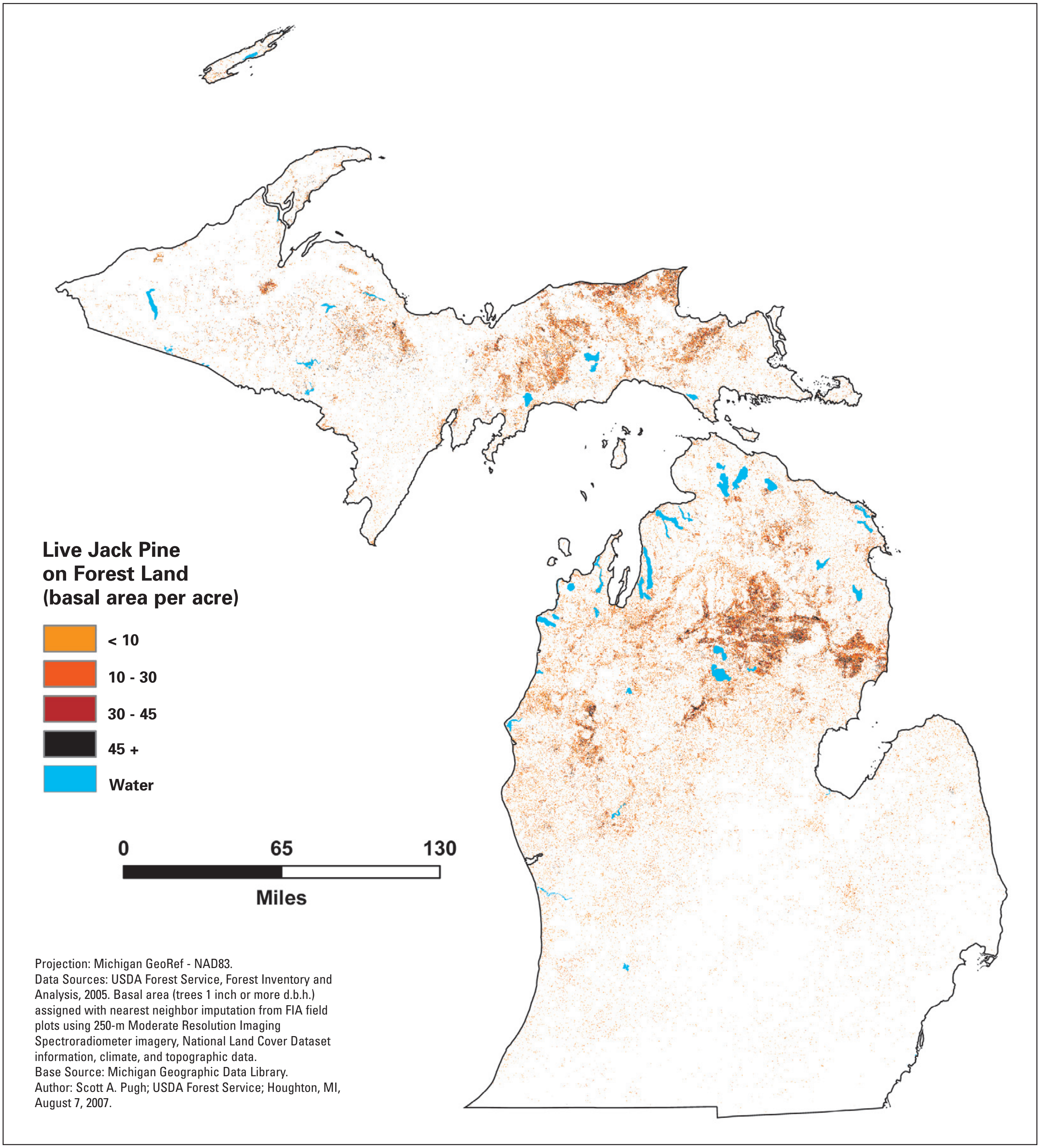


Figure 92.—Live-tree volume (trees at least 5 inches d.b.h.) for jack pine on forest land by stand age and physiographic class, Michigan, 2004.

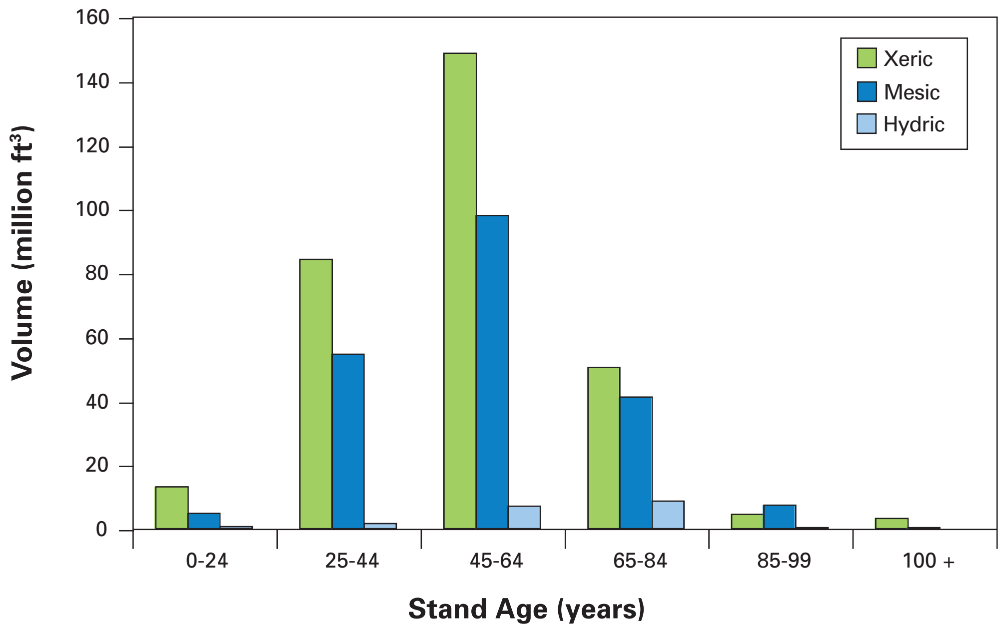
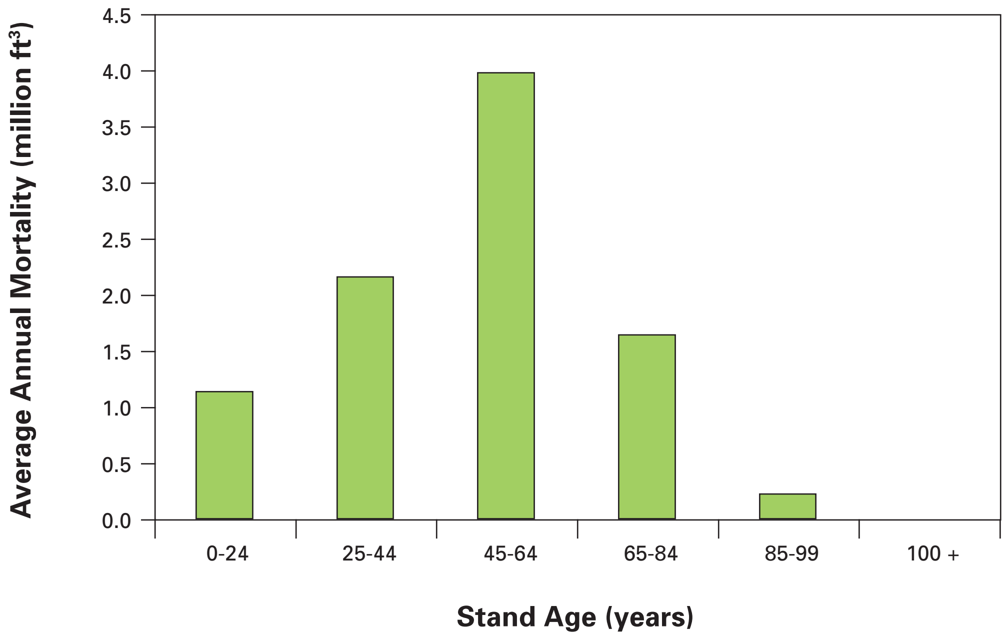


Figure 93.—Average annual mortality of jack pine growing stock on timberland by stand-age class, Michigan, 1993-2004.



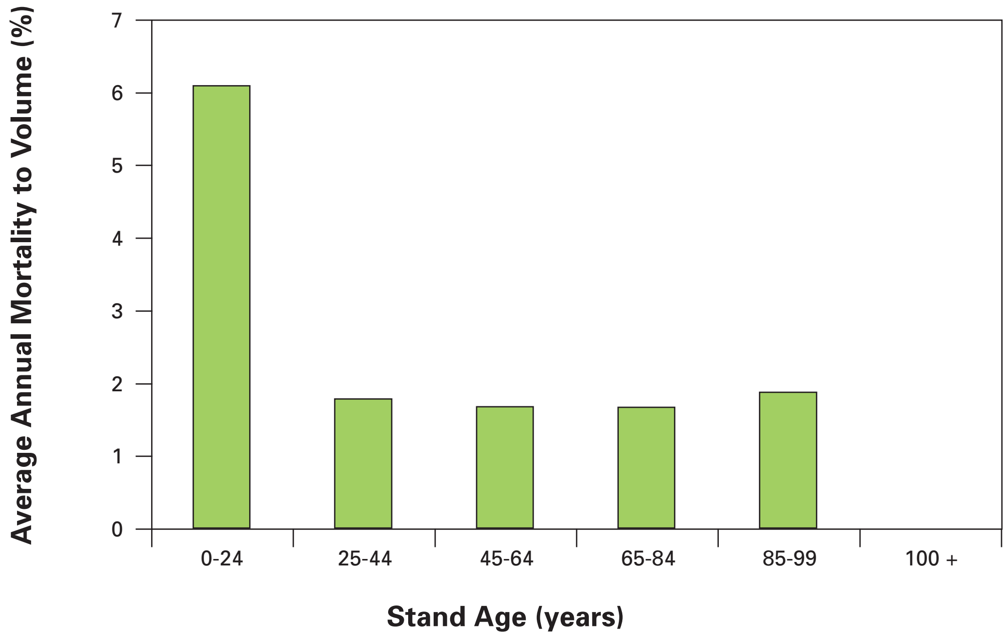


Figure 94.—Average annual mortality for jack pine growing stock on timberland as a percentage of current volume (2004) by stand-age class, Michigan, 1993-2004.

What this means

Michigan's jack pine resource contains an abundance of trees older than 45 years on low-quality sites (see page 119) and areas of low jack pine basal area. As a result, a substantial portion of the State's jack pine faces high risk of budworm defoliation. This species has been experiencing significant declines in volume and number of trees in association with a moderately high mortality rate (see Table 3, Figs. 29 and 42).

The northern Lower Peninsula is at the southern edge for jack pine. In addition, it is adapted to dry sandy soils but has been at greater risk to pathogens like jack pine budworm due partly to a number of droughts. Except on the poorest soils, it is expected that this species will continue to experience replacement by other pines and hardwood species.

If left unmanaged, budworm damage and mortality creates fuels for intense, fast-moving crown fires (McCullough et al. 1994). Management practices such as harvesting can reduce the risk of budworm defoliation and the threat of wildfire. Management also could focus on creating regeneration because jack pine has experienced significant loses in the number of sapling and poletimber-size trees.

Young jack pine stands are important to wildlife as they provide good winter deer cover and a fair food source (Michigan Dep. Nat. Resour. 2007b), and young jack pine stands are the sole source of breeding habitat for the Kirtland's warbler. Maintaining a younger and more vigorous jack pine resource will increase habitat availability for this rare and endangered species (McCullough et al. 1994, Michigan Dep. Nat. Resour. 2006b).

Forest Products and Stewardship

Forester counsels a forest-land owner. Photo by Lynn Betts, USDA Natural Resources Conservation Service, http://photogallery.nrcs.usda.gov/index.asp.

Timber Product Output

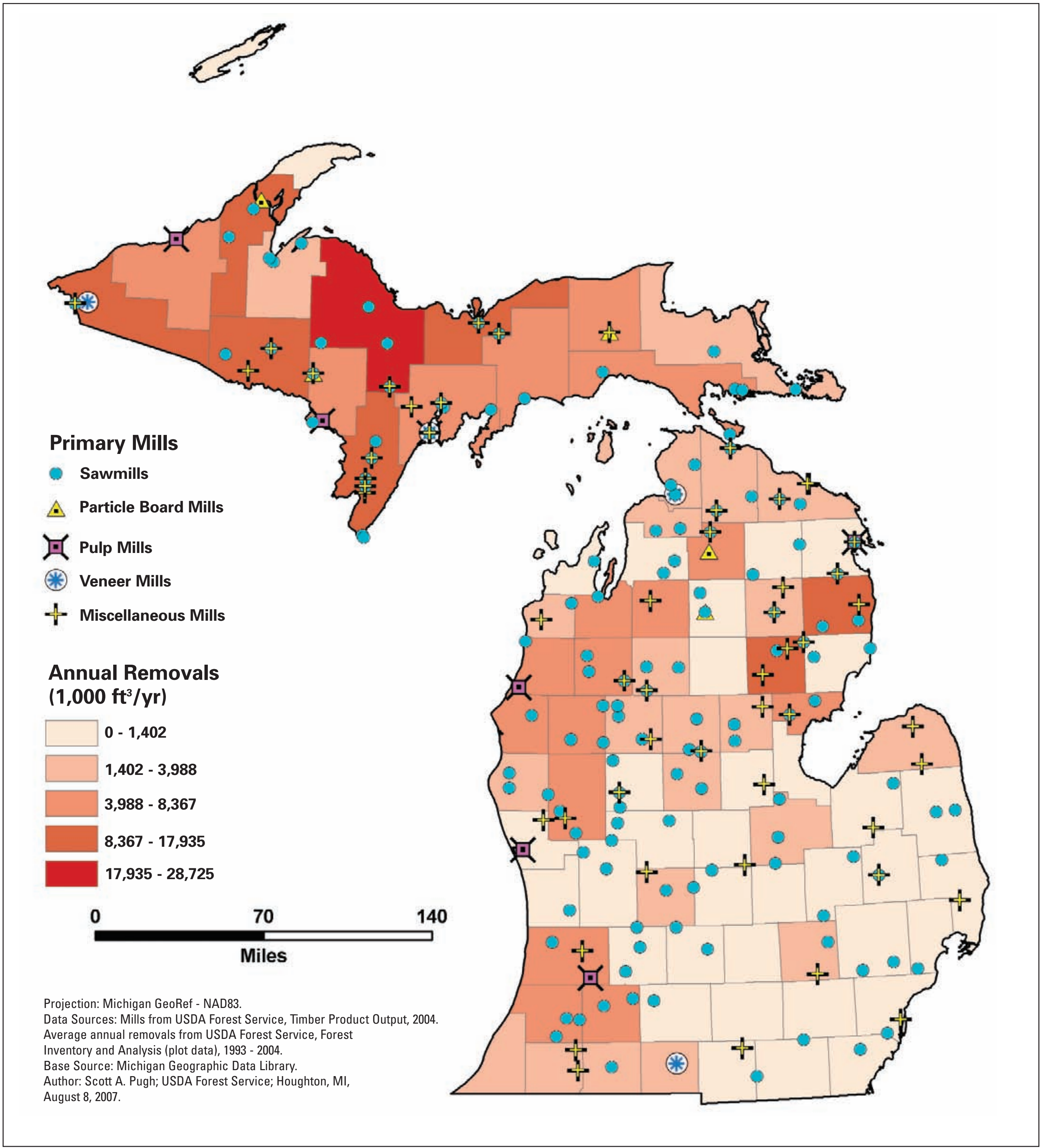
Background

Michigan's paper and wood-products industries employ over 19,000 workers with an output of approximately $4.4 billion annually (U.S. Census Bur. 2002). These primary wood-using industries include sawmills, pulp and paper manufacturers, and veneer and plywood manufacturers. To properly manage and sustain Michigan's forests, it is essential to have information on the location and species of timber that supply these industries.

A mill survey was conducted of all known primary wood-using mills in Michigan in 2004 (Fig. 95). Since the late 1970s, the survey usually has been conducted every 2 years. The study includes the size of the industry, amount of wood delivered to primary wood-processing mills, and its uses. Information on the generation and distribution of wood residues also is included. Here, production estimates refer only to the wood coming from the forests of Michigan. This wood can be processed in Michigan or abroad. By contrast, the term "receipts" refers to any wood processed by Michigan mills.

Landing area for sawtimber. Photo by Scott A. Pugh, U.S. Forest Service.

Figure 95.—Location and type of primary wood-using mills in Michigan (2004) overlaid on average annual removals (1993-2004) from FIA plot data.



The 2004 Michigan Timber Product Output (TPO) report is based on the 2004 Michigan TPO mill survey, the most recent TPO mill surveys from other states that reported processing wood harvested from Michigan, and regional harvest utilizations studies. The TPO mill surveys determine an estimate of the total wood usage in the State from all land (i.e., total roundwood estimate). From this total wood usage, estimates are made for the volume that came from timberland, forest land, and nonforest land. Also, estimates are produced for the volume from growing-stock trees, cull trees, dead trees, limbwood, nonforest-land trees, and other sources. Regional harvest utilization studies provide harvest residue estimates from the total roundwood estimate.

The average annual removals estimate (see page 83) derived from FIA plot observations can differ from the TPO survey estimate. As mentioned, the TPO estimate for growing stock on timberland is derived from harvest utilization studies and total wood usage in the State from all land. Average annual removals are based on FIA plot observations and include harvest removals, mortality removals (trees killed in the harvesting process and left on site), and diversion removals. The TPO survey estimate is based on data from a single year. The average removals estimate is a yearly average from one inventory to the next.

The TPO estimates of removals or production (growing stock on timberland) have ranged from 168 million ft^3 in 1965 to 354 million ft^3 in 1994. From 1977 through the 1980s there was a noticeable rise in TPO production estimates (wood usage from all land), particularly in pulpwood (Fig. 96). The TPO estimates generally have been higher than average annual removals estimated from the 1993 and 2004 plot inventories. The average TPO estimate (growing stock on timberland) from 1992 through 2004 was 335 million ft^3. By contrast, the average annual removals estimate (growing stock on timberland, adjusted by not counting diversion and mortality removals) derived from FIA plots for the 2004 inventory was 261 million ft^3. Although TPO estimates are higher, it is difficult to determine which estimate more accurately reflects actual removals because the estimates are based on different designs measuring related but different variables.

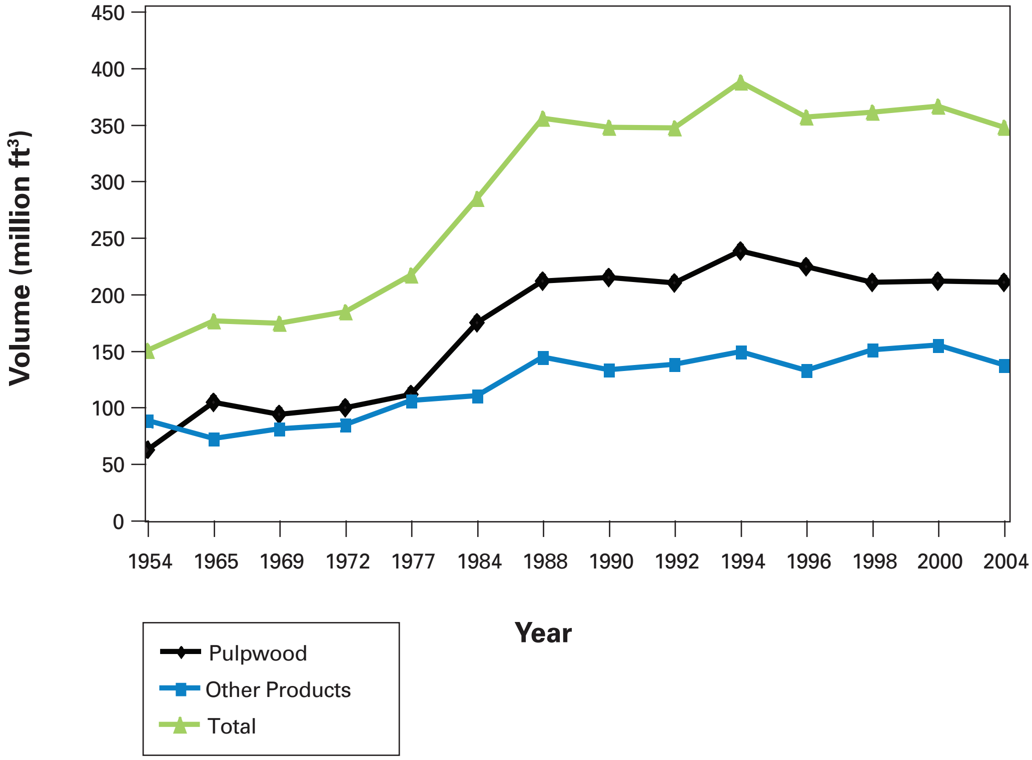


Figure 96.—Production of industrial roundwood by product, Michigan, 1954-2004.

What we found

Wood material harvested for industrial roundwood on Michigan's forests exceeded 442 million ft^3 in 2004. Seventy-eight percent was used for products, 17 percent was logging slash, and 5 percent was logging residues. By product, pulpwood accounted for 61 percent of all the roundwood produced, saw logs represented 35 percent and veneers, industrial fuelwood, and other miscellaneous items accounted for 4 percent (Fig. 97). About 41 percent of the roundwood produced in Michigan was from the northern Lower Peninsula (Fig. 98).

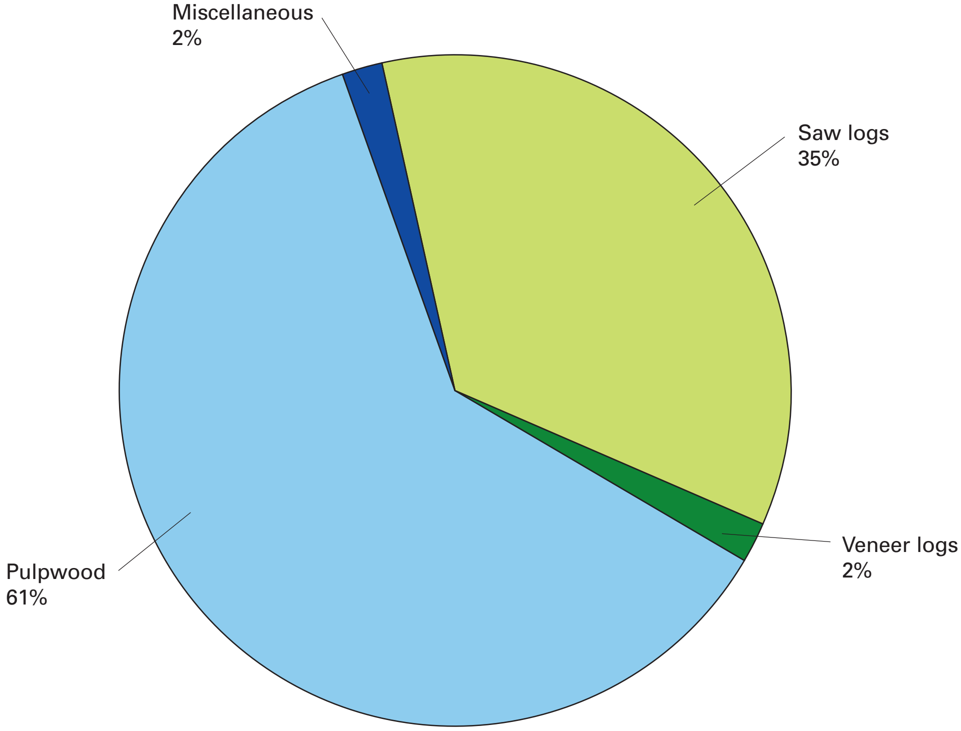


Figure 97.—Percentage of industrial roundwood production by product, Michigan, 2004.

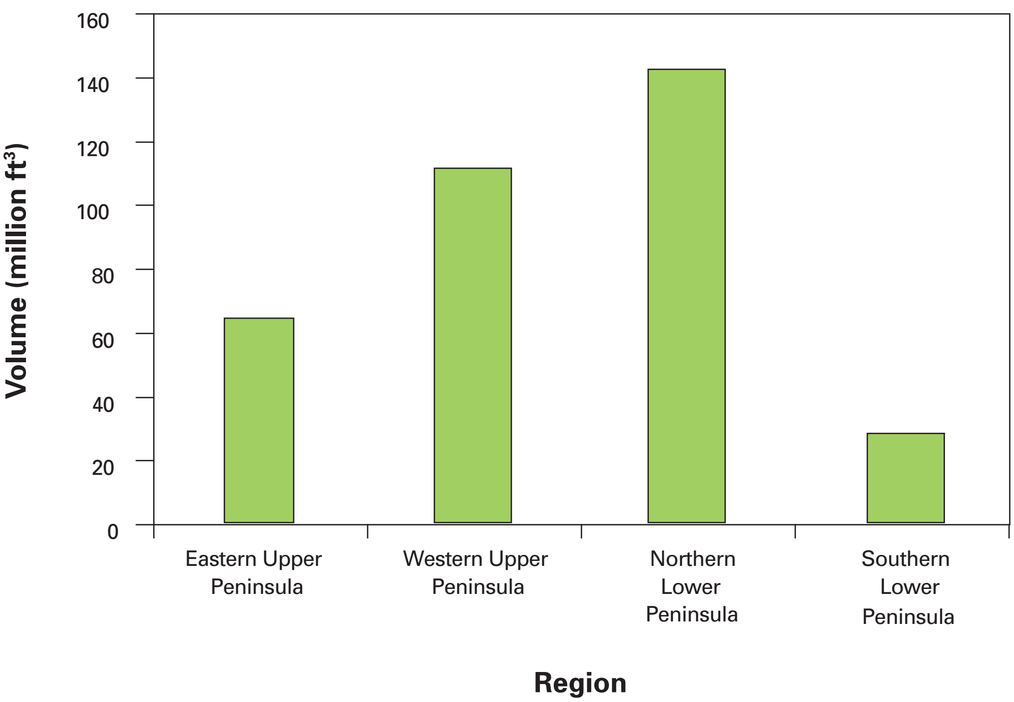
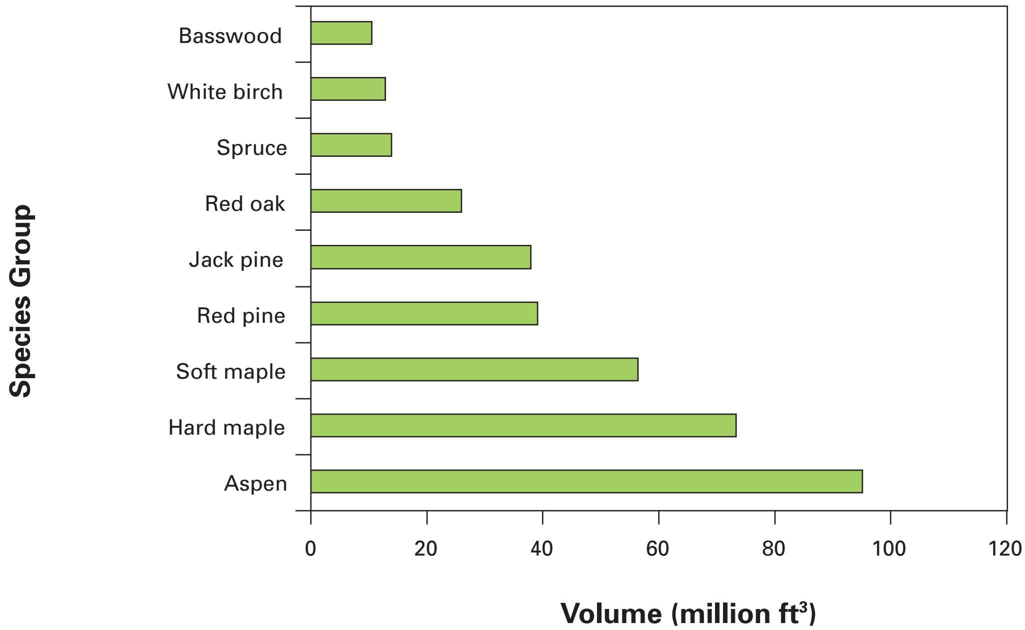


Figure 98.—Industrial roundwood production by region, Michigan, 2004.

The top six hardwood species groups harvested were aspen (23 percent), hard maple (17 percent; e.g., sugar maple), soft maple (13 percent; e.g., red maple), red oak (6 percent), paper birch (3 percent) and basswood (2 percent). Red pine (9 percent), jack pine (8 percent) and spruce (3 percent) were the top three softwood species groups harvested (Fig. 99).

Figure 99.—Industrial roundwood harvested by select species group, Michigan, 2004.



In 2004, more than 92 percent of Michigan's saw-log production (saw logs from Michigan's forests) went to Michigan mills. The remaining 8 percent was exported to mills in Wisconsin (4 percent), Indiana (3 percent), Minnesota, Ohio, and Canada (Fig. 100). Saw-log mill receipts from the 2004 survey tell us that 87 percent of the wood coming into the mills is home grown. Exports from Wisconsin equaled 12 percent of the mill receipts with the remaining 1 percent coming from Canada, Minnesota, Indiana, Ohio, and Kentucky (Fig. 101).

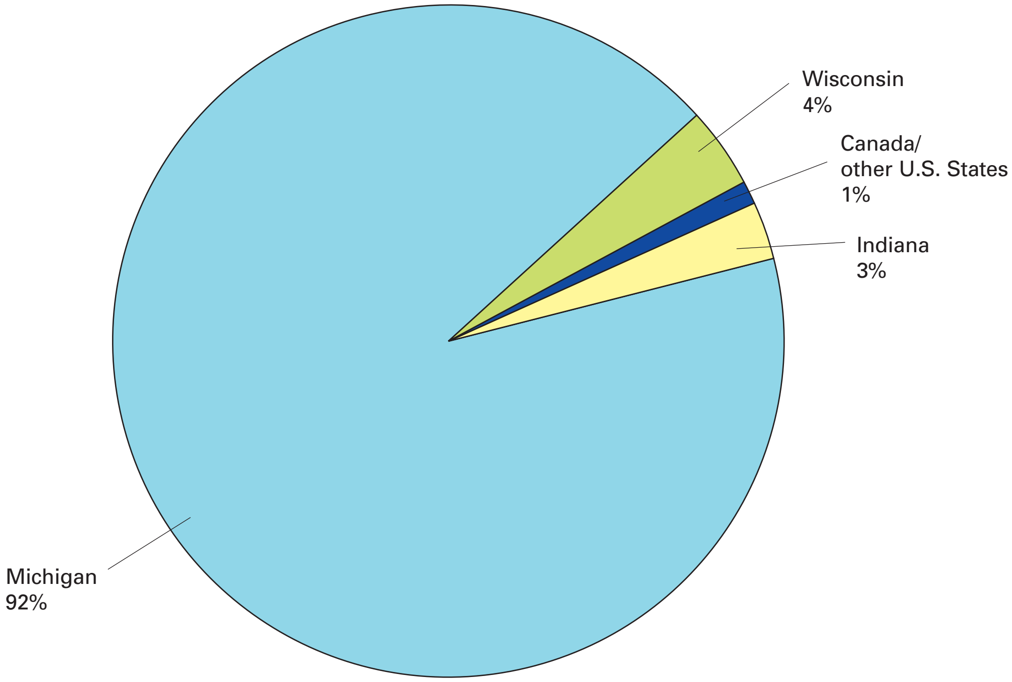


Figure 100.—Percentage of saw-log production by state/country of destination, Michigan, 2004.

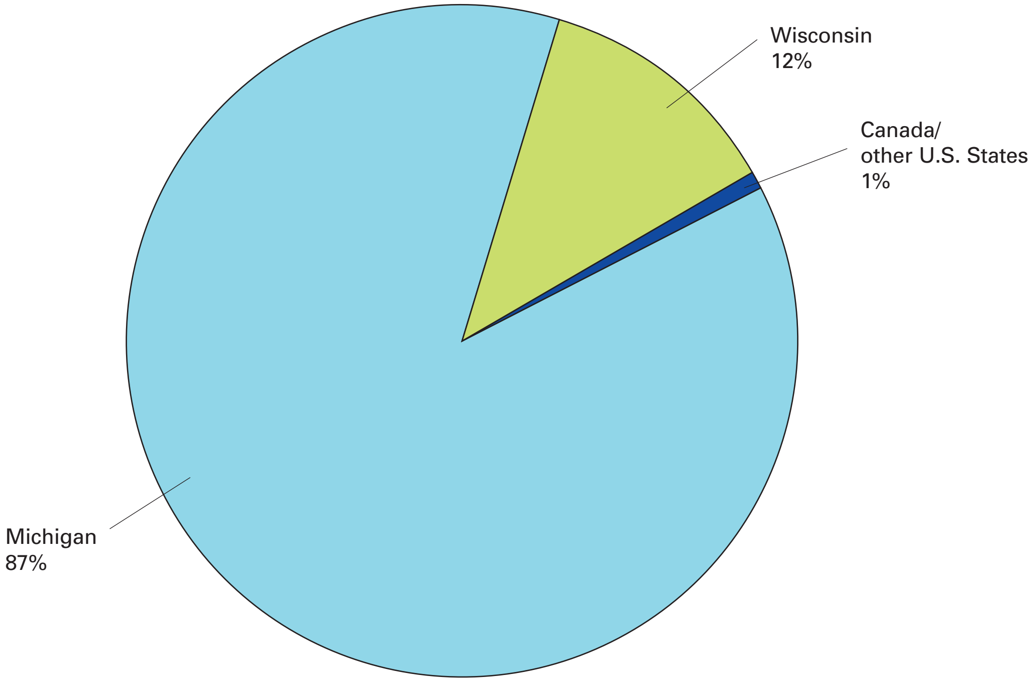


Figure 101.—Percentage of saw-log receipts by origin, Michigan, 2004.

Between 2000 and 2004 there was a 26-percent decrease in veneer-log production, due in part to the closure of one of the five veneer mills in Michigan. Pulpwood production remained steady, showing only a decrease of less than 1 percent.

More than 2.6 million cords of pulpwood were produced on Michigan forest lands in 2004, of which 2.36 million cords (89 percent) remained in Michigan. Wisconsin mills imported slightly more than 213,000 cords of this pulpwood (8 percent) and Minnesota mills imported slightly more than 59,000 cords (2 percent). The remaining 1 percent went to mills in Canada and other U.S. States (Fig. 102). Pulpwood mill receipts showed cordwood at just over 2.7 million cords with 88 percent produced in Michigan. Wisconsin exported 9 percent of the total cordwood receipts with Canada exporting 3 percent (Fig. 103).

Figure 102.—Percentage of pulpwood production by state/country of destination, Michigan, 2004.

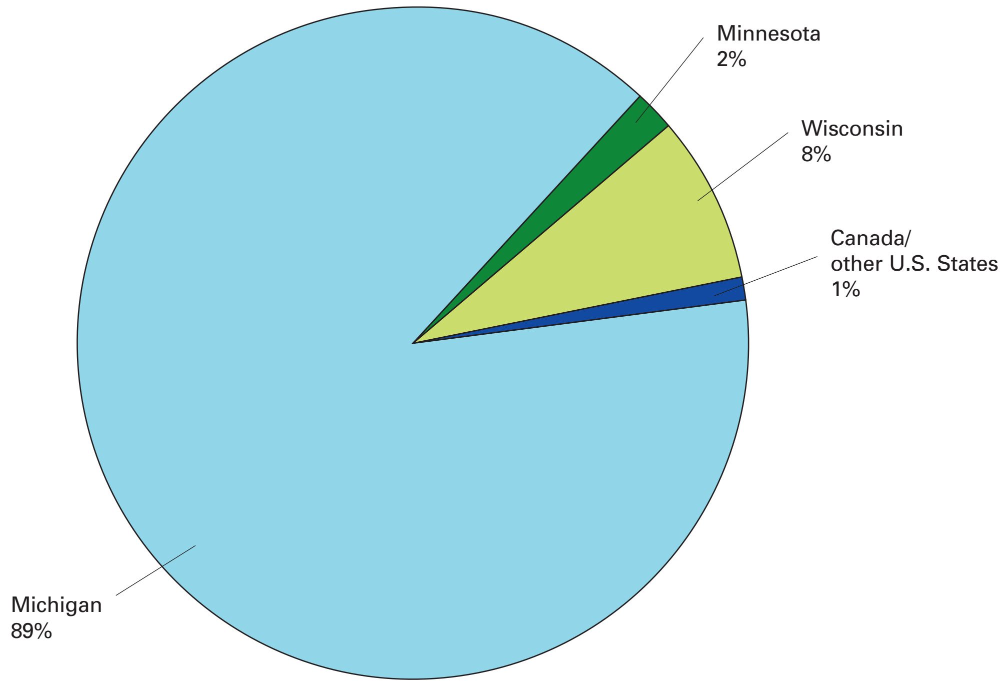
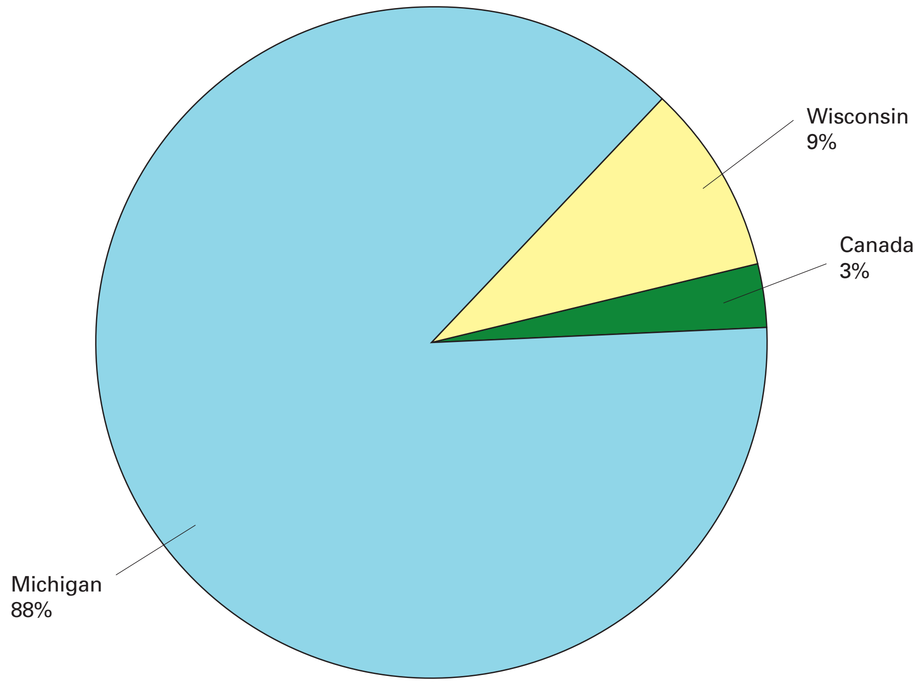


Figure 103.—Percentage of pulpwood mill receipts by origin, Michigan, 2004.



Accoding to mill surveys, the number of active primary wood-using mills decreased from 305 in 2000 to 246 in 2004. Medium sawmills (lumber production of 1 to 5 million board feet annually) and small sawmills (lumber production less than 1 million board feet annually) decreased by 27 and 21 mills, respectively (Table 10). Large sawmills (lumber production exceeding 5 million board feet annually) actually increased by two mills between surveys.

Table 10.—Active primary wood-using mills, Michigan, 2000 and 2004 (pulp mills include particle board plants, OSB, and waferboard; other mills include posts, poles, piling, cooperage, shavings, and mine timber).

Kind of mill	Size	2000	2004
Sawmill	Large	35	37
Sawmill	Medium	81	54
Sawmill	Small	131	110
Pulp mill		12	12
Veneer mill		5	4
Other mill		41	29
Total		**305**	**246**

What this means

As in the past, the northern Lower Peninsula was the largest producer of roundwood with more than 141 million ft^3; the western Upper Peninsula produced more than 110 million ft^3. Industrial roundwood production for the two units was more than 72 percent of the State total. This is not surprising as the northern Lower Peninsula and western Upper Peninsula account for the majority of timberland with 7.2 and 4.6 million acres, respectively.

Aspen is the most commonly harvested species in the State. This is partly due to the strong competitive nature of the pulp, paper, and OSB/panel industries. The relatively large amount of hard and soft maple produced likely is a function of both its availability and its desirability as a commercial species (lumber, veneer, and pulpwood). More than 837,000 cords of maple (hard and soft) were produced for pulpwood in 2004, only 9,000 fewer cords than aspen harvested for pulpwood.

Mill receipts and production indicate that Michigan is processing most of its own wood resources. Since the late 1980s, receipts and production have remained fairly constant while the number of small and medium-size mills has been declining. There is an abundance of sustainable wood resources in the State based on the ratio of net growth to removals (see Fig. 49) and current volumes (see Fig. 25). Net growth, removals, and volume indicate that an increase in the harvest of timber products in Michigan would be biologically sustainable. Although, this opportunity to increase harvest is influenced by difficult-to-measure factors such as landowner objectives, stumpage prices, and available markets. Parcelization, stumpage price and market volatility, and the number of wood-processing mills decreasing make it more difficult to increase the harvest level in Michigan.

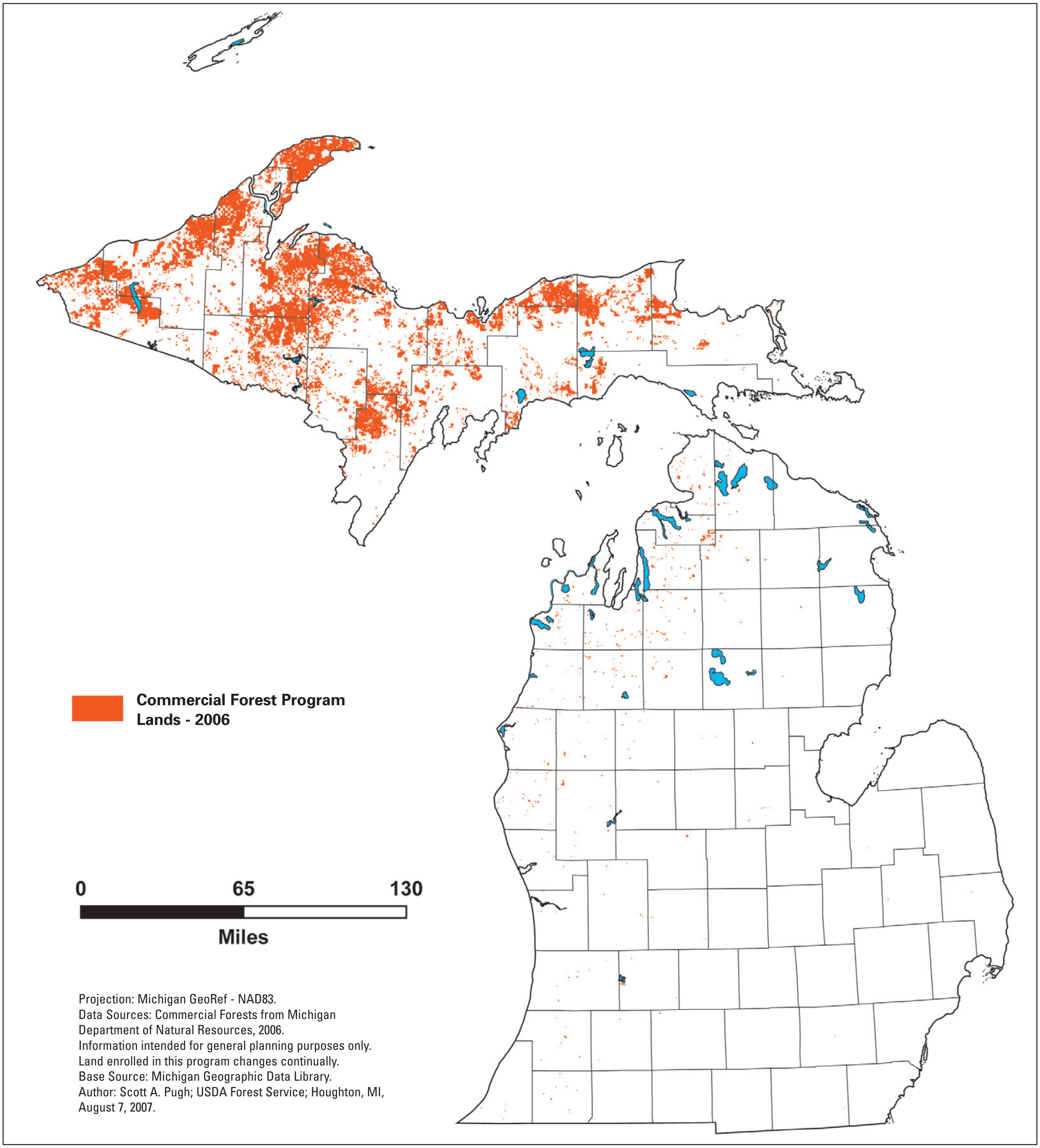
Forest Stewardship

The economic benefits of Michigan's forests are enormous as more than $12 billion and 150,000 jobs contribute to Michigan's economy annually through forest-based industries, recreation, and tourism (Michigan Dep. Nat. Resour. 2007a). Quality forest stewardship can help assure that these benefits will continue into the future.

Michigan has many programs and groups that foster sound forest stewardship. The State of Michigan and the USDA Forest Service offer a number of incentives and resources (http://www.michigan.gov/dnr/0,1607,7-153-30301---,00.html). The Commercial Forest (CF) and Qualified Forest Property Programs are available through the Forest, Mineral, and Fire Management Division of the Michigan Department of Natural Resources. They provide tax incentives to manage private forest land. The acreage in the CF Program changes (Fig. 104) but the most recent estimate is about 2.2 million acres (Michigan Dep. Nat. Resour. 2006a).

Boy scout planting a tree. Photo by Lynn Betts, USDA Natural Resources Conservation Service, http://photogallery.nrcs.usda.gov/index.asp.

Figure 104.—Commercial Forest Program lands, Michigan, 2006.



The Forest Stewardship Program (FSP) is operated by the U.S. Forest Service and the Forest, Mineral, and Fire Management Division of the Michigan Department of Natural Resources. FSP provides cost-share assistance for developing a forest stewardship plan written for nonindustrial, private forest lands, as well as educational, technical, and financial assistance to private forest owners. The Forest Legacy Program is another partnership between the Forest Service and the State of Michigan. This voluntary program protects private and environmentally important forest land from diversion to nonforest.

The Natural Resources Conservation Service alone or in combination with other agencies also offers programs that can include forest improvement (http://www.nrcs.usda.gov/PROGRAMS/). These programs change over time but the Environmental Quality Incentives Program, Wetland Reserve Program, Wildlife Habitat Incentives Program, Conservation Reserve Program, and Conservation Reserve Enhancement Program have been offered in the past.

There are many private, nonprofit conservancies that assist landowners in making forest stewardship decisions and keeping land as forest. One of the most well known, The Nature Conservancy (TNC), helped establish a partnership with the State of Michigan and the Forestland Group, LLC to retain 271,000 acres in forest land through a working forest easement and acquisition in 2005. TNC also brokered a land transaction between International Paper and the Michigan Department of Natural Resources in 2002. This transaction placed 11,000 acres of land at the tip of the Keweenaw Peninsula under State ownership.

A number of groups promote sustainable forest management. The Michigan Society of American Foresters, Michigan State University Extension, Michigan Forest Association, Michigan Forest Resource Alliance, Michigan Forest Products Council, Michigan Urban and Community Forestry Council, Michigan Department of Agriculture Environmental Stewardship Division, Michigan Association of Timbermen, Michigan Professional Loggers Council, Michigan Association of Conservation Districts, and Michigan Tree Farm System are a few of these organizations.

A stamp of sustainability is available to landowners through various certification programs. The Forest Stewardship Council and the Sustainable Forestry Initiative are two primary channels that offer certification. Other certification programs include the American Tree Farm System Certification and Michigan's Master Logger Certification. An investigation by a third party ensures that the entity meets forest management standards that are environmentally, socially, and economically sustainable.

Data Sources and Techniques

Estivant Pines, Keweenaw County, Michigan. Photo used with permission by Neil Harri, neilharriphotos.com.

Forest Inventory

Hansen and Brand (2006) described the annualized inventory methods for Michigan. Since the 1993 inventory, several changes in FIA inventory methods have improved the quality of the inventory and have met increasing demands for timely information. The most substantial change between inventories has been the shift from periodic to annual inventories. Historically, FIA inventoried each state on a cycle that averaged about 12 years. However, the need for timely and consistent data across large geographical regions along with national legislative mandates resulted in FIA implementing an annual inventory. This system was initiated in Michigan in 2000.

With the Northern Research Station-FIA (NRS-FIA) annual inventory system, about one-fifth of all field plots are measured in any single year. After 5 years, the entire inventory is completed. After this initial 5-year period, NRS-FIA will report and analyze results using a moving 5-year average. For example, NRS-FIA will be able to generate inventory results for 2001 through 2005 or for 2002 through 2006.

Other noteworthy changes between inventories include implementing new remote sensing technology as well as a new field-plot configuration and sample design, and gathering additional remotely sensed and field data. The use of new remote sensing technology allows NRS-FIA to use classifications of Multi-Resolution Land Characterization (MRLC) data and other remote-sensing products to stratify the total area of Michigan, thus improving estimates.

New algorithms were used in the 2004 inventory to assign stocking, forest type, and stand-size classes to each condition observed on a plot. These algorithms are being used nationwide by FIA to provide consistency from state to state.

Sampling Phases

The 2004 Michigan survey was conducted in three phases. In the first phase, satellite imagery was used to stratify the State and aerial photography was used to select plots for measurement. The second phase entailed measuring the traditional suite of mensurational variables. The third phase focused on a suite of variables related to forest health.

Land that could not be sampled included private tracts where field personnel were unable to obtain permission to measure a plot or the plot access was too hazardous. The methods used in preparing this report were adjusted to account for such sites.

Phase 1

For the Michigan inventory, FIA used a classification of satellite imagery for stratification. The imagery was used to form two initial strata: forest and nonforest. Pixels within 60 m (2 pixel widths) of a forest/nonforest boundary formed two additional strata: forest edge and nonforest edge. Forest pixels within 60 m of the boundary on the forest side were classified as forest edge and pixels within 60 m of the boundary on the nonforest side were classified as nonforest edge. All strata were divided into public or private ownership based on information available in the Protected Lands Database (DellaSala et al. 2001). The estimated population total for a variable is the sum across all strata of the product of each stratum's area (from the pixel count) and the mean per-unit area (from plot measurements) of the variable for the stratum.

Phase 2

Phase 2 of the inventory consisted of the measurement of an annual sample of field plots in Michigan. Current FIA precision standards for annual inventories require a sampling intensity of 1 plot for about every 6,000 acres. FIA has tessellated the entire United States using nonoverlapping hexagons, each of which contains 5,937 acres (McRoberts 1999). An array of field plots was established by selecting one plot from each hexagon based on the following rules: (1) if a Forest Health Monitoring (FHM) plot (Mangold 1998) fell within a hexagon, it was selected as the grid plot; (2) if no FHM plot fell within the hexagon, the existing NRS-FIA plot nearest the hexagon center was selected as the grid plot; and (3) if neither FHM nor existing NRS-FIA plots fell within the hexagon, a new NRS-FIA grid plot was established (McRoberts 1999). This array of plots is designated the Federal base sample and is considered an equal probability sample; its measurement in Michigan is funded by the Federal government. The State of Michigan provided additional funds to intensify the sampling of phase 2 plots. Instead of a single intensity survey (1 plot approximately every 6,000 acres), a triple intensity survey was conducted (1 plot approximately every 2,000 acres). The 2004 inventory collected data from 18,910 phase 2 plots; 10,355 of these plots were forest-land plots.

The total Federal base sample was divided systematically into five interpenetrating, nonoverlapping subsamples or panels. 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 can be considered an independent random sample of all land in the State. Field crews measured vegetation on plots forested at the time of the last inventory and on plots classified as forest by trained photointerpreters using aerial photos or digital orthophotoquads.

Phase 3

NRS-FIA has two categories of field measurements: Phase 2 and Phase 3 (formally FHM plots) field plots. Both types are systematically distributed both geographically and temporally. Phase 3 plots are measured with the full array of FHM vegetative and health variables as well as the full suite of measures associated with Phase 2 plots. Phase 3 plots must be measured between June 1 and August 30 to accommodate measurement of nonwoody understory vegetation, ground cover, soils, and other variables. The complete 5-year annual inventory of Michigan includes 215 forested Phase 3 plots. On the remaining plots, only variables that can be measured throughout the entire year are collected. In Michigan, the complete 5-year annual inventory includes 10,355 forested Phase 2 plots. Of these, 10,069 plots were established on timberland.

The national FIA 4-subplot cluster configuration was first used for data collection in Michigan in 2000 and will be used in subsequent years (Fig. 105). The national plot configuration requires mapping all forest conditions on each plot. Due to the small sample size each year, precision associated with estimates of components of change such as mortality will be relatively low. Consequently, we report components of change only after multiple annual panels have been measured. With completion of the annual inventory in 2004, the full range of change estimates now is available.

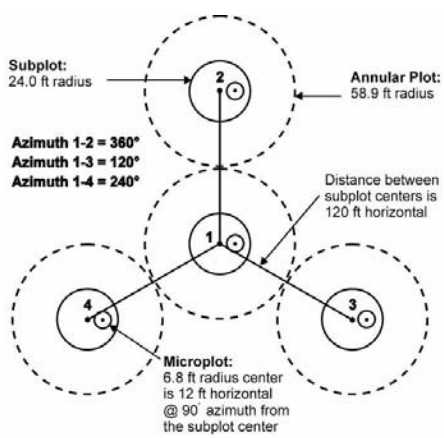


Figure 105.—National FIA plot design (from Bechtold and Patterson 2005).

The overall plot layout for the new configuration 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. The center of the new plot is located at the same point as the center of the previous plot if a previous plot existed at the location. Trees that are 5 inches and larger in d.b.h. 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 due east of the center of each of the four subplots. Forest conditions on each subplot are recorded. Factors that differentiate forest conditions are changes in forest type, stand-size class, land use, regeneration status, reserved status, ownership, and density. Each condition on every subplot is identified, described, and mapped. In general, the minimum area for classification must be at least 1 acre in size and 120 feet in width. There are a number of more specific area criteria for defining forest land near streams, rights-of-way, and shelterbelt strips (North Cent. Res. Stn. 2003).

Field-plot measurements are combined with Phase 1 estimates in the compilation process and table production. A number of tables can be produced with data and tools at http://www.fia.fs.fed.us/tools-data/default.asp and http://www.fia.fs.fed.us/tools-data/other/default.asp. The primary web tool is FIDO or Forest Inventory Data Online (http://199.128.173.26/fido/index.html). For additional information, contact: Program Manager, Northern Research Station, Forest Inventory and Analysis, 1992 Folwell Avenue, St Paul, MN 55108.

Mapping Procedures

Maps in this report were constructed by various methods and from a number of data sources. Data sources are listed with each map. Many of the maps have a mask applied so that only forest land is shown. Forest-land delineation comes from the 2001 National Land Cover Dataset (NLCD). The Michigan Geographic Data Library supplied most of the base themes like State and county boundaries. When multiple states are presented, base themes also are from the Environmental Systems Research Institute. Hexagon based maps utilize 160,000-acre hexagons from the U.S. Environmental Protection Agency's (EPA) Environmental Monitoring and Assessment Program.

Information on volume, trees per acre, basal area, and forest type were mapped as continuous variables using data from FIA plots that are distinct points. As noted on the maps, we used a technique known as nearest neighbor imputation to accomplish this. Our methods were adapted from Ohmann and Gregory (2002). We were able to assign actual field-measured estimates to surrounding areas using the FIA plot data, 250-m Moderate Resolution Imaging Spectroradiometer imagery, 30-m NLCD classified imagery, and climate and topographic data.

Besides the U.S. Forest Service and others already mentioned, data originated from a number of other sources. The circa 1800 land cover is from the Michigan Natural Features Inventory. The dominant soil orders are from the U.S. General Soil Map of the National Cooperative Soil Survey (Soil Survey Staff 2006). The point-source O_3 is from the EPA. Finally, additional boundary information is from the USDI Fish and Wildlife Service and U.S. National Park Service.

NLCD Imagery

Derived from Landsat Thematic Mapper satellite data (30-m pixel), the NLCD is a land-cover classification scheme (21 classes) applied consistently across the United States by the U.S. Geological Survey (USGS) and EPA. NLCD was developed from data acquired by the MRLC, 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, Forest Service, and National Oceanic and Atmospheric Administration.

National Woodland Owner Survey

The National Woodland Owner Survey (NWOS) is conducted annually by FIA to increase our understanding of private woodland owners (Butler and Leatherberry 2004, Butler 2008), specifically:

- Who are the forest owners of the United States?
- Why do they own forest land?
- What do they intend to do with it?

Each year, questionnaires are mailed to individuals and private groups who own woodlands where FIA has established forest inventory plots. Twenty percent of these ownerships (about 50,000) are contacted. More detailed questionnaires are mailed in years that end in 2 or 7 to coincide with national census, inventory, and assessment programs. Additional results from NWOS can be found at http://www.fia.fs.fed.us/nwos/ and details about NWOS sampling design, estimates, and analysis procedures are available in Butler et al. (2005).

Insects, Diseases, and Invasive Plants

Information on insects, pathogens, and invasive plant species affecting Michigan's forests was gathered from the FHM program and the Forest Service's Northeastern Area, State and Private Forestry. To view and download aerial survey information for states in the North-central United States, visit http://na.fs.fed.us/fhp/ta/av/index.shtm. Additional information on the FHM program is available at http://fhm.fs.fed.us/. For additional information on invasives, access the Michigan Invasive Plant Council website (http://invasiveplantsmi.org/) and the National Invasive Species Information Center website (http://www.invasivespeciesinfo.gov). For additional information on the health of Michigan's forests, contact the Michigan Department of Natural Resources (http://www.michigan.gov/dnr/0,1607,7-153-30301_30505_30830---,00.html).

Timber Products Output Inventory

The Timber Product Output survey is a cooperative effort of the Forest, Mineral, and Fire Management Division of the Michigan Department of Natural Resources (MIDNR) and the Northern Research Station (NRS). The MIDNR canvassed all primary wood-using mills within the State using mail questionnaires supplied by the NRS. These questionnaires are designed to determine the size and composition of Michigan's primary wood-using industry, its use of roundwood, and its generation and disposition of wood residues. The MIDNR then contacted nonresponding mills through additional mailings, telephone calls, and personal contacts until achieving nearly a 100-percent response. Completed questionnaires were forwarded to NRS for compilation and analysis.

As part of data processing and analysis, all industrial roundwood volumes reported on the questionnaires were converted to standard units of measure using regional conversion factors. Timber removals by source of material and harvest residues generated during logging were estimated from standard product volumes using factors developed from logging utilization studies previously conducted by NRS. Data on Michigan's industrial roundwood receipts were added to a regional timber removals database and supplemented with data on out-of-state uses of Michigan's roundwood to provide a complete assessment of timber product output for Michigan.

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Appendix

Tree Species in Michigan (2004)

The following are tree species that were on sample plots; this is not a complete list of tree species known in Michigan.

ailanthus	*Ailanthus altissima*
American basswood	*Tilia americana*
American beech	*Fagus grandifolia*
American chestnut	*Castanea dentata*
American elm	*Ulmus americana*
American hornbeam, musclewood	*Carpinus caroliniana*
American mountain-ash	*Sorbus americana*
American sycamore	*Platanus occidentalis*
apple spp.	*Malus spp.*
Austrian pine	*Pinus nigra*
balsam fir	*Abies balsamea*
balsam poplar	*Populus balsamifera*
Bebb willow	*Salix bebbiana*
bigtooth aspen	*Populus grandidentata*
bitternut hickory	*Carya cordiformis*
black ash	*Fraxinus nigra*
black cherry	*Prunus serotina*
black locust	*Robinia pseudoacacia*
black maple	*Acer nigrum*
black oak	*Quercus velutina*
black spruce	*Picea mariana*
black walnut	*Juglans nigra*
black willow	*Salix nigra*
blackgum	*Nyssa sylvatica*
blue ash	*Fraxinus quadrangulata*
blue spruce	*Picea pungens*
boxelder	*Acer negundo*
buckeye, horsechestnut spp.	*Aesculus spp.*

bur oak	*Quercus macrocarpa*
butternut	*Juglans cinerea*
cherry and plum spp.	*Prunus spp.*
chestnut oak	*Quercus prinus*
chinkapin oak	*Quercus muehlenbergii*
chokecherry	*Prunus virginiana*
cockspur hawthorn	*Crataegus crus-galli*
common serviceberry	*Amelanchier arborea*
cottonwood and poplar spp.	*Populus spp.*
cucumbertree	*Magnolia acuminata*
Douglas-fir	*Pseudotsuga menziesii*
downy hawthorn	*Crataegus mollis*
eastern cottonwood	*Populus deltoides*
eastern hemlock	*Tsuga canadensis*
eastern hophornbeam	*Ostrya virginiana*
eastern redbud	*Cercis canadensis*
eastern redcedar	*Juniperus virginiana*
eastern white pine	*Pinus strobus*
European alder	*Alnus glutinosa*
flowering dogwood	*Cornus florida*
green ash	*Fraxinus pennsylvanica*
hackberry	*Celtis occidentalis*
hawthorn spp.	*Crataegus spp.*
honeylocust	*Gleditsia triacanthos*
jack pine	*Pinus banksiana*
Kentucky coffeetree	*Gymnocladus dioicus*
larch spp.	*Larix spp.*
mimosa, silktree	*Albizia julibrissin*
mockernut hickory	*Carya alba*
mountain maple	*Acer spicatum*
northern catalpa	*Catalpa speciosa*
northern pin oak	*Quercus ellipsoidalis*

northern red oak	*Quercus rubra*
northern white-cedar	*Thuja occidentalis*
Norway spruce	*Picea abies*
Ohio buckeye	*Aesculus glabra*
paper birch	*Betula papyrifera*
pawpaw	*Asimina triloba*
peachleaf willow	*Salix amygdaloides*
pecan	*Carya illinoinensis*
pignut hickory	*Carya glabra*
pin cherry	*Prunus pensylvanica*
pin oak	*Quercus palustris*
quaking aspen	*Populus tremuloides*
red maple	*Acer rubrum*
red mulberry	*Morus rubra*
red pine	*Pinus resinosa*
redcedar/juniper spp.	*Juniperus spp.*
river birch	*Betula nigra*
rock elm	*Ulmus thomasii*
Russian-olive	*Elaeagnus angustifolia*
sassafras	*Sassafras albidum*
scarlet oak	*Quercus coccinea*
Scotch pine	*Pinus sylvestris*
serviceberry spp.	*Amelanchier spp.*
shagbark hickory	*Carya ovata*
shellbark hickory	*Carya laciniosa*
shingle oak	*Quercus imbricaria*
Shumard oak	*Quercus shumardii*
Siberian elm	*Ulmus pumila*
silver maple	*Acer saccharinum*
slippery elm	*Ulmus rubra*
striped maple	*Acer pensylvanicum*

sugar maple	*Acer saccharum*
swamp white oak	*Quercus bicolor*
tamarack (native)	*Larix laricina*
walnut spp.	*Juglans spp.*
white ash	*Fraxinus americana*
white mulberry	*Morus alba*
white oak	*Quercus alba*
white spruce	*Picea glauca*
white willow	*Salix alba*
willow spp.	*Salix spp.*
winged elm	*Ulmus alata*
yellow birch	*Betula alleghaniensis*
yellow-poplar	*Liriodendron tulipifera*

Insects and Diseases

The following is a list of insects and diseases mentioned in this report. It is not a complete list of insects and diseases in Michigan and includes species that have not been detected in Michigan.

annosus root disease	*Heterobasidion annosum*
Armillaria root rot	*Armillaria spp.*
ash yellows	mycoplasmalike organisms et al.
Asian longhorned beetle	*Anoplophora glabripennis*
balsam woolly adelgid	*Adelges piceae*
beech bark disease	*Cryptococcus fagisuga* and *Nectria*
black ash decline	ash yellows et al.
bronze birch borer	*Agrilus anxius*
cherry scallop shell moth	*Hydria prunivorata*
chestnut blight	*Cryphonectria parasitica*

diplodia blight	*Diplodia pinea*
Dutch elm disease	*Ophiostoma ulm* and bark beetles
eastern larch beetle	*Dendroctonus simplex*
emerald ash borer	*Agrilus planipennis*
fall cankerworm	*Alsophila pometaria*
fall Webworm	*Hyphantria cunea*
forest tent caterpillar	*Malacosoma disstria*
gypsy moth	*Lymantria dispar*
hemlock wooly adelgid	*Adelges tsugae*
jack pine budworm	*Choristoneura pinus*
larch casebearer	*Coleophora laricella*
large aspen tortrix	*Choristoneura conflictana*
linden looper	*Erranis tiliaria*
maple trumpet skeletonizer	*Epinotia aceriella*
oak decline	*Armillaria mellea, Agrilus bilineatus* et al.
oak skeletonizer	*Bucculatrix ainsliella*
oak wilt	*Ceratocystis fagacearum*
pine needleminer	*Exoteleia pinifoliella*
red-headed pine sawfly	*Neodiprion lecontei*
sirex wooodwasp	*Sirex noctilio*
spruce Budworm	*Choristoneura fumiferana*
sudden oak death	*Phytophthora ramorum*
two-lined chestnut borer	*Agrilus bilineatus*

Glossary

Average annual mortality: The average annual change in mortality of trees during the period between inventories. This estimate can be provided in cubic feet for live and growing-stock trees that died or in board feet for sawtimber trees that died.

Average annual net growth: The average annual change in the volume of trees during the period between inventories. Components include the change in volume of trees that have met the minimum size requirements over the inventory period, plus the volume of trees reaching the minimum size during the period (ingrowth), minus the volume of trees that died during the period, minus the volume of cull during the period. Mortality removals (trees killed in the harvesting process and left on site) and diversion removals (trees removed from the forest-land base due to a change from forest to nonforest land) are not included. This estimate can be provided in cubic feet for live and growing-stock trees or in board feet for sawtimber trees.

Average annual removals: The average annual change in removals of trees during the period between inventories. The estimate includes harvest removals, mortality removals (trees killed in the harvesting process and left on site), and diversion removals (trees removed from the forest-land base due to a change from forest to nonforest land). This estimate can be provided in cubic feet for live and growing-stock trees or in board feet for sawtimber trees.

Basal area: Tree area in square feet of the cross section at breast height of a single tree. When the basal areas of all trees in a stand are summed, the result usually is expressed as square feet of basal area per acre.

Bioindicator species: A tree, woody shrub, or nonwoody herb species that responds to ambient levels of ozone pollution with distinct visible foliar symptoms that are easy to diagnose.

Biomass: The aboveground volume of live trees (including bark but excluding foliage) reported in dry tons (dry weight). Biomass has four components:

> **Bole:** Biomass of a tree from 1 foot above the ground to a 4-inch top outside bark or to a point where the central stem breaks into limbs.
>
> **Tops and limbs:** Total biomass of a tree from a 1-foot stump minus the bole.
>
> **1-to 5-inch trees:** Total aboveground biomass of a tree from 1 to 5 inches in d.b.h.
>
> **Stump:** Biomass of a tree 5 inches d.b.h. and larger from the ground to a height of 1 foot.

Bulk density: The mass of soil per unit volume. A measure of the ratio of pore space to solid materials in a given soil. It is expressed in units of grams per cubic centimeter of oven dry soil.

Coarse woody debris (CWD): Dead branches, twigs, and wood splinters 3.0 inches in diameter and larger measured at the smallest end.

Commercial species: Tree species suitable for industrial wood products.

Compacted live crown ratio: The percent of the total length of the tree that supports a full, live crown. To determine compacted live crown ratio for trees that have uneven length crowns, lower branches are visually transferred to fill holes in the upper portions of the crown, until a full, even crown is created.

County and municipal: An ownership class of public lands owned by counties or local public agencies, or lands leased by these governmental units for more than 50 years. Also known as local government.

Cropland: Land under cultivation within the last 24 months, including cropland harvested, crop failures, cultivated summer fallow, idle cropland used only for pasture, orchards, active Christmas tree plantations indicated by annual shearing, nurseries, and land in soil improvement crops but excluding land cultivated in developing improved pasture.

Crown: The part of a tree or woody plant bearing live branches or foliage.

Crown dieback: Recent mortality of branches with fine twigs, which begins at the terminal portion of a branch and proceeds toward the trunk. Dieback is considered only when it occurs in the upper and outer portions of the tree. When whole branches are dead in the upper crown, without obvious signs of damage such as breaks or animal injury, it is assumed the branches died from the terminal portion of the branch. Dead branches in the lower portion of the live crown are assumed to have died from competition and shading.

Cull tree: A live tree, 5.0 inches in d.b.h. or larger, that is unmerchantable for saw logs now or prospectively because of rot, roughness, or specie. (see definitions for rotten and rough trees.)

Decay class: Qualitative assessment of stage of decay (5 classes) of coarse woody debris based on visual assessments of color of wood, presence/absence of twigs and branches, texture of rotten portions, and structural integrity.

Diameter class: A classification of trees based on diameter outside bark measured at breast height (4-1/2 feet above ground). D.b.h. is the common abbreviation for "diameter at breast height." With 2-inch diameter classes, the 6-inch class, for example, includes trees 5.0 through 6.9 inches d.b.h.

Down woody material (DWM): Woody pieces of trees and shrubs that have been uprooted (no longer supporting growth) or severed from their root system, not self-supporting, and lying on the ground.

Duff: A soil layer dominated by organic material derived from the decomposition of plant and animal litter and deposited on either an organic or a mineral surface. This layer is distinguished from the litter layer in that the original organic material has undergone sufficient decomposition that the source of this material (e.g., individual plant parts) no longer can be identified.

Effective cation exchange capacity (ECEC): The sum of cations that a soil can adsorb in its natural pH. It is expressed in units of centimoles of positive charge per kilogram of soil.

Federal: An ownership class of public lands owned by the U.S. Government.

Fiber products: Products derived from wood and bark residues, such as pulp, composition board products, and wood chips for export.

Fine materials: Wood residues not suitable for chipping, such as planer shavings and sawdust.

Fine woody debris (FWD): Dead branches, twigs, and wood splinters 0.1 to 2.9 inches in diameter.

Forest industry: An ownership class of private lands owned by companies or individuals operating wood-using plants.

Forest land: Land at least 10-percent stocked by forest trees of any size, including land that formerly had such tree cover and that will be naturally or artificially regenerated. Forest land includes transition zones, such as areas between heavily forested and nonforested lands that are at least 10-percent stocked with forest trees and forest areas adjacent to urban and builtup lands. Also included are pinyon-juniper and chaparral areas in the West and afforested areas. The minimum area for classification of forest land is 1 acre. Roadside, streamside, and shelterbelt strips of trees must have a crown width of at least 120 feet to qualify as forest land. Unimproved roads and trails, streams, and clearings in forest areas are classified as forest if less than 120 feet wide.

Forest type: A classification of forest land based on the species presently forming a plurality of the live-tree stocking. If softwoods predominate (50 percent or more), then the forest type will be one of the softwood types and vice versa for hardwoods. For the Eastern United States, there are mixed hardwood-pine forest types when the pine and/or redcedar (either eastern or southern) component is between 25 and 49 percent of the stocking. If the pine/redcedar component is less than 25 percent of the stocking, then one of the hardwood forest types is assigned. The following are common or well known forest types in the State of Michigan:

Jack pine: Associates – northern pin oak, bur oak, red pine, bigtooth aspen, paper birch, northern red oak, eastern white pine, red maple, balsam fir, white spruce, black spruce, and tamarack. Sites – dry to mesic sites. Softwood forest type that is a member of the white/red/jack pine forest-type group.

Red pine: Associates – eastern white pine, jack pine, red maple, northern red oak, white spruce, balsam fir, quaking aspen, bigtooth aspen, paper birch, northern pin oak. Sites – common on sandy soils but reaches best development on well drained sandy loam to loam soils. Softwood forest type that is a member of the white/red/jack pine forest-type group.

Eastern white pine/ eastern hemlock (includes Carolina hemlock): Associates – beech, sugar maple, basswood, red maple, yellow birch, gray birch, red spruce, balsam fir, black cherry, white ash, paper birch, sweet birch, northern red oak, white oak, chestnut oak, yellow-poplar, and cucumbertree. Sites – wide variety but favors cool locations, moist ravines, and north slopes. Softwood forest type that is a member of the white/red/jack pine forest-type group.

Eastern white pine: Associates – pitch pine, gray birch, aspen, red maple, pin cherry, white oak, paper birch, sweet birch, yellow birch, black cherry, white ash, northern red oak, sugar maple, basswood, hemlock, northern white-cedar, yellow-poplar, white oak, chestnut oak, scarlet oak, and shortleaf pine. Sites – wide variety but best development on well drained sands and sandy loams. Softwood forest type that is a member of the white/red/jack pine forest-type group.

Eastern hemlock (includes Carolina hemlock): Associates – white pine, balsam fir, red spruce, beech, sugar maple, yellow birch, basswood, red maple, black cherry, white ash, paper birch, sweet birch, northern red oak, and white oak. Sites – cool locations, moist ravines, and north and east slopes. Softwood forest type that is a member of the white/red/jack pine forest-type group.

Balsam fir: Associates – black, white, or red spruce; paper or yellow birch; quaking or bigtooth aspen, beech; red maple; hemlock; tamarack; black ash; or northern white-cedar. Sites – upland sites on low-lying moist flats and in swamps. Softwood forest type that is a member of the spruce/fir forest-type group.

White spruce: Associates – black spruce, paper birch, quaking aspen, red spruce, balsam fir, and balsam poplar. Sites – Transcontinental; grows well on calcareous and well-drained soils but is found on acidic rocky and sandy sites, and sometimes in fen peat lands along the maritime coast. Softwood forest type that is a member of the spruce/fir forest-type group.

Black spruce: Associates – white spruce, quaking aspen, balsam fir, paper birch, tamarack, northern white-cedar, black ash, and red maple. Sites – wide variety from moderately dry to very wet. Softwood forest type that is a member of the spruce/fir forest-type group.

Tamarack: Associates – black spruce, balsam fir, white spruce, northern white-cedar, and quaking aspen. Sites – found on wetlands and poorly drained sites. Softwood forest type that is a member of the spruce/fir forest-type group.

Northern white-cedar: Associates – balsam fir, tamarack, black spruce, white spruce, red spruce, black ash, and red maple. Sites – mainly occurs in swamps but also in seepage areas, limestone uplands, and old fields. Softwood forest type that is a member of the spruce/fir forest-type group.

Scotch pine: plantation type, not naturally occurring. Softwood forest type that is a member of the nonnative softwood forest-type group.

Eastern white pine/northern red oak/white ash: Associates – red maple, basswood, yellow birch, bigtooth aspen, sugar maple, beech, paper birch, black cherry, hemlock, and sweet birch. Sites – deep, fertile, well drained soil. Mixed hardwood-pine forest type and member of the oak/pine forest-type group.

Other pine/hardwood: A type used for those unnamed pine-hardwood combinations that meet the requirements for oak-pine. These are stands where hardwoods (usually oaks) comprise the plurality of the stocking with at least a 25 to 49 percent pine, eastern redcedar, or southern redcedar component. Mixed hardwood-pine forest type and member of the oak/pine forest-type group.

Post oak/blackjack oak (includes dwarf post oak): Associates – black oak, hickory, southern red oak, white oak, scarlet oak, shingle oak, live oak, shortleaf pine, Virginia pine, blackgum, sourwood, red maple, winged elm, hackberry, chinkapin oak, shumard oak, dogwood, and eastern redcedar. Sites – dry uplands and ridges. Hardwood forest type and member of the oak/hickory forest-type group.

White oak/red oak/hickory (includes all hickories except water and shellbark hickory): Associates – pin oak, northern pin oak, chinkapin oak, black oak, dwarf chinkapin oak, American elm, scarlet oak, bur oak, white ash, sugar maple, red maple, walnut, basswood, locust, beech, sweetgum, blackgum, yellow-poplar, and dogwood. Sites – wide variety of well drained upland soils. Hardwood forest type and member of the oak/hickory forest-type group.

White oak: Associates – black oak, northern red oak, bur oak, hickory, white ash, yellow-poplar. Sites – scattered patches on upland, loamy soils but on drier sites than white oak/red oak/hickory forest type. Hardwood forest type and member of the oak/hickory forest-type group.

Northern red oak: Associates – black oak, scarlet oak, chestnut oak, and yellow-poplar. Sites – spotty distribution on ridge crests and north slopes in mountains but also found on rolling land, slopes, and benches on loamy soil. Hardwood forest type and member of the oak/hickory forest-type group.

Yellow-poplar/white oak/northern red oak: Associates – black oak, hemlock, blackgum, and hickory. Sites – northern slopes, coves, and moist flats. Hardwood forest type and member of the oak/hickory forest-type group.

Sassafras/persimmon: Associates – elm, eastern redcedar, hickory, ash, sugar maple, yellow-poplar, Texas sophora, and oaks. Sites – abandoned farmlands and old fields. Hardwood forest type and member of the oak/hickory forest-type group.

Chestnut oak/black oak/scarlet oak: Associates – northern and southern red oaks, post oak, white oak, sourwood, shagbark hickory, pignut hickory, yellow-poplar, blackgum, sweetgum, red maple, eastern white pine, pitch pine, Table Mountain pine, shortleaf pine, and Virginia pine. Sites – dry upland sites on thin-soiled rocky outcrops on dry ridges and slopes. Hardwood forest type and member of the oak/hickory forest-type group.

Red maple/oak: Associates – the type is dominated by red maple and some of the wide variety of central hardwood associates include upland oak, hickory, yellow-poplar, black locust, sassafras as well as some central softwoods like Virginia and shortleaf pines. Sites – uplands. Hardwood forest type and member of the oak/hickory forest-type group.

Mixed upland hardwoods: Includes Ohio buckeye, yellow buckeye, Texas buckeye, red buckeye, painted buckeye, American hornbeam, American chestnut, eastern redbud, flowering dogwood, hawthorn spp., cockspur hawthorn, downy hawthorn, Washington hawthorn, fleshy hawthorn, dwarf hawthorn, honeylocust, Kentucky coffeetree, Osage orange, all mulberries, blackgum, sourwood, southern red oak, shingle oak, laurel oak, water oak, live oak, willow oak, black locust, blackbead ebony, anacahuita, and September elm. Associates – Any mixture of hardwoods of species typical of the upland central hardwood region, should include at least some oak. Sites – wide variety of upland sites. Hardwood forest type and member of the oak/hickory forest-type group.

Black ash/American elm/red maple (includes slippery and rock elm): Associates – swamp white oak, silver maple, sycamore, pin oak, blackgum, white ash, and cottonwood. Sites – moist to wet areas, swamps, gullies, and poorly drained flats. Hardwood forest type and member of the elm/ash/cottonwood forest-type group.

Cottonwood: Associates – willow, white ash, green ash, and sycamore. Sites –streambanks where bare, moist soil is available. Hardwood forest type and member of the elm/ash/cottonwood forest-type group.

Sugarberry/hackberry/elm/green ash (includes American, winged, cedar, slippery and rock elm): Associates – boxelder, pecan, blackgum, persimmon, honeylocust, red maple, hackberry, and boxelder. Sites – low ridges and flats in flood plains. Hardwood forest type and member of the elm/ash/cottonwood forest-type group. This type was renamed to green ash/red maple/elm for this report. In Michigan, sugarberry is not part of this type.

Green ash/red maple/elm: See sugarberry/hackberry/elm/green ash. Sugarberry/hackberry/elm/green ash was renamed to green ash/red maple/elm for this report. In Michigan, sugarberry is not part of this type.

Silver maple/American elm: Silver maple and American elm are the majority species in this type. Associates – chalk maple, sweetgum, pin oak, swamp white oak, eastern cottonwood, sycamore, green ash, and other moist-site hardwoods, according to the region. Sites – primarily on well drained moist sites along river bottoms and floodplains, and beside lakes and larger streams. Hardwood forest type and member of the elm/ash/cottonwood forest-type group.

Red maple/lowland: Red maple comprises a majority of the stocking. Because this type grows on a wide variety of sites over an extensive range, associates are diverse. Associates – yellow-poplar, blackgum, sweetgum, and loblolly pine. Site – generally restricted to very moist to wet sites with poorly drained soils, and on swamp borders. Hardwood forest type and member of the elm/ash/cottonwood forest-type group.

Cottonwood/willow (includes peachleaf, black and Bebb willow): Associates – white ash, green ash, sycamore, American elm, red maple and boxelder. Sites – stream banks where bare, moist soil is available. Hardwood forest type and member of the elm/ash/cottonwood forest-type group.

Sugar maple/beech/yellow birch: Associates – butternut, basswood, red maple, hemlock, northern red oak, white ash, white pine, black cherry, sweet birch, American elm, rock elm, and eastern hophornbeam. Sites – fertile, moist, well drained sites.

Black cherry: Associates – sugar maple, northern red oak, red maple, white ash, basswood, sweet birch butternut, American elm, and hemlock. Sites – fertile, moist, well drained sites. Hardwood forest type and member of the maple/beech/birch forest-type group.

Cherry/ash/yellow-poplar: Associates – sugar maple, American beech, northern red oak, white oak, blackgum, hickory, cucumbertree, and yellow birch. Sites – fertile, moist, well drained sites. Hardwood forest type and member of the oak/hickory forest-type group.

Hard maple/basswood (includes American, Carolina, and white basswood): Associates – black maple, white ash, northern red oak, eastern hophornbeam, American elm, red maple, eastern white pine, eastern hemlock. Sugar maple and basswood occur in different proportions but together comprise the majority of the stocking. Sites – fertile, moist, well drained sites. Hardwood forest type and member of the maple/beech/birch forest-type group.

Elm/ash/locust: Associates – Black locust, silver maple, boxelder, blackbead ebony, American elm, slippery elm, rock elm, red maple, green ash predominate. Found in the Midwest, unknown in the Northeast. Sites – upland. Hardwood forest type and member of the oak/hickory forest-type group.

Red maple/upland: Associates – the type is dominated by red maple and some northern hardwood associates include sugar maple, beech, birch, aspen, as well as some northern softwoods like white pine, red pine, and hemlock; this type is often the result of repeated disturbance or cutting. Sites – uplands. Hardwood forest type and member of the maple/beech/birch forest-type group.

Aspen: Associates – Engelmann spruce, lodgepole pine, ponderosa pine, Douglas-fir, subalpine fir, white fir, white spruce, balsam poplar, and paper birch. Sites – aspen has the capacity to grow on a variety of sites and soils, ranging from shallow stony soils and loamy sands to heavy clays. Hardwood forest type and member of the aspen/birch forest-type group.

Paper birch (includes northern paper birch): Associates – aspen, white spruce, black spruce, and lodgepole pine. Sites – can be found on a range of soils but best developed on well-drained sandy loam and silt loam soils. Hardwood forest type and member of the aspen/birch forest-type group.

Balsam poplar: Associates – paper birch, white spruce, black spruce, and tamarack. Sites – occurs on rich floodplains where erosion and folding are active. Hardwood forest type and member of the aspen/birch forest-type group.

Forest-type group: Combinations of forest types that share closely associated species or site requirements and are generally combined for brevity of reporting. See forest type for examples of forest-type group members.

Growing stock: A classification of timber inventory that includes live trees of commercial species meeting specified standards of quality or vigor. Rough and rotten cull trees are excluded. When associated with volume, this includes only trees 5.0 inches d.b.h. and larger.

Hardwood: A dicotyledonous tree, usually broad-leaved and deciduous.

> **Soft hardwoods:** A category of hardwood species with wood generally of low specific gravity (less than 0.5). Notable examples include red maple, paper birch, quaking aspen, and American elm.

> **Hard hardwoods:** A category of hardwood species with wood generally of high specific gravity (greater than 0.5). Notable examples include sugar maple, yellow birch, black walnut, and oaks.

Industrial wood: All commercial roundwood products except fuelwood.

Land area: The area of dry land and land temporarily or partly covered by water, such as marshes, swamps, and river flood plains; streams, sloughs, estuaries, and canals less than 200 feet wide; and lakes, reservoirs, and ponds less than 4.5 acres in area.

Litter: Undecomposed or only partially decomposed organic material that can be readily identified (e.g., plant leaves, twigs).

Live cull: A classification that includes live, cull trees. When associated with volume, it is the net volume in live, cull trees that are 5.0 inches d.b.h. and larger.

Local government: An ownership class of public lands owned by counties or local public agencies, or lands leased by these governmental units for more than 50 years. Also known as county and municipal.

Logging residues: The unused portions of growing-stock and nongrowing-stock trees cut or killed by logging and left in the woods.

Merchantable: Refers to a pulpwood or saw log section that meets pulpwood or saw log specifications, respectively.

National Forest: An ownership class of Federal lands, designated by executive order or statute as National Forests or purchase units, and other lands under the administration of the U.S. Forest Service, including experimental areas.

Net volume in cubic feet: The gross volume in cubic feet less deductions for rot, roughness, and poor form. Volume is computed for the central stem from a 1-foot stump to a minimum 4.0-inch top diameter outside bark, or to the point where the central stem breaks into limbs.

Noncommercial species: Tree species of typically small size, poor form, or inferior quality, which normally do not develop into trees suitable for industrial wood products.

Nonforest land: Land that has never supported forests and lands formerly forested where use of timber management is precluded by development for other uses. (Note: Includes area used for crops, improved pasture, residential areas, city parks, improved roads of any width and adjoining clearings, powerline clearings of any width, and 1- to 4.5-acre areas of water classified by the Bureau of the Census as land. If intermingled in forest areas, unimproved roads and nonforest strips must be more than 120 feet wide, and clearings, etc., must be more than 1 acre in area to qualify as nonforest land.)

Nonindustrial private: An ownership class of private lands where the owner does not operate wood-using plants.

Nonstocked areas: Timberland less than 10-percent stocked with live trees.

Other red oaks: A group of species in the genus *Quercus* that includes scarlet oak, northern pin oak, southern red oak, bear oak, shingle oak, laurel oak, blackjack oak, water oak, pin oak, willow oak, and black oak.

Other white oaks: A group of species in the genus *Quercus* that includes overcup oak, chestnut oak, and post oak.

Ownership: The property owned by one ownership unit.

Ownership unit: A classification of ownership encompassing all types of legal entities having an ownership interest in land, regardless of the number of people involved. A unit may be an individual, a combination of persons; a legal entity such as a corporation, partnership, club, or trust, or a public agency. An ownership unit has control of a parcel or group of parcels of land.

Ozone: A regional, gaseous air pollutant produced primarily through sunlight-driven chemical reactions of nitrogen dioxide and hydrocarbons in the atmosphere and causing foliar injury to deciduous trees, conifers, shrubs, and herbaceous species.

Ozone bioindicator site: An open area used for ozone injury evaluations on ozone-sensitive species. The area must meet certain site selection guidelines on size, condition, and plant counts to be used for ozone injury evaluations in FIA.

Physiographic class: A measure of soil and water conditions that affect tree growth on a site. The physiographic classes are as follows:

Xeric: Very dry soils where excessive drainage seriously limits both growth and species occurrence. These sites are usually on upland and upper half slopes.

Xeromesic: Moderately dry soils where excessive drainage limits growth and species occurrence to some extent. These sites are usually on the lower half slopes.

Mesic: Deep, well drained soils. Growth and species occurrence are limited only by climate. These include all cove sites and bottomlands along intermittent streams.

Hydromesic: Moderately wet soils where insufficient drainage or infrequent flooding limits growth and species occurrence to some extent.

Hydric: Very wet sites where excess water seriously limits both growth and species occurrence.

Poletimber trees: Live trees at least 5.0 inches in d.b.h. but smaller than sawtimber trees.

Primary wood-using mill: A mill that converts roundwood products into other wood products. Common examples are sawmills that convert saw logs into lumber and pulpmills that convert pulpwood into wood pulp.

Productivity class: A classification of forest land in terms of potential annual cubic-foot volume growth per acre at culmination of mean annual increment in fully stocked natural stands.

Pulpwood: Roundwood, whole-tree chips, or wood residues used for the production of wood pulp.

Reserved forest land: Forest land withdrawn from timber utilization through statute, administrative regulation, or designation without regard to productive status.

Residues: Bark and woody materials that are generated in primary wood-using mills when roundwood products are converted to other products. Examples include slabs, edgings, trimmings, miscuts, sawdust, shavings, veneer cores and clippings, and pulp screenings. Includes bark residues and wood residues (both coarse and fine materials) but excludes logging residues.

Rotten tree: A live tree of commercial species that does not contain a saw log now or prospectively primarily because of rot (that is, when rot accounts for more than 50 percent of the total cull volume).

Rough tree: (a) A live tree of commercial species that does not contain a saw log now or prospectively primarily because of roughness (that is, when sound cull due to such factors as poor form, splits, or cracks accounts for more than 50 percent of the total cull volume); or (b) a live tree of noncommercial species.

Roundwood products: Logs, bolts, and other round timber generated from harvesting trees for industrial or consumer use.

Salvable dead tree: A downed or standing dead tree considered currently or potentially merchantable by regional standards.

Saplings: Live trees 1.0 inch through 4.9 inches d.b.h.

Saw log: A log meeting minimum standards of diameter, length, and defect, including logs at least 8 feet long, sound and straight, and with a minimum diameter inside bark of 6 inches for softwoods and 8 inches for hardwoods, or meeting other combinations of size and defect specified by regional standards.

Sawtimber tree: A live tree of commercial species containing at least a 12-foot saw log or two noncontiguous saw logs 8 feet or longer, and meeting regional specifications for freedom from defect. Softwoods must be at least 9.0 inches d.b.h. Hardwoods must be at least 11.0 inches diameter outside bark (d.o.b.).

Sawtimber volume: Net volume of the saw-log portion of live sawtimber in board feet, International 1/4-inch rule (unless specified otherwise), from stump to a minimum 7.0 inches top d.o.b. for softwoods and a minimum 9.0 inches top d.o.b. for hardwoods.

Seedlings: Live trees less than 1.0 inch d.b.h. and at least 1 foot in height.

Select red oaks: A group of species in the genus *Quercus* that includes cherrybark oak, northern red oak, and Shumard oak.

Select white oaks: A group of species in the genus *Quercus* that includes white oak, swamp white oak, bur oak, swamp chestnut oak, and chinkapin oak.

Site index: An expression of forest site quality based on the height of a free-growing dominant or codominant tree of a representative species in the forest type at age 50.

Snag: A standing dead tree. In the current inventory, a snag must be 5.0 inches d.b.h./d.r.c. and 4.5 feet tall, and have a lean angle less than 45 degrees from vertical. A snag may be either self-supported by its roots, or supported by another tree or snag.

Softwood: A coniferous tree, usually evergreen, having needles or scale-like leaves.

Soil Order: The broadest category or class of soil based largely on the processes that formed the soil as indicated by the presence or absence of diagnostic horizons or layers. Several dominant soil orders in Michigan are as follows:

Alfisols: Moist mineral soils that form mostly in cool to hot humid areas. These soils usually form under deciduous forests and are usually quite productive. These soils are more weathered than Inceptisols but less than Spodosols.

Entisols: Mineral soils with no horizons or only the beginning of horizons. These soils are basically unaltered from their parent material. Soils of this order vary widely in productivity.

Histisols: Organic soils that form in saturated wet conditions. These can occur in any wet area and can be very productive when drained.

Inceptisols: Soils with few diagnostic features that have formed quickly from the parent material. They form under a wide variety of climates. These soils are more advanced than Entisols but less than other orders. They vary widely in productivity.

Mollisols: Organic soils that form in semiarid to semihumid areas mostly under prairie vegetation. These are some of the most productive soils.

Spodosols: Mineral soils that form in humid climates usually where it is cold and temperate. Most of these soils develop naturally under forests. They are not naturally very fertile but can be productive with fertilizer.

Sound dead: The net volume in salvable dead trees.

Stand: A group of trees on a minimum of 1 acre of forest land that is stocked by forest trees of any size.

Stand-size class: A classification of forest land based on the size class of live trees in the area. The classes are as follows:

Nonstocked: Forest land stocked with less than 10 percent of full stocking with live trees. Examples are recently cutover areas or recently reverted agricultural fields.

Seedling-sapling: Forest land stocked with at least 10 percent of full stocking with live trees with half or more of such stocking in seedlings or saplings or both.

Poletimber: Forest land stocked with at least 10 percent of full stocking with live trees with half or more of such stocking in poletimber or sawtimber trees or both, and in which the stocking of poletimber exceeds that of sawtimber.

Sawtimber: Forest land stocked with at least 10 percent of full stocking with live trees with half or more of such stocking in poletimber or sawtimber trees or both, and in which the stocking of sawtimber is at least equal to that of poletimber.

State: An ownership class of public lands owned by states or lands leased by states for more than 50 years. Also a general reference to one of the political and geographic subdivisions of the United States.

Stocking: The degree of occupancy of land by trees, measured by basal area or number of trees by size and spacing, or both, compared to a stocking standard; that is, the basal area or number of trees, or both, required to fully utilize the growth potential of the land.

Timberland: Forest land that is producing or is capable of producing crops of industrial wood and not withdrawn from timber utilization by statute or administrative regulation. (Note: Areas qualifying as timberland are capable of producing in excess of 20 cubic feet per acre per year of industrial wood in natural stands. Currently inaccessible and inoperable areas are included.)

Timber products output: All timber products cut from roundwood and byproducts of wood manufacturing plants. Roundwood products include logs, bolts, or other round sections cut from growing-stock trees, cull trees, salvable dead trees, trees on nonforest land, noncommercial species, sapling-size trees, and limbwood. Byproducts from primary manufacturing plants include slabs, edging, trimmings, miscuts, sawdust, shavings, veneer cores and clippings, and screenings of pulpmills that are used as pulpwood chips or other products.

Tree: A woody plant usually having one or more erect perennial stems, a stem diameter at breast height of at least 3.0 inches, a more or less definitely formed crown of foliage, and a height of at least 15 feet at maturity.

Tree size class: A classification of trees based on diameter at breast height, including sawtimber trees, poletimber trees, saplings, and seedlings.

Tops: The wood of a tree above the merchantable height (or above the point on the stem 4.0 inches diameter outside bark (d.o.b.) or to the point where the central stem breaks into limbs). It includes the usable material in the uppermost stem.

Urban forest land: Land that would otherwise meet the criteria for timberland but is in an urban-suburban area surrounded by commercial, industrial, or residential development and not likely to be managed for the production of industrial wood products on a continuing basis. Wood removed would be for land clearing, fuelwood, or esthetic purposes. Such forest land may be associated with industrial, commercial, residential subdivision, industrial parks, golf course perimeters, airport buffer strips, and public urban parks that qualify as forest land.

Unreserved forest land: Forest land not withdrawn from harvest by statute or administrative regulation. This includes forest lands that are not capable of producing in excess of 20 cubic feet per acre per year of industrial wood in natural stands.

Veneer log: A roundwood product from which veneer is sliced or sawn and that usually meets certain standards of minimum diameter and length and maximum defect.

Weight: The weight of wood and bark, oven-dry basis (approximately 12 percent moisture content).

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Pugh, Scott A.; Hansen, Mark H.; Pedersen, Lawrence D.; Heym, Douglas C.; Butler, Brett J.; Crocker, Susan J.; Meneguzo, Dacia; Perry, Charles H.; Haugen, David E.; Woodall, Christopher; Jepsen, Ed. 2009. **Michigan's forests 2004.** Resour. Bull. NRS-34. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 210 p.

The first annual inventory of Michigan's forests, completed in 2004, covers more than 19.3 million acres of forest land. The data in this report are based on visits to 10,355 forested plots from 2000 to 2004. Timberland accounts for 97 percent of this forest land, and 63 percent is privately owned. The sugar maple/beech/yellow birch forest type accounts for 22 percent of the State's forest land, followed by aspen (13 percent) and northern white-cedar (7 percent). Balsam fir, red maple, and sugar maple are the top three species in the number of trees. Growing-stock volume on timberland has increased continually, totaling about 27.3 billion cubic feet (ft^3). Estimated net growth, removals, and mortality totaled 787, 291, and 225 million ft^3/year, respectively. In addition to detailed information on forest attributes, this report includes data on forest health, biomass, land-use change, and timber-product outputs.

KEY WORDS: inventory, biomass, forest area, timberland, forest land, sustainability, volume, mortality, forest health, land-use change

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