Michigan's Forests 2009

Resource Bulletin
NRS-66

USDA United States Department of Agriculture

Forest Service

Northern Research Station

Abstract

The seventh inventory of Michigan's forests, completed in 2009, describes more than 19.9 million acres of forest land. The data in this report are based on visits to 7,516 forested plots from 2005 to 2009. Timberland accounts for 97 percent of this forest land, and 62 percent is privately owned. The sugar maple/beech/yellow birch forest type accounts for 18 percent of the State's forest land, followed by aspen (13 percent) and white oak/red oak/hickory (7 percent). Balsam fir, red maple, and sugar maple are the three most common species by number of trees. Growing-stock volume on timberland has continued to increase totaling about 28.7 billion cubic feet (ft^3). The associated net growth, harvest removals, and mortality totaled 698, 311, and 272 million ft^3/year, respectively. In addition to information on forest attributes, this report includes data on forest health, biomass, land-use change, and timber-product outputs. Detailed information on forest inventory methods, data quality estimates, and important resource statistics can be found in Statistics, Methods, and Quality Assurance on the DVD in the back of this publication.

Acknowledgments

We thank the field crew for their hard work and dedication while collecting the information that is the basis for this report. Special thanks also go to Gary Brand, Carol Alerich, Mark Hatfield, Patrick Miles, John Vissage, Barry Wilson, and Dale Gormanson who also contributed to this report.

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

Manuscript received for publication September 2011

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

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

February 2012

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

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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.

Michigan has more forest land than any other state in the Northeast or Midwest. Nearly all of its forest land was cut and/or burned during European settlement (Dickmann and Leefers 2003). The lumber boom and fires occurred primarily in the late 1800s and early 1900s. By 1920, the lumber boom had ended and secondary succession and the recovery of the forests had begun. Since then, these forests have been maturing and forest management has evolved. 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 assistance programs to help small forest-land owners. An active, diverse wood products industry exists which provides jobs and goods to meet consumer demands.

The status and trends of forest resources can indicate how Michigan's forests are fairing over time in the face of physical and social changes. The U.S. Forest Service, through its Forest Inventory and Analysis (FIA) program and in partnership with the Michigan Department of Natural Resources (MIDNR), Forest Management Division, inventoried the State's forest resources in 1935, 1955, 1966, 1980, 1993, and 2004. 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 second annual inventory of Michigan (7,516 forested plots) was completed in 2009 and covers the period 2005-09.

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.

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Highlights

Forest Features

Among the 50 states, Michigan ranks 21st in area but ninth in forest-land area, accounting for 19.9 million acres.

Forest land has continued to increase; the 2009 estimate of 19.9 million acres is the highest estimate since the 1930s.

The annual reversion rate (nonforest to forest) since 1993 is between 3 to 5 percent and the annual diversion rate (forest to nonforest) has been approximately 2 percent.

The southern Lower Peninsula has the least amount of forest land at 17 percent but it is experiencing the most change to forest land, accounting for 60 percent of the State's increase since the 2004 inventory.

Overall, the forests continue to mature. The number of sawtimber-size trees has increased considerably. Shade-tolerant species such as eastern white pine are increasing in number and volume while intolerant and short-lived species such as jack pine and paper birch are declining.

There are 13.5 billion trees on timberland, 64 percent of which are hardwoods. The number of saplings and sawtimber-size trees increased by 16 and 65 percent, respectively, while the number of poletimber-size trees remained constant from 1980 to 2009.

There are 28.7 billion cubic feet (ft^3) of growing stock on timberland or about 1,487 ft^3/acre. Although Michigan is still 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. From 1955 to 1966, the increase was nearly 4 percent per year. From 1980 to 2004, the increase was just under 2 percent per year. Since the 2004 inventory, total growing-stock volumes increased 1 percent per year.

Average annual net growth of growing stock on timberland was 698.4 million ft^3 or 2.5 percent of growing-stock volume on timberland. All prominent species except paper birch have moderate or high ratios of average annual net growth to volume (percent) and most of these species gained significantly in volume from 1980 to 2009. Since the 2004 inventory, average annual net growth decreased in the eastern Upper Peninsula (18 percent) and western Upper Peninsula (28 percent) but not in the Lower Peninsula.

Average annual mortality of growing stock on timberland was 271.8 million ft^3 which is an increase of 21 percent since the 2004 inventory level of 224.5 million ft^3. The 2009 estimate is 1 percent of growing-stock volume on timberland, which is low. Since the 2004 inventory, the southern Lower Peninsula had the greatest increase in mortality (50 percent) followed by the eastern Upper Peninsula (43 percent) and western Upper Peninsula (27 percent). The northern Lower Peninsula had no significant change in mortality.

Average annual harvest removals of growing stock on timberland increased from 260.6 million ft^3 in the 2004 inventory to 311.2 million ft^3 in the 2009 inventory. The increases were greatest in the western Upper Peninsula (47 percent) and southern Lower Peninsula (62 percent). Even with a 19 percent increase in harvest, the rate of harvest removals to volume is low at 1.1 percent.

The ratio of net growth to total removals (includes land-use change) for this most recent inventory is at a moderate to high level of 2.1, a drop from historical levels at 2.7. The ratio of net growth to harvest removals for the 2009 inventory was 2.4 (does not include land-use change).

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

Forest Health

Nonnative species such as the emerald ash borer and beech bark disease are playing a larger role in affecting Michigan's forest health. Compared to the 2004 inventory, the 2009 estimate for mortality of green ash is nearly seven times higher, while white ash is more than four times higher. The estimate of mortality in American beech is more than five times higher.

Forest Products

Michigan's paper and wood products industries directly employ nearly 25,000 workers with an output of approximately $7.4 billion annually (North American Industry Classification System codes 321 and 322; U.S. Census Bur. 2007). Additional Michigan wood-product jobs and economic outputs are in logging, transportation, trade, and wood furniture industries.

More than 90 percent of the roundwood harvested in Michigan is processed by Michigan mills. The amounts harvested and processed in Michigan have remained fairly constant since the 1980s.

Background

Beaver pond. Photo by Scott A. Pugh, U.S. Forest Service.

An Overview of Forest Inventory

What is a tree?

Trees are perennial woody plants with central stems and distinct crowns. In general, the Forest Inventory and Analysis (FIA) program defines a tree as any perennial woody plant species that can attain a height of 15 feet at maturity. A 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 Statistics, Methods, and Quality Assurance found on the DVD in the back of this publication. 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?

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 (see Stocking). 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 (U.S. For. Serv. 2007). The area of forest land sometimes determines the allocation of funding for certain State and Federal programs.

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. Inaccessible and inoperable areas are included.

- Reserved forest land—forest land that is withdrawn from timber utilization through statute without regard to productive status, e.g., some natural areas in 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. Sometimes such forest lands are referred to as being "less productive" or "unproductive" with respect to wood fiber production.

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

Prior to 2000 in Michigan, 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 2000, the new annual inventory design allows us to report volumes on all forest land. We have one set of remeasured plots across all forest land with associated estimates of growth, removals, and mortality. In this report, most trend analyses focus on timberland but the emphasis in future reports will shift to forest land.

How do we estimate a tree's volume?

FIA expresses volume in cubic and board feet (International ¼-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. Board foot is only applicable for sawtimber-size trees (see Number of Trees).

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, site basal area, 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 ¼-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 (2,000 pounds/ton) of green biomass equals 1 ton of oven-dry biomass.

How can I analyze FIA data?

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 (approximately 20 percent) are made every year. It is still necessary to look over long time periods because many trends like succession can be difficult to discern in short time spans.

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 such as 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 the northern Lower Peninsula and red pine on public land.

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 (Fig. 1). 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.

Definitions and procedures have changed among inventories. Besides reviewing definition and procedural changes, it is often helpful to investigate multiple variables over time to corroborate changes and identify their causes. 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.

Sampling error—what is significant?

We measured approximately one plot for every 2,690 acres of land, noncensus water, and inland census water (Great Lakes excluded). Compared to the rates in many other states, this is a high sampling rate due to triple-

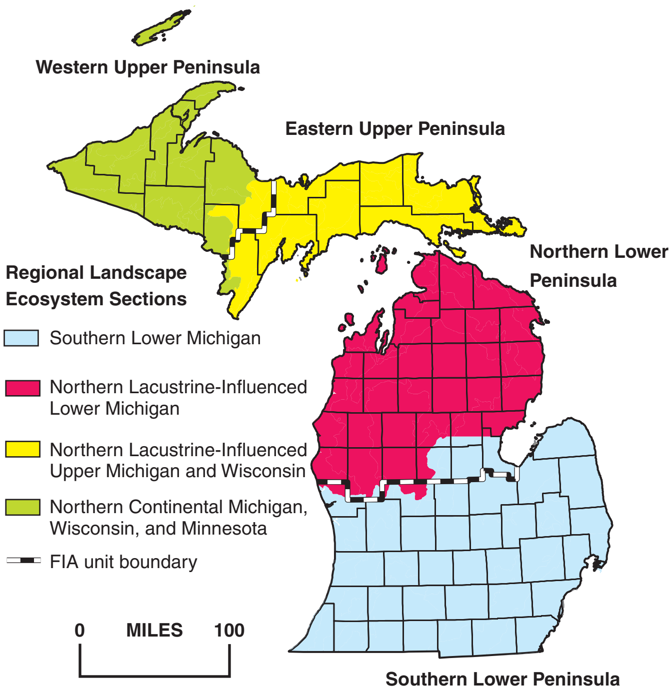

Figure 1.—Regional landscape ecosystem sections and FIA inventory units or regions, Michigan (see Map Descriptions and Acknowledgments in Statistics, Methods, and Quality Assurance).

intensity sampling in 2005 thru 2007 (sample every 2,000 acres). Single intensity sampling occurred in 2008 thru 2009 (sample every 6,000 acres). Sampling errors are associated with the estimates. The sampling error represents one standard error, which is a 68-percent confidence interval. For instance, the estimate of timberland in Michigan is 19.29 million acres with a sampling error of ± 0.4 percent resulting in a range from 19.21 to 19.37 million acres. If the entire population were known, the odds are 2 to 1 (68-percent chance) that the area of timberland would be 19.21 to 19.37 million acres. Error bars shown in some of the figures in this report use one standard error to represent the uncertainty in the estimates.

We often try to determine whether there are statistically significant differences among estimates. Throughout this report, any statement indicating 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 to 2.5 million acres at one standard error. The estimate for the southern Lower Peninsula for 2009 ranges from 3.3 to 3.4 million acres at one standard error. Though there were some minor definitional and procedural changes, we can conclude that there was significantly more timberland in the southern Lower Peninsula in 2009 versus 1980.

Comparing data from different inventories: Apples to oranges?

The annual inventory measures a subset of observations (approximately 20 percent) every year. After 5 years of data collection, an analysis and report are created based on the full set, or "cycle" of plots. This creates a yearly moving window of 5-year cycles. The last year of each full cycle is used to identify the full set of plots. For example, the cycle of plots measured from 2005 through 2009 are collectively labeled the "2009 inventory" and were used to produce this 2009 report.

In 2009, FIA completed measurement of the fifth panel of inventory plots in Michigan. The 2009 panel, along with those surveyed in 2005, 2006, 2007, and 2008, comprise the dataset for the seventh full inventory of Michigan, the 2009 inventory of Michigan. Previous inventories of Michigan's forest resources were completed in 1935, 1955, 1966, 1980, 1993 and 2004 (Chase et al. 1970, Findell et al. 1960, Lake States For. Exp. Stn. 1936, Leatherberry and Spencer 1996, Raile and Smith 1983, Schmidt et al. 1997, Spencer 1983, Pugh et al. 2009).

To improve the consistency, efficiency, and reliability of the inventory, updates have been implemented over time. Major changes occurred with the annual inventory that started in 1999. For the sake of consistency, a new, national plot design was implemented by all five regional FIA units in 1999 (see Statistics, Methods, and Quality Assurance). 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.

Methods for determining stocking, forest type, and stand-size estimates were improved twice since the annual inventory started. All annual data were updated with the improvements to facilitate easier temporal analyses. There were fewer and less precise forest types assigned in the periodic inventories. For additional information, 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/ (Arner et al. 2003).

Estimates of net growth, mortality, and removals were updated after the 2004 inventory. Estimates for the 2009 inventory use the updated methods. Improvements were made to compensate for changes in site conditions (e.g., site index and basal area) and/or tree class (e.g., growing stock and cull). In addition, an increase in the sample size of ingrowth (trees reaching minimum sample size of 5 inches d.b.h.) improved precision.

The analysis of the inventory in Michigan's Forests 2004 (Pugh et al. 2009) did compensate for changes in tree class but was completed before the other improvements. To better facilitate comparisons in this report, we recalculated net growth, mortality, and harvest removals in the 2009 inventory using the earlier methods employed by Pugh et al. (2009). Using the earlier methods at the state level, the estimate for mortality of growing stock on timberland increased 0.4 percent. The estimate for harvest removals of growing stock on timberland decreased 0.2 percent. By species, the differences in mortality and harvest removals varied little from those at the State level and were not significantly different at the 68-percent confidence interval. The effects on net growth were not significantly different either but the absolute differences were substantial for some species (Table 1). In this report, unless otherwise stated, 2009 estimates are based on the most recent and improved methods.

Some comparisons over time will be made back to 1980 rather than 1993. 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. Unfortunately, the use of modeled plots introduced errors, so the practice was discontinued (Pugh et al. 2009).

Table 1.—Average annual net growth of growing stock on timberland using 2004 versus 2009 methods of estimation, Michigan, 2009.

Species	2009 methods	2004 methods	Difference (using 2004 methods)
	million ft³		*percent*
Balsam fir	9.9	10.7	7.9
White spruce	15.1	14.8	-2.4
Jack pine	4.8	3.9	-18.5
Red pine	71.2	66.8	-6.1
Eastern white pine	41.2	38.2	-7.3
Northern white-cedar	44.1	40.5	-8.1
Eastern hemlock	12.6	12.7	0.5
Red maple	103.0	103.4	0.4
Silver maple	14.6	14.1	-3.5
Sugar maple	96.3	97.7	1.5
Yellow birch	4.3	4.3	-1.9
Paper birch	-3.8	-3.4	-10.7
American beech	6.6	5.8	-12.1
Green ash	18.3	17.7	-3.0
Bigtooth aspen	31.6	30.8	-2.6
Quaking aspen	40.4	42.0	3.9
Black cherry	23.5	23.3	-0.8
White oak	13.4	12.9	-3.6
Northern red oak	48.4	48.9	1.0
Black oak	16.8	16.3	-2.8
American basswood	11.9	11.8	-0.5
Total	624.1	613.1	-1.8
Total All species	698.4	687.3	-1.6

A word of caution on harvest suitability and availability

FIA data can only aid in identifying possible land available for timber production. 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) in the estimate of timberland. Most forest lands FIA classifies as reserved are federal lands. About 99 percent of the reserved plots in the 2009 inventory are on the following lands: 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 Wilderness Area, Nordhouse Dunes National Wilderness Area, Delirium Wilderness Area, Horseshoe Bay Wilderness Area, Mackinac Wilderness Area, Big Island Lake Wilderness Area, Rock River Canyon Wilderness Area, and Pictured Rocks National Lakeshore. This 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 withheld 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 withheld and not suitable or accessible for timber harvesting due to changing laws, owner objectives, markets, and site conditions.

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

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 2006 National Woodland Owner Survey (NWOS) conducted by FIA, 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 (Butler 2008). 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 but over time timber harvests tend to occur on most private lands.

National Forests have not harvested as much as other ownership groups due to many factors (Bosworth and Brown 2007, Keele et al. 2006, U.S. For. Serv. 2002). In Michigan, the U.S. Forest Service has the lowest ratio of average annual removals to current volume (0.4 percent) compared to private (1.2 percent) or State and local government (1.0 percent) ownerships.

Where can I find additional information?

Detailed information on forest inventory methods, data quality estimates, and important resource statistics can be found in Statistics, Methods, and Quality Assurance found on the DVD in the back of this publication. This DVD also contains most of the data used in this report accessible through Evalidator, included software (requires Microsoft Access). Some graphs and tables in the printed portion of this report show only a sample of the prominent categories and values available for summarizing data. Tables on the DVD have more categories; summary values and custom tables can be created with Evalidator. Definitions of tables and fields are available in the database user's manual (Woudenberg et al. 2010).

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://apps.fs.fed.us/fiadb-downloads/datamart.html). A primary web tool is FIDO or Forest Inventory Data Online (http://apps.fs.fed.us/fido/). Other tools including a web version of Evalidator also are available (http://fia.fs.fed.us/tools-data/other/default.asp). Field guides are at http://www.fia.fs.fed.us/library/field-guides-methods-proc/.

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

Forest Features

Sugar maple in autumn. 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 and timberland can be indicative of natural factors or human caused changes in land use, sustainability, and forest health. Summarizing general stand characteristics such as size and age class can provide additional information on the status of the forest resource.

What we found

Fifty-five percent of land in Michigan is forested (19.9 million acres; Fig. 2). Timberland accounts for 97 percent of this forest land or 19.3 million acres. Two percent of the forest land is reserved and 1 percent is other forest land.

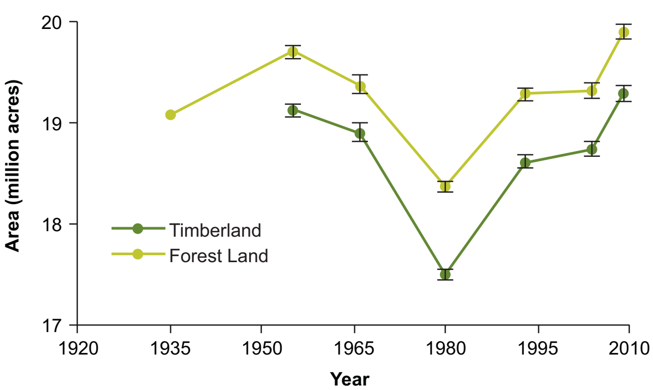

Figure 2.—Forest land and timberland by year, Michigan (error bars represent 68-percent confidence interval around estimate; no error bars available for 1935).

The Upper Peninsula of Michigan accounts for only 29 percent of the land in Michigan but has 45 percent of the forest land (4.2 and 5.0 million acres for eastern and western Upper Peninsula, respectively). The southern Lower Peninsula has the least amount of forest land (3.3 million acres or 17 percent of forest land) even though it is the largest region. The northern Lower Peninsula has the most forest land (7.4 million acres).

Sixty-two percent (12.4 million acres) of Michigan's forest land is owned by families, individuals, private corporations, and other noncorporate private groups (Table 2 and Fig. 3). The latter groups include nongovernmental conservation and natural resource organizations; unincorporated local partnerships, associations, and clubs; and Native American communities. Families or individuals (45 percent) own the most forest land. Corporations are the second largest private forest land owners with 14 percent of forest land.

Table 2.—Area and percent of forest land by owner, Michigan, 2009. Change in forest land by owner, Michigan 1993 to 2009 and 2004 to 2009 (numbers in bold italics indicate a significant change using 68-percent confidence interval).

Ownership	2009 estimate	2009 ratio	Change since 2004	Change since 1993
	1,000 acres	*percent*	*percent*	*percent*
Family or individual	9,036.7	45.4	***2.9***	***6.0***
State	4,212.4	21.2	1.5	***6.7***
Corporate	2,797.4	14.1	***6.2***	***-22.2***
U.S. Forest Service	2,678.9	13.5	0.4	-0.4
Other private and public	890.1	4.4	10.2	***219.8***
Other federal	287.8	1.4	7.3	15.0
Total	19,903.2	100.0	***3.1***	***3.2***

Many large holdings, particularly in the Upper Peninsula, are owned by corporations. Traditionally, these consisted primarily of vertically integrated companies that used 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. Most of these lands have been acquired by timber investment management organizations (TIMOs), real estate investment trusts (REITs), 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 involving TIMOs and REITs in 2005 and 2006 (Froese et al. 2007).

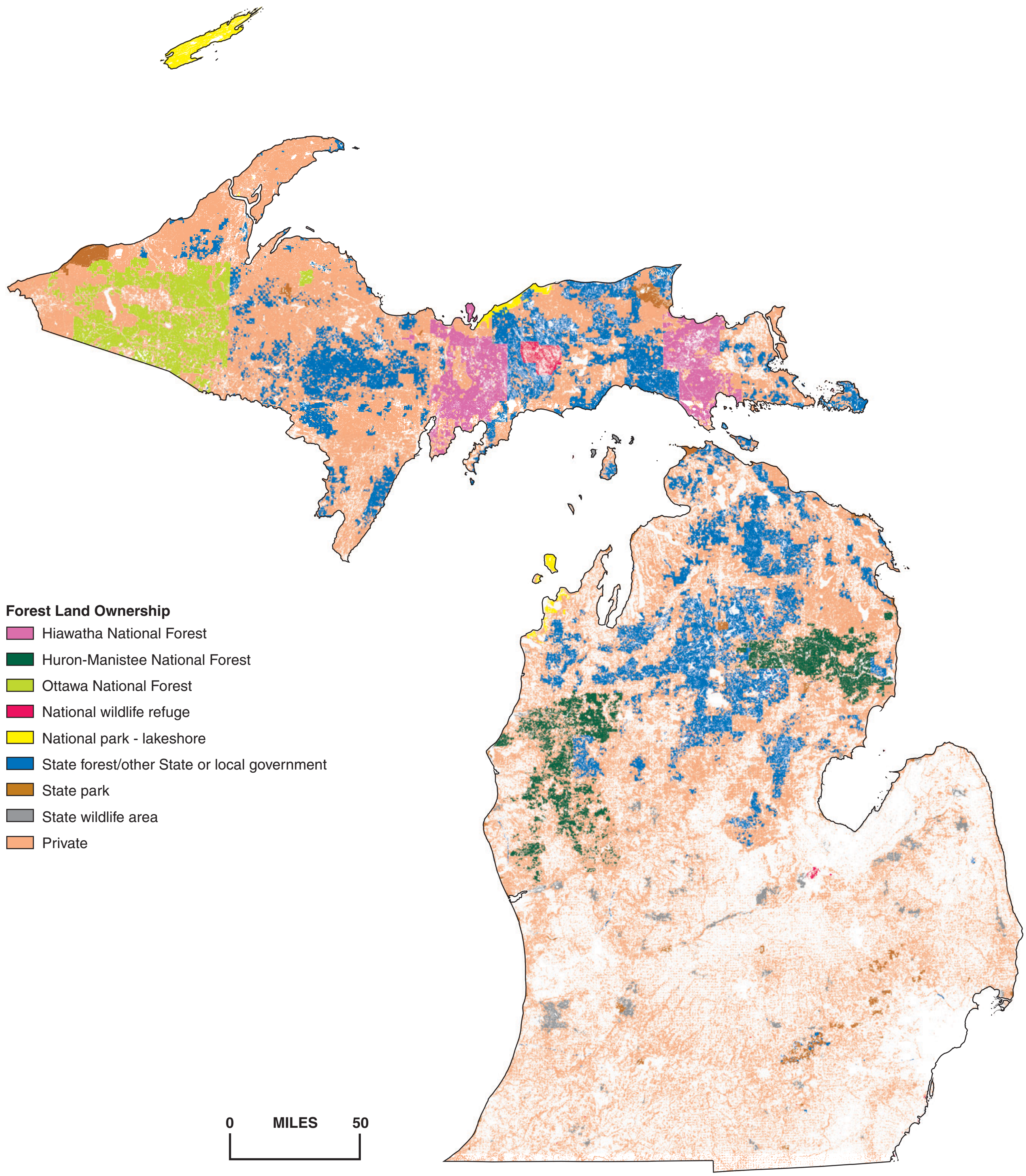

Figure 3.—Forest land ownership, Michigan, circa 2009 (see Map Descriptions and Acknowledgments in Statistics, Methods, and Quality Assurance).

According to the 2006 NWOS, family forests are owned for numerous reasons and many of these center around amenities such as aesthetics, privacy, and nature protection (see Statistics, Methods, and Quality Assurance). 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 while recreation is relatively less important. Pugh et al. (2009) and Butler (2008) present more analysis on the 2006 NWOS.

Public forest land (7.6 million acres or 38 percent) is owned by Federal, State, and local government agencies with the State (21 percent) and U.S. Forest Service (13 percent) being the primary owners. Depending on the specific tract of land, these forests may be managed for wildlife habitat, water protection, nature preservation, timber production, recreation, other uses, or, quite commonly, a combination thereof. Public forest land has been increasing gradually. Between 1993 and 2009, the area of public forest land increased nearly 6 percent, due mostly to an increase in State lands.

Ownership patterns vary across the State (Fig. 3). 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 and their management practices but also recreation opportunities and other services for the general public.

Since the first FIA inventory in 1935, timberland has held at a fairly constant ratio to all forest land (95 to 98 percent). The greatest estimates of forest and timberland were observed in the 1955 and 2009 inventories (Fig. 2). The 1955 estimates are significantly less than the 2009 estimates. The least amounts of forest and timberland were noted in the 1980 inventory. Changes in forest land are depicted in Figure 4, which shows the percentage of forest land by county and changes in forest land by county. The high amount of forest land in 1955 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 classified as less productive, were reclassified as productive timberland (Schmidt et al. 1997). From 1993 to 2004, there were no significant changes in the estimates of forest or timberland.

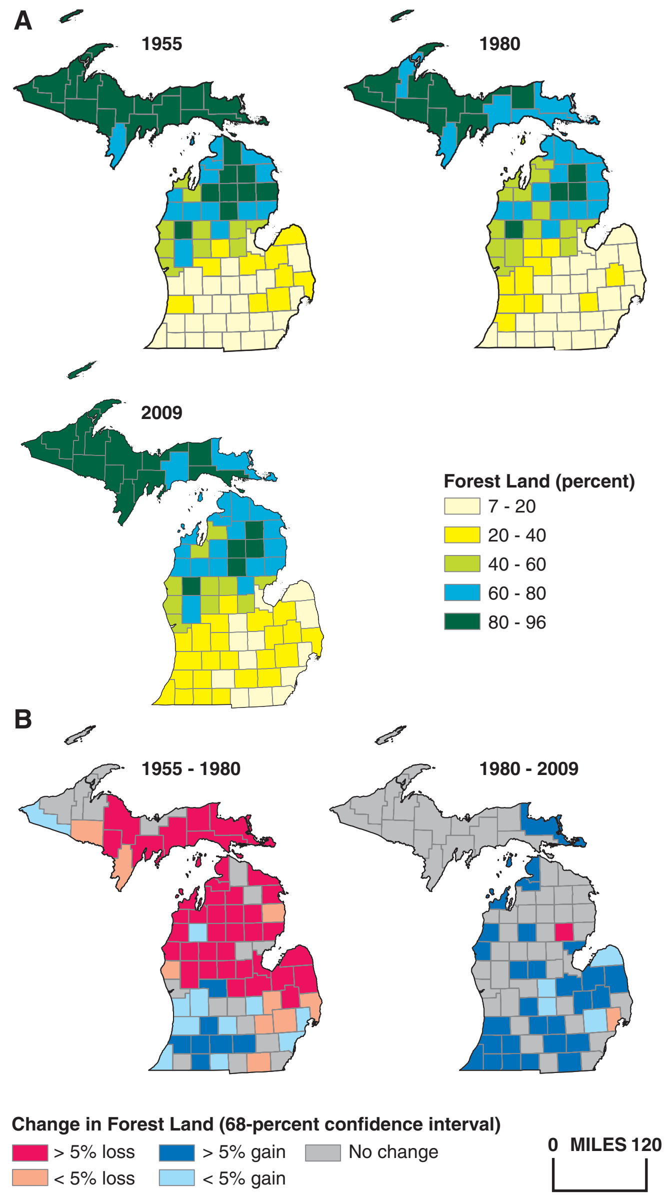

Figure 4.—Percentage of forest land (A) and change in forest land (B) by county, Michigan, 1955-2009 (see Map Descriptions and Acknowledgments in Statistics, Methods, and Quality Assurance).

There were significant increases in the estimates of area of forest land (3.1 percent) and timberland (3.0 percent) from 2004 to 2009. All units except the northern Lower Peninsula experienced significant increases in forest land. The gains in the eastern Upper Peninsula (2.2 percent) and western Upper Peninsula (1.2 percent) were small while there was a large increase in the southern Lower Peninsula at 11.7 percent. The eastern Upper Peninsula (1.9 percent) and southern Lower Peninsula (11.8 percent) had significant increases in timberland.

Between 2004 and 2009, 5 percent of the State's nonforest land and water (Great Lakes waters excluded) reverted to forest land while 2 percent of forest land diverted to nonforest land and water (Great Lakes waters excluded). Land that changes to forest land typically is referred to as reversions and land that changes from forest land to nonforest typically is referred to as diversions. Most diversions were due to developed/cultural sources (e.g., intense human activity) followed by water/marsh/wetland and farmland (Fig. 5). Reversions came from a variety of sources (top 90 percent in decreasing order): water/marsh/wetland, farmland, developed/cultural, and pasture/rangeland (Fig. 5). For the southern Lower Peninsula, more reversions came from farmland (34 percent) and developed/cultural (28 percent) sources and less from water/marsh/wetland (14 percent) when compared to the whole State.

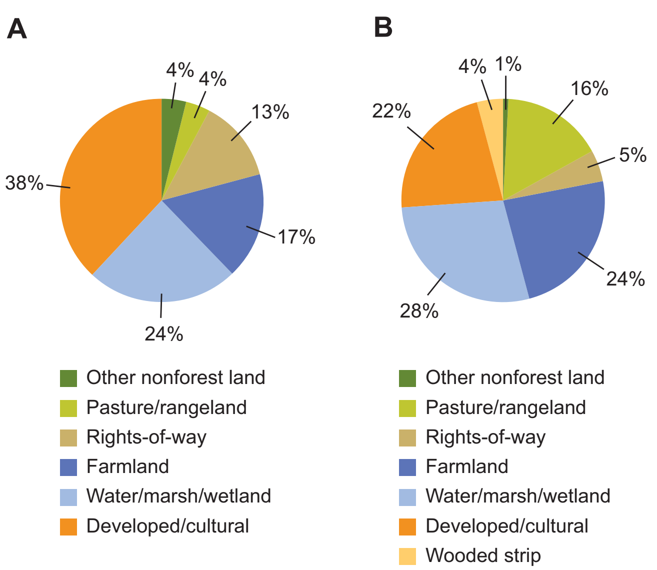

Figure 5.—Percentage of forest-land diversion by current land use (A) and forest-land reversion by previous land use (B), Michigan, 2009.

From 1993 to 2004, the diversion rate was 2 percent and reversion was 3 percent (Pugh et al. 2009). Forest land has been gradually increasing since the 1980s and there was a significant increase in the estimate for the 2009 inventory (3 percent from 1993 to 2004 versus 5 percent from 2004 to 2009). The actual reversion rate for 2009 might be lower than reported. FIA initially identifies forest and nonforest land categories from interpreting aerial imagery. All plots currently identified as forest land from imagery are inventoried on the ground and any previously forested plots are also visited on the ground. Plots that do not appear to be currently forested and were not previously forested are not visited on the ground. Aerial imagery available for the 2004 inventory was not as high of quality as that used in the 2009 inventory. It is suspected that more forest land would have been identified in the 2004 inventory if the higher quality imagery were available at that time. Thus, the rate of reversion from the 2004 to 2009 inventory might be less than reported.

The recent increase in forest land is most apparent in the southern Lower Peninsula. The southern Lower Peninsula has the least amount of forest land at 17 percent but it is experiencing the most change, accounting for 60 percent of the state level increase in forest land.

Michigan's forests have been maturing, as can be seen in the distribution of timberland by stand-size classes (Fig. 6). 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, acreage has been increasing in large-diameter stands (plurality of sawtimber-size trees). Acreage in small-diameter stands (plurality of seedlings/saplings) was declining until the 2009 inventory; no significant change was found between the 2004 and 2009 inventories. Forest types and forest-type groups, such as aspen, red pine, oak/hickory, and elm/ash/red maple, experienced noticeable shifts in acreage from medium to large-diameter stands in the 1993 inventory (Schmidt et al. 1997). From 1980 to 2009, increases in sawtimber-size trees support this general trend (see Number of Trees). In the sawtimber-size class from 2004 to 2009, few species had increases; red pine, red maple, sugar maple, and green ash were the only prominent species with significant gains.

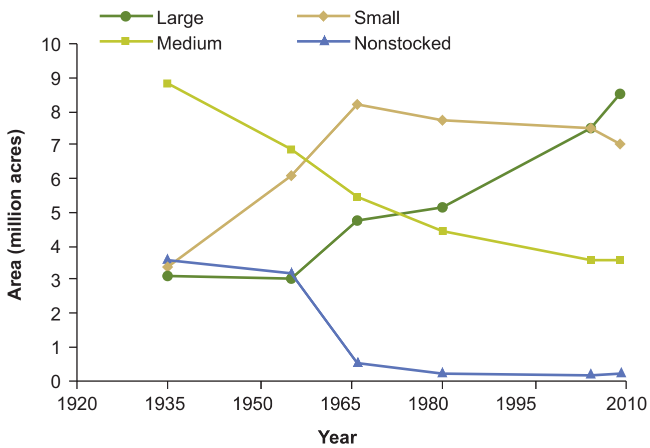

Figure 6.—Area of timberland by stand-size class and year, Michigan.

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 increased by 65 percent. The number of saplings increased by 16 percent and the number of poletimber-size trees has not changed significantly. From 2004 to 2009, the number of sawtimber-size trees increased 7 percent while the numbers of sapling and poletimber-size trees have not changed significantly.

The current stand-age class distribution in Michigan indicates that most stands are 40 to 80 years old and that 23 percent of timberland area is younger (Fig. 7). Four percent of timberland area is over 100 years old. Estimates of stand age are less precise than most other stand variables. One reason for this is that the estimate of stand age is based on the composition of all age classes within a stand. Often, stands are heterogeneous by age but FIA methods require a single value be assigned.

There are nearly 1.2 million acres of timberland designated as plantations in the 2009 inventory. Ninety-nine percent of these artificially regenerated stands are softwood types with red pine comprising roughly 60 percent. Jack pine ranks second. Seventy percent of all red pine stands (both plantations and natural) are less than 60 years of age. Forty-two 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.

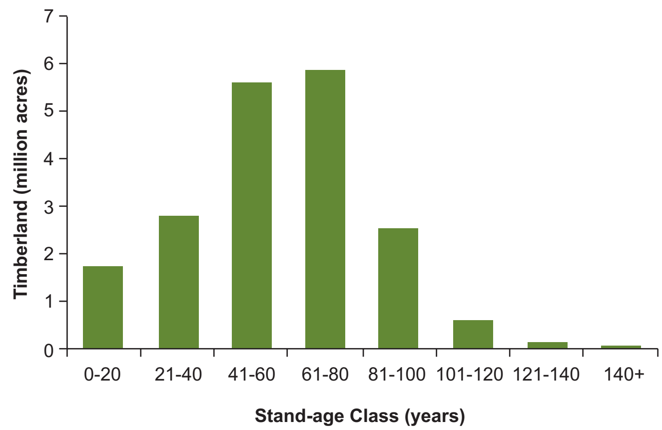

Figure 7.—Area of timberland by stand-age class, Michigan, 2009.

What this means

Michigan's forest-land base has remained relatively stable at the State level. Ninety-eight percent of forest land in 2004 remained so in 2009, but development, low wet areas, and farmland have contributed substantially to reversions and diversions. At the State level, estimates of forest land have been increasing since the 1980 inventory. Losses in forest land may occur as development increases but the current forest land estimate is at the highest level since the 1930s.

Current forest stand-size and age-class distributions indicate a maturing forest resource but there are young stands with 23 percent of timberland identified as less than 40 years old. Forest management and land use changes can greatly affect the distribution of stand-age classes. The overall trend toward maturing forests is expected to continue. Over time, the large acreage in the 40- to 80-year range probably will decrease due to management (resulting in younger stands) and some natural progression to older age classes. This may result in a more even balance among age classes.

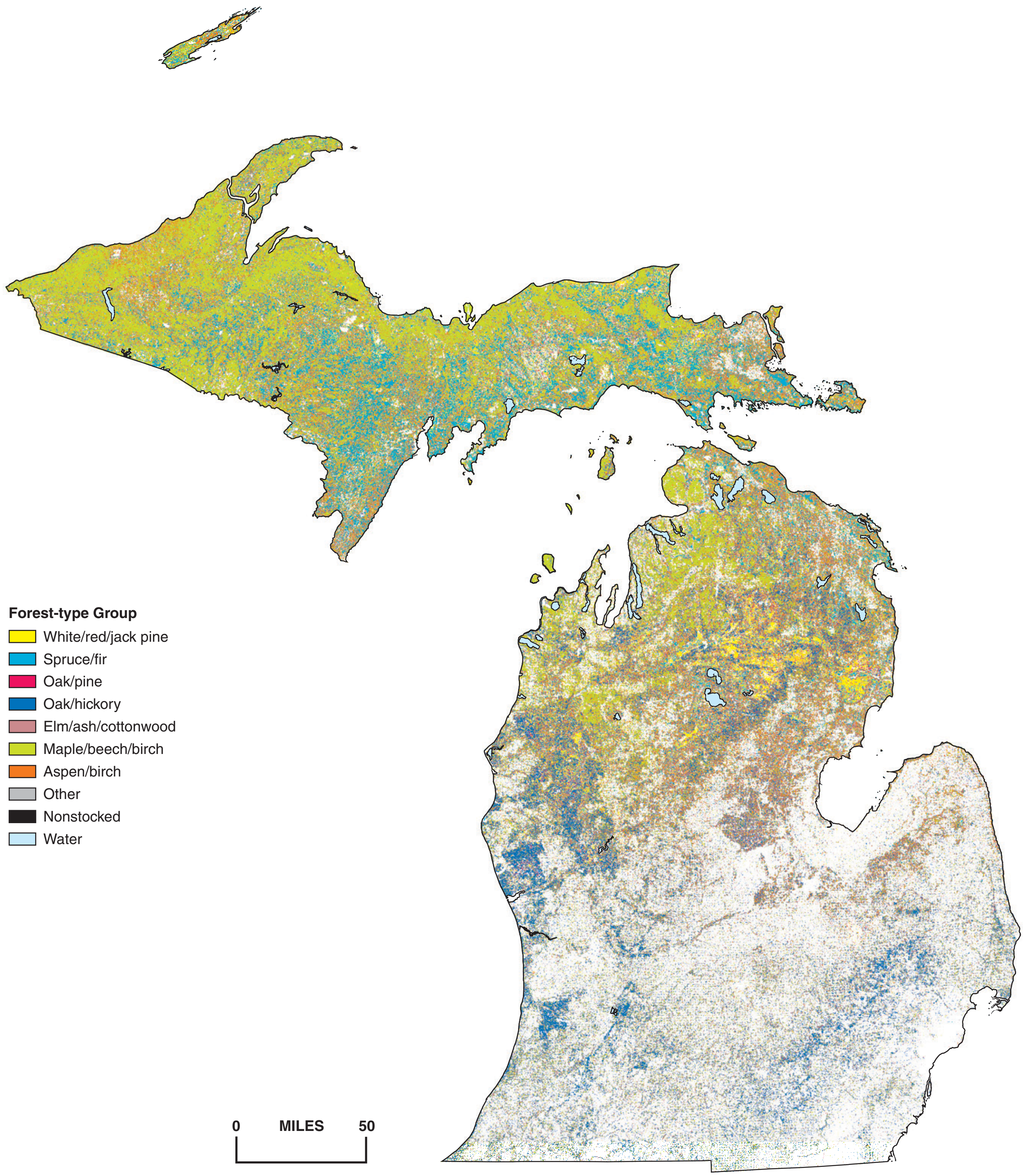

Figure 8.—Distribution of forest-type groups, Michigan, 2005 (see Map Descriptions and Acknowledgments in Statistics, Methods, and Quality Assurance).

Forest-type Distribution

Background

Forest type is determined by the stocking (relative density) that tree species contribute to a sampled condition (see Stocking). In stands with a mixture of size classes, the assignment of forest types is more heavily weighted toward the larger trees which contribute more to stocking. The current cover-type distribution stems from many influences ranging from competition between species, succession, and natural and manmade disturbances. Figure 8 is the modeled distribution of forest-type groups based on FIA plot attributes and ancillary data, e.g., information on topography and climate (see Statistics, Methods, and Quality Assurance). Related forest types are combined into forest-type groups that can then be used with other information, such as soils and climate, to create regional ecosystem classifications. Here, we focus primarily on specific forest types. Forest types are named based on a single or few species but the types are often comprised of many species (see Statistics, Methods, and Quality Assurance). For example, overall, the jack pine forest type is 62 percent jack pine, 19 percent red pine, 5 percent white pine, and 14 percent other species by volume (live trees at least 5 inches d.b.h.), none of which comprise more than 2 percent each.

What we found

Michigan has a diverse set of forest types. Most timberland is categorized as a hardwood forest type (72 percent) followed by softwood (24 percent), mixed (3 percent, comprised of softwood species such as jack or red pines and hardwood species such as oak or aspen), and nonstocked (1 percent).

No single forest type comprises more than 18 percent of timberland (Figs. 9 to 11). 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 percent is privately owned and the largest portion (50 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; 56 percent is privately owned and 52 percent is in the eastern Upper Peninsula.

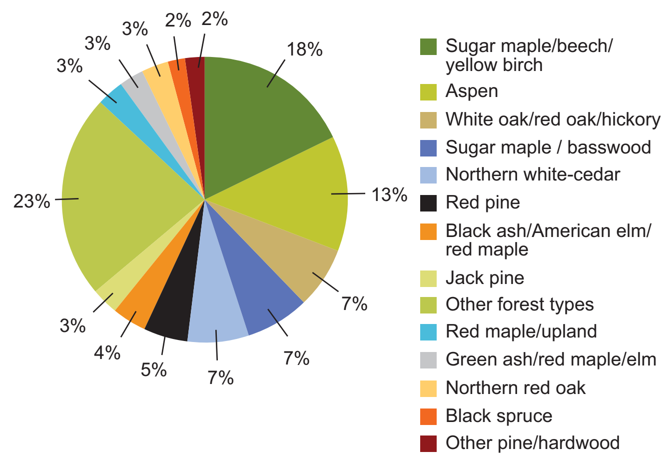

Figure 9.—Percentage of timberland by forest type, Michigan, 2009 (types that comprise at least 2 percent of timberland acreage).

Forest-type distributions vary by region (Fig 10). Black spruce (50 percent) and balsam fir (38 percent) are relatively abundant in the eastern Upper Peninsula. The northern Lower Peninsula has most of the other pine/hardwood (72 percent), northern red oak (70 percent), red pine (66 percent), and jack pine (53 percent). The southern Lower Peninsula has relatively little acreage in many of the prominent types; however, this region has the bulk of the white oak/red oak/hickory (56 percent), and green ash/red maple/elm (61 percent) forest types.

Some forest types are relatively more abundant in certain ownership groups given the amount of timberland in each group (Fig. 11). For example, red pine (64 percent of total acreage is publicly owned), jack pine (79 percent), other pine/hardwood (57 percent), and black spruce (53 percent) are relatively more abundant on public land. Aspen (32 percent) and northern white-cedar (32 percent) are more common on State and local government land. Sugar maple/beech/yellow birch (71 percent), sugar maple/basswood (73 percent), white

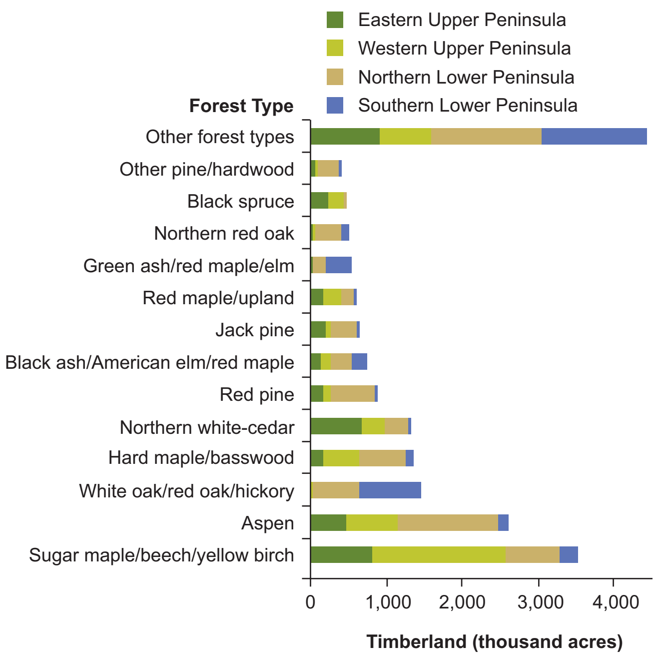

Figure 10.—Area of timberland by forest type and region, Michigan, 2009 (types that comprise at least two percent of timberland acreage).

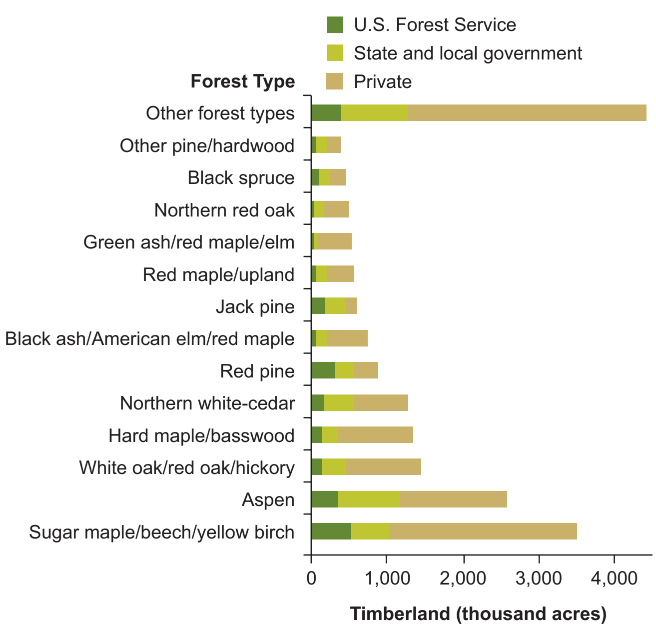

Figure 11.—Area of timberland by forest type and ownership group, Michigan, 2009 (types that comprise at least two percent of timberland acreage).

oak/red oak/hickory (67 percent), black ash/American elm/red maple (74 percent), red maple/upland (66 percent), and green ash/red maple/elm (87 percent) are found most often on private land. Some forest types such as 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 owns virtually no timberland.

Over the decades there have been many changes in the acreage of forest types. The definitions have changed among past inventories but are constant from 2000 to present. From 2004 to 2009 acreage significantly increased in the white oak/red oak/hickory (12 percent), green ash/red maple/elm (29 percent) and red maple/lowland (29 percent) types. This coincided with increases in the number of trees for red maple and green ash in pole and sawtimber-size trees from 2004 to 2009 (see Number of Trees). Since 1980, the number of northern red oak sawtimber-size trees has increased approximately 41 percent.

What this means

Site characteristics, past utilization, and adaptive abilities of species within forest types have influenced the forest-type distribution in Michigan. As land was cleared and logged during the European settlement, early successional species and associated forest types such as aspen and paper birch became established. These forest types have peaked and declined in acreage. Many of these early successional species depend on fire to regenerate, but wildfire has been suppressed. Some aspen and paper birch forest types have converted to late successional forest types, primarily to 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 by volume and are among the most important species to the State's wood-products industry (see Timber Product Output) and wildlife.

There are many other examples of forest-type acreage changing over time. There has been gradual increases in softwood forest types such as 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 planting programs by public agencies in the last century. Thousands of acres of softwoods were planted; 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. These planting programs are also partially responsible for the relative abundance of 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. These niches vary the 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 such as 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 such as 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

The estimated number of trees in a forest is useful when combined with data on diameter-class distribution. Young forests generally have a greater number of trees per acre than older forests but the latter usually have much more biomass. 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 13.9 and 13.5 billion live trees (at least 1 inch d.b.h.) on forest and timberland, respectively, or about 699 trees/acre on timberland. Sixty-four percent of the trees on timberland are hardwoods. Softwoods and hardwoods generally follow the same size-class distribution at the State level. 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 among species with no species accounting for more than 14 percent of trees.

Some species disproportionately occur in certain size classes (Figs. 12, 13). Balsam fir (not shown in Fig. 13) has more saplings (17 percent of saplings) than any other species in Michigan but only accounts for 2 percent of sawtimber-size trees. Red maple (12 percent) and sugar maple (10 percent) rank second and third in saplings, respectively.

Red maple (14 percent), sugar maple (13 percent), northern white-cedar (12 percent) and quaking aspen (6 percent) comprise nearly 50 percent of poletimber-size trees. Northern white-cedar (14 percent), sugar maple (12 percent), red pine (11 percent), red maple (10 percent), and northern red oak (5 percent) account for over 50 percent of sawtimber-size trees. The oaks account for 25 percent of all trees greater than the 18-inch size class but only 2 percent of saplings. Red pine is the only species with more poletimber-size trees than saplings (Fig. 13).

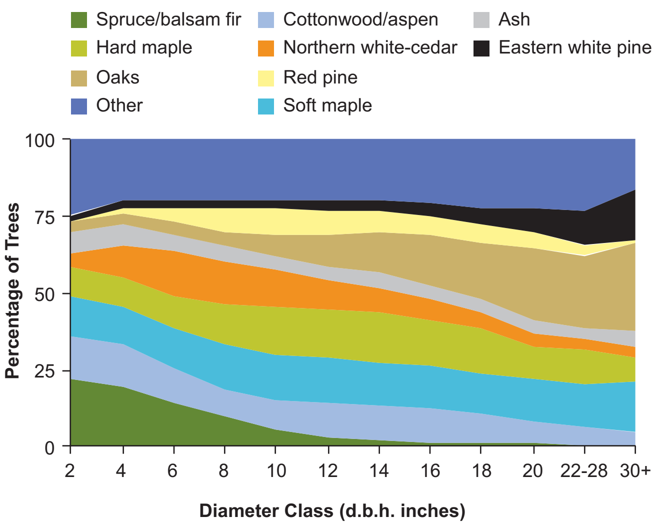

Figure 12.—Species composition on timberland by diameter class, Michigan, 2009.

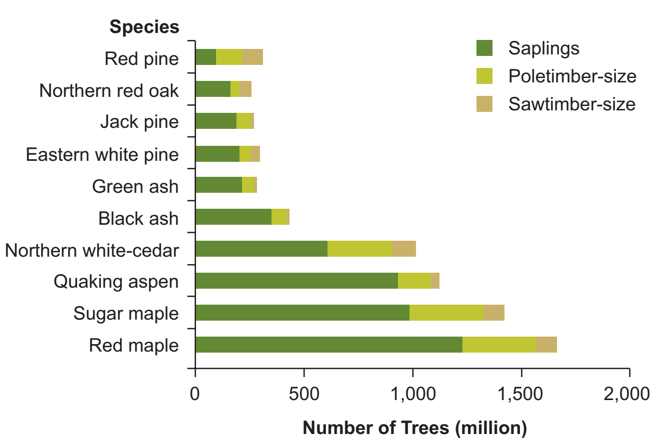

Figure 13.—Number of live trees (at least 1 inch d.b.h.) on timberland by size class and species, Michigan, 2009 (selected prominent species).

The number of trees on timberland increased significantly from 1980 to 2009 (675 to 699 trees/acre). There was a 23 percent increase in the number of softwoods and a 10 percent increase in hardwoods. Since 1980, the number of sawtimber-size trees increased by 65 percent. The number of saplings increased by 16 percent and the number of poletimber-size trees did not change significantly.

Changes since the 1980 inventory are shown in Table 3. Red maple, black cherry, eastern white pine, green ash, and white spruce experienced significant increases in all size classes. Red maple had the second largest increase in total number of trees at 263 million. Balsam fir had the largest overall increase but this was due to the increase in saplings. Balsam fir had fewer poletimber and sawtimber-size trees.

Quaking and bigtooth aspen both experienced a significant increase in saplings but a decrease in poletimber-size trees. Bigtooth aspen increased in the number of sawtimber-size trees while quaking aspen remained unchanged.

Sugar maple, northern white-cedar, black spruce, red pine, northern red oak, and white ash are either losing or maintaining sapling and/or poletimber-size trees while gaining sawtimber-size trees.

Northern white-cedar, red pine, and sugar maple experienced significant declines in saplings. Each had increases in the sawtimber-size class. Paper birch, yellow birch, and jack pine have experienced significant losses since 1980. Yellow birch lost in all size classes. Paper birch lost in the sapling and poletimber sizes and jack pine lost in pole and sawtimber sizes.

There were a few significant changes in the number of trees from 2004 to 2009. From 2004 to 2009, the number of sawtimber-size trees increased 7 percent while the numbers of sapling and poletimber-size trees did not change significantly. Red maple increased by 4 and 18 percent in pole and sawtimber-size trees, respectively. Green ash increased by 15 and 14 percent in pole and sawtimber-size trees, respectively. Red pine (14 percent) and sugar maple (8 percent) made significant gains in sawtimber-size trees. Black cherry (9 percent) increased in poletimber-size trees and white spruce (21 percent) increased in saplings. Paper birch (-11 percent) was the only species to decrease in number, losing in the sawtimber-size class.

The number of trees by size class varies somewhat by region or ownership group (Table 4). The numbers

Table 3.—Change in number of live trees on timberland by size class and species, Michigan, 1980-2009 (21 select species by number of live trees shown; numbers in bold italics indicate a significant change using 68-percent confidence interval).

Species	Sapling Trees	Sapling Percent	Poletimber-size Trees	Poletimber-size Percent	Sawtimber-size Trees	Sawtimber-size Percent	Total Trees	Total Percent
	million		*million*		*million*		*million*	
Balsam fir	***770***	***79***	***-27***	***-16***	***-5***	***-26***	***737***	***63***
Red maple	***166***	***16***	***53***	***18***	***45***	***108***	***264***	***19***
Sugar maple	***-473***	***-32***	14	4	***45***	***82***	***-414***	***-23***
Quaking aspen	***135***	***17***	***-55***	***-26***	-3	-7	77	7
Northern white-cedar	***-168***	***-22***	20	7	***50***	***75***	***-98***	***-9***
Bigtooth aspen	***87***	***33***	***-12***	***-12***	***6***	***30***	***80***	***21***
Black ash	33	10	***16***	***31***	0	13	***49***	***13***
Black spruce	16	6	6	8	***5***	***89***	27	7
Black cherry	***122***	***62***	***12***	***26***	***10***	***150***	***145***	***58***
Red pine	***-86***	***-48***	5	4	***71***	***324***	-9	-3
Eastern white pine	***107***	***111***	***32***	***144***	***20***	***100***	***159***	***114***
Green ash	***126***	***136***	***41***	***305***	***12***	***768***	***178***	***166***
Eastern hophornbeam	***107***	***67***	-1	-7	0	-17	***105***	***59***
Jack pine	-32	-15	***-54***	***-45***	***-4***	***-16***	***-90***	***-25***
Northern red oak	10	7	***-36***	***-41***	***12***	***41***	-14	-5
American elm	4	2	-3	-7	***-2***	***-35***	-1	0
White spruce	***89***	***115***	***11***	***35***	***4***	***24***	***104***	***83***
Paper birch	***-50***	***-26***	***-61***	***-47***	-1	-10	***-113***	***-34***
American beech	***79***	***78***	2	9	1	9	***82***	***60***
White ash	-2	-1	***-10***	***-31***	***4***	***47***	-8	-
Yellow birch	***-29***	***-24***	***-10***	***-20***	***-2***	***-11***	***-41***	***-22***
Total	***1,387***	***16***	-41	-2	***334***	***65***	***1,680***	***14***

Table 4.—Number of trees per acre on timberland by size class and region or ownership.

	Sapling	Poletimber-size	Sawtimber-size
	---------	*trees per acre*	---------
Region:			
Eastern Upper Peninsula	686	147	46
Western Upper Peninsula	564	137	44
Northern Lower Peninsula	497	128	44
Southern Lower Peninsula	367	98	40
Ownership:			
National Forests	513	141	57
State and local government	592	128	40
Private	512	126	42

of sapling and poletimber-size trees per acre decrease in rank order from the eastern Upper, western Upper, northern Lower, and southern Lower Peninsula, respectively. The number of sawtimber-size trees per acre is lowest in the southern Lower Peninsula and does not vary significantly among the other regions. The sawtimber-size trees in the southern Lower Peninsula are slightly larger and there are proportionally more than in other regions (8 percent versus 5 to 7 percent in other regions). This explains the larger estimates for biomass and volume per acre for the southern Lower Peninsula compared to the rest of Michigan (see Volume; Biomass and Carbon). National Forests have more pole- and sawtimber-size trees per acre than other ownerships. State and local government ownership has the most saplings per acre.

What this means

With succession acting as a major influence, 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 such as sugar maple and northern white-cedar are losing recruitment (young trees). This trend reflects concerns 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 Volume). These increases have contributed to the increase in acreage of the red pine forest type. Sawtimber-size trees are weighted more heavily than smaller trees when classifying forest types. Red pine was the most popular plantation species 45 to 75 years ago and now much has grown to a commercially harvestable size. The rate of planting has been low over the past 45 years. Most red pine are poletimber-size trees.

Balsam fir has more saplings than any other species in Michigan and thus balsam fir acreage could increase in the future as saplings mature. Some of this potential increase will be offset by the fact that balsam fir also has decreased in volume (Fig. 23) and has one of the highest ratios of average annual mortality to current volume (Fig. 35). Contrary to the increase in saplings, poletimber and sawtimber-size trees have been decreasing and the acreage of the balsam fir forest type has followed the decrease since the 1980s. 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. It is a prominent member of many of the forest types.

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.

The increase in northern red oak sawtimber-size trees is typical for most of the other oak species also. It appears that the acreage of oak forest types has been increasing with the increase in sawtimber-size trees. Only a few oaks, such as northern pin oak and black oak, appear to be gaining in saplings. Most oaks are midtolerant and respond well after fire. Oaks also have a number of health threats. These elements pose management challenges and make it unclear what direction oak acreage will go in the future.

Some species are on a steep decline. Since 1980, paper birch and jack pine have decreased sharply in number (34 and 25 percent, respectively). They have also decreased significantly in volume (Fig. 23). 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 Insects, Disease, and Decline) and are more susceptible partly because Michigan is located at 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 wildlife species such as the Kirtland's warbler (*Dendroica kirtlandii*). Some Michigan management areas focus on improving habitat for this warbler. In these areas, the decline in poletimber-size jack pine trees is expected to level off in response to management (Pugh 2011).

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 medium-diameter stands (plurality of poletimber-size trees) have a basal area of more than 80 square feet (ft^2)/acre. Using this example, a fully stocked small-diameter 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 Arner et al. 2003. 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. Methods for determining stocking class changed during the switch to annual inventories but data available since 2000 use a consistent approach. Temporal comparisons back to periodic inventories are difficult to interpret except it is certain that nonstocked acreage dropped considerably after the 1955 inventory and has continued to remain low.

What we found

Seventy-eight percent of Michigan's forest land is medium or fully stocked. Six percent is overstocked and 16 percent is poorly stocked or nonstocked. Stocking levels have not changed appreciably since the 2004 inventory. Wisconsin (35 percent) and Minnesota (33 percent) have fewer fully stocked stands compared to Michigan (42 percent).

In Michigan, stocking varies by owner, region, and forest type (Figs. 14-16). Forest Service lands have the greatest percentage of fully and overstocked stands at 52 and 8 percent, respectively. Private lands have the lowest percentage of fully and overstocked stands at 41 and 5 percent, respectively. State and local government ownerships have 43 and 8 percent fully and overstocked stands, respectively. The Forest Service has a significantly lower percentage of poorly and nonstocked stands (11 percent) compared to private (17 percent) and State and local government (16 percent). These poor and nonstocked areas do not include nonforest land such as barrens, marshes, and rangeland.

The eastern Upper Peninsula and northern Lower Peninsula have stocking distributions that closely follow the statewide trend (Fig. 15). By contrast, the southern

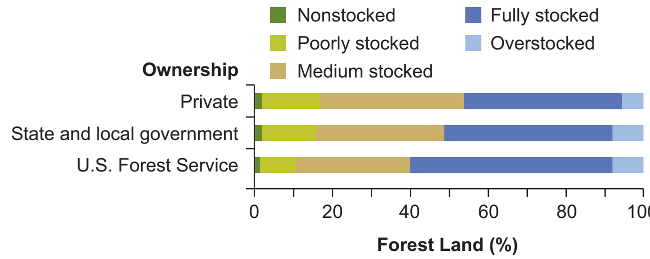

Figure 14.—Percentage of forest land by stocking class and ownership group, Michigan, 2009.

Lower Peninsula has a significantly lower percentage of its stands in the fully (33 percent) and overstocked classes (3 percent) and a higher percentage in the lower stocking classes (38-percent medium and 26-percent poorly or nonstocked). The western Upper Peninsula has the greatest percentage of fully stocked stands (51 percent) and the lowest percentage of poorly and nonstocked stands at 10 and 1 percent, respectively.

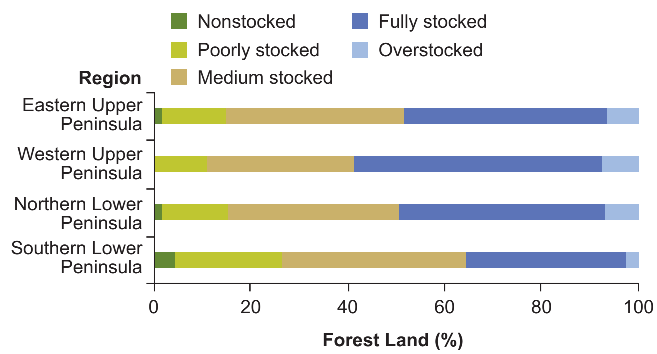

Figure 15.—Percentage of forest land by stocking class and region, Michigan, 2009.

Stocking levels vary by forest type (Fig. 16). This variation is influenced by the inherent characteristics of the forest types, site characteristics, and past utilization of the forest types. Sugar maple/basswood, sugar maple/beech/yellow birch, northern white-cedar, and northern red oak forest types have higher percentages of fully stocked stands. Jack pine, other pine/hardwood, black spruce, and green ash/red maple/elm forest types have lower percentages of fully stocked stands and higher percentages of poorly and nonstocked stands.

Forest types with the highest stocking (e.g., sugar maple/beech/yellow birch) are more common on mesic sites.

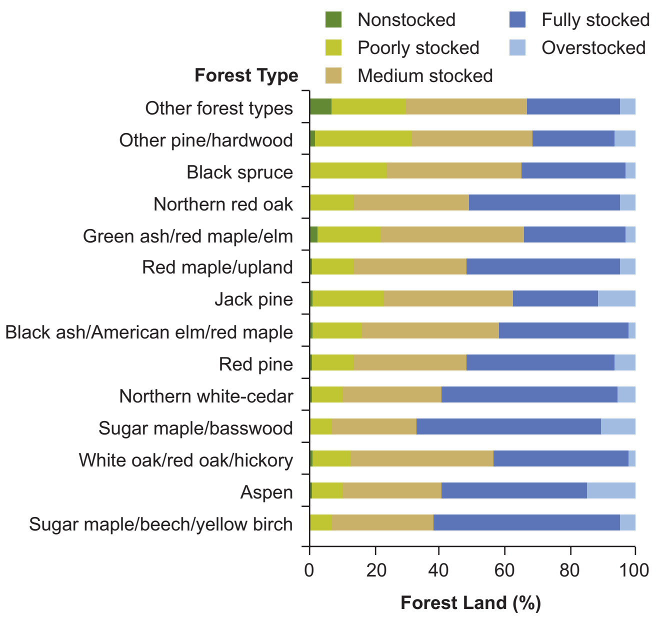

Figure 16.—Percentage of forest land by stocking class and forest type, Michigan, 2009 (types that comprise at least two percent of timberland acreage).

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 usually occur 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 but much better soils and site productivity. Forty-seven percent of forest land 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 25 percent of forest land 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 is due to nonforest land reverting to forest land. Fifty-five percent of the low and nonstocked forest land in 2009 was nonforest land in 2004. Nearly half of this reverting nonforest land was cropland and pasture. Twenty-eight percent of the reversions came from developed and cultural lands. 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 (Fig. 10).

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 and Carbon

Background

There is increasing interest in biomass and carbon. Among other things, biomass estimates are important in determining carbon sequestration, fuel availability, and fuel loading in forest stands. Forests and wood waste from industry are important sources of biomass. Tree biomass includes the whole tree, including roots, but most of the focus in this report is on live aboveground tree biomass (at least 1 inch d.b.h., including bark but excluding foliage).

A new procedure for estimating biomass was implemented in 2008 to promote national consistency and provide better estimates of biomass from individual tree components. This new procedure, the component ratio method (Heath et al. 2009), is based on: converting the sound volume of wood in the bole to biomass using a compiled set of wood specific gravities; calculating the biomass of bark on the bole using a compiled set of percent bark and bark specific gravities; estimating the stump, tops, and limbs as a proportion of the bole based on component proportions; and summing the parts for a total aboveground live biomass. The new methods are employed in this analysis. Generally, trends in biomass follow trends in volume.

Roughly half of dry tree biomass is carbon. Concern over global climate change has focused attention on the capacity of forests to act as carbon sinks. The introduction of markets for trading in carbon credits could result in a different mix of forest management practices and require additional information on forest carbon stocks.

A combination of sampled (directly measured stocks, such as live-tree carbon) and modeled (based on forest attributes such as forest-type group for estimating carbon from soil organic matter) estimates provide a total carbon stock for Michigan's forests. Estimation procedures are detailed by Smith et al. (2007) and the Environmental Protection Agency (EPA) (2008).

What we found

Biomass on forest land is estimated at 805.5 million dry tons averaging 40.5 tons/acre. The distribution of biomass/acre on forest land varies by region (Table 5). Although the greatest per-acre biomass is in the southern Lower Peninsula, most of Michigan's biomass is in the northern Lower Peninsula and western Upper Peninsula.

Eighty-two percent of live aboveground tree 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. 17). Nongrowing-stock trees larger than saplings are rough or rotten cull trees (saplings are also excluded from growing stock) or nongrowing-stock species such as apple. Standing dead trees account for 45.5 million dry tons (2.2 tons/acre). Seventy-seven percent of the biomass consists of hardwood species. Biomass ownership is divided at 63, 20, 15, and 2 percent for private, State and local government, U.S. Forest Service, and other Federal, respectively. This distribution is consistent with acreage of forest land ownership.

Table 5.—Live aboveground tree (at least 1 inch d.b.h.) biomass and forest land by region, Michigan, 2009.

Region	Forest land	Biomass	Biomass	Biomass
	million acres	*million dry tons*	*dry tons/acre*	*percent*
Eastern Upper Peninsula	4.2	146.5	34.9	18.2
Western Upper Peninsula	5.0	210.5	42.5	26.1
Northern Lower Peninsula	7.4	289.4	39.1	35.9
Southern Lower Peninsula	3.4	159.2	47.4	19.8
Statewide	19.9	805.5	40.5	100

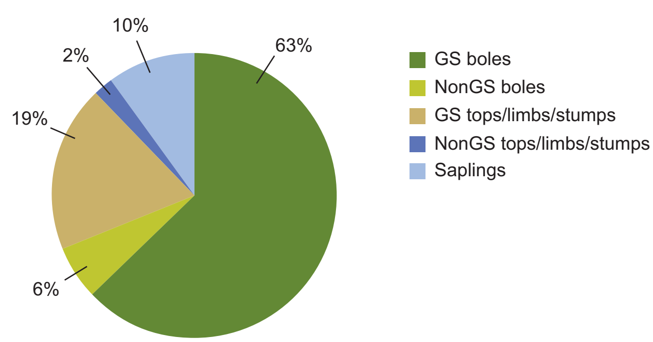

Figure 17.—Percentage of live-tree biomass on forest land by aboveground component, Michigan, 2009. Saplings include trees at least 1 but less than 5 inches d.b.h. Growing-stock (GS) and nongrowing-stock (NonGS) trees are at least 5 inches d.b.h.

Biomass on timberland in 1980 was 555.6 million dry tons. Biomass increased to 781.6 million dry tons in the 2009 inventory. This increase was mainly due to the increasing size of trees in Michigan. In 1980, nearly half of the live-tree biomass on timberland was in the 8-inch d.b.h. class and smaller. Since the 2004 inventory, half of it has been in the 10-inch d.b.h. class and smaller (Fig. 18).

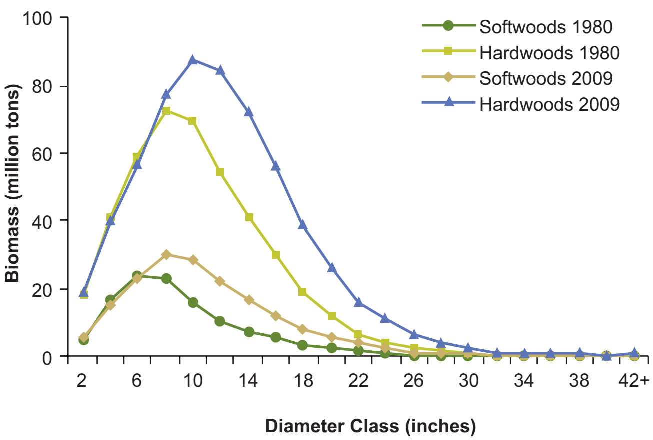

Figure 18.—Distribution of live aboveground tree biomass (trees at least 1 inch d.b.h.) on timberland by species category and 2-inch diameter class, Michigan, 1980 and 2009.

There are 2,080.9 million tons of carbon in Michigan's forests (Fig. 19). Organic matter in mineral soil (1,326.4 million tons) contains the largest carbon component followed by aboveground live trees (trees at least 1 inch d.b.h. at 402.7 million tons). For comparison, the aboveground live-tree carbon component in Michigan is approximately equal to one and a half times the amount of carbon sequestered (captured and stored) in the United States in 2006 (EPA 2008).

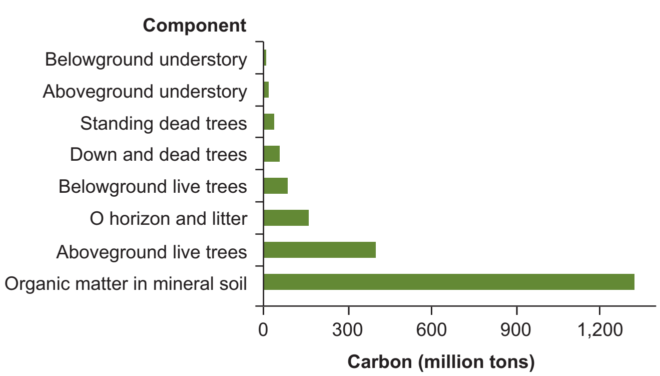

Figure 19.—Forest land carbon stock by component, Michigan, 2009. Litter includes leaves and small woody debris (less than 3 inch diameter) such as small branches. Mineral soil occurs below O horizon.

What this means

Interest is high in the use of wood biomass for future energy production. Michigan is continuing to gain biomass as its forests mature. Most of this biomass is in the boles of the growing-stock trees and most of the biomass 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; however, the forest soil pool contains most of the carbon.

Volume

Background

Like stocking, current volumes and change in volume over time characterize the forests and reveal important resource trends. It is also useful to compare components of change such as 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 most past estimates of net growth, removals, and mortality are available only for this category.

Estimates of live-tree volume include live, rough, rotten, and noncommercial species 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 28.7 billion ft^3 of growing stock on timberland, or about 1,487 ft^3/acre. Of this volume, 69 and 31 percent are in hardwood and softwood species, respectively. Sugar maple (22 percent), red maple (18 percent), quaking aspen (8 percent), northern red oak (8 percent), and bigtooth aspen (6 percent) account for 62 percent of hardwood growing-stock volume. Northern white-cedar (25 percent), red pine (24 percent), and eastern white pine (15 percent) account for 64 percent of softwood growing-stock volume.

Sixty-three percent of the timberland growing stock 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. Only 37 percent of timberland is publicly owned; however, public land has 51 percent of the softwood growing-stock volume due partially to public planting programs and softwood management since the 1920s. Also, much of the public land is inherently in softwood forest types.

Growing-stock volume on timberland has increased significantly in each inventory since 1955 (Figs. 20, 21). 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. From 1980 to 2004, the increase was just under 2 percent per year. Since 2004, total growing-stock volumes increased significantly but only at 1 percent per year. The hardwoods increased by just over 1 percent per year, the same rate observed from 1980 to 2004. The increase in softwoods dropped from 2 percent per year (1980 to 2004) to 0.6 percent per year (2004 to 2009).

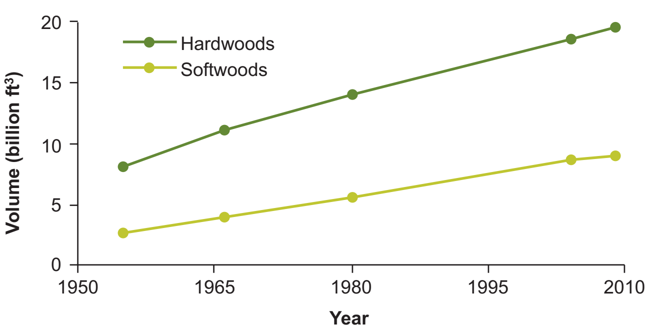

Figure 20.—Distribution of growing-stock volume on timberland by species category, Michigan.

The change in hardwood volume has remained fairly constant since 1980, but the increase (0.6 percent per year) in softwood volume between the 2004 to 2009 inventories was a significant drop from the net change observed between 1980 and 2004 (2 percent per year).

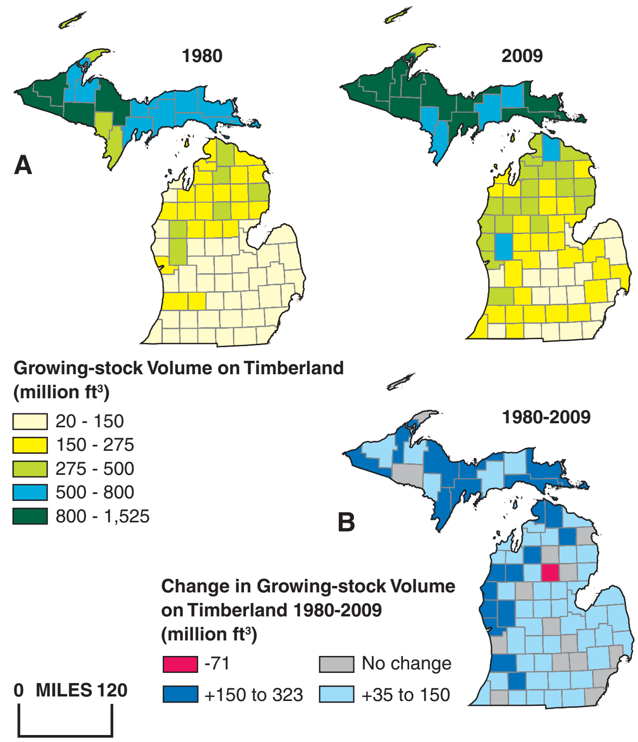

Figure 21.—Growing-stock volume (A) and change in growing-stock volume on timberland (B) by county, Michigan, 1980-2009 (see Map Descriptions and Acknowledgments in Statistics, Methods, and Quality Assurance).

Another way to measure net change uses estimates of growth, removals, and mortality. Net change in softwood volume derived using the alternative method is more than double (1.4 percent per year) the estimate derived from comparing volumes in the 2004 and 2009 inventories. Both methods produced the same estimate of just over 1 percent for net change in hardwoods. The growth, removals, and mortality estimates are derived from remeasured plots. Different sets of FIA plots were used for current (e.g., volume) and remeasured estimates.

Total live net volume on all forest land is 30.2 billion ft^3 (trees at least 5 inches d.b.h.) and includes rough and rotten cull trees. Nearly 8 percent of this volume is in live-cull trees, some of which are used in commercial production. Salvable dead trees contribute 1.2 billion ft^3 of volume. These dead trees are important for wildlife and are often used for firewood.

Per-acre volume by species varies geographically (Fig. 22). There are higher concentrations of softwood volume in the eastern Upper Peninsula and northeastern

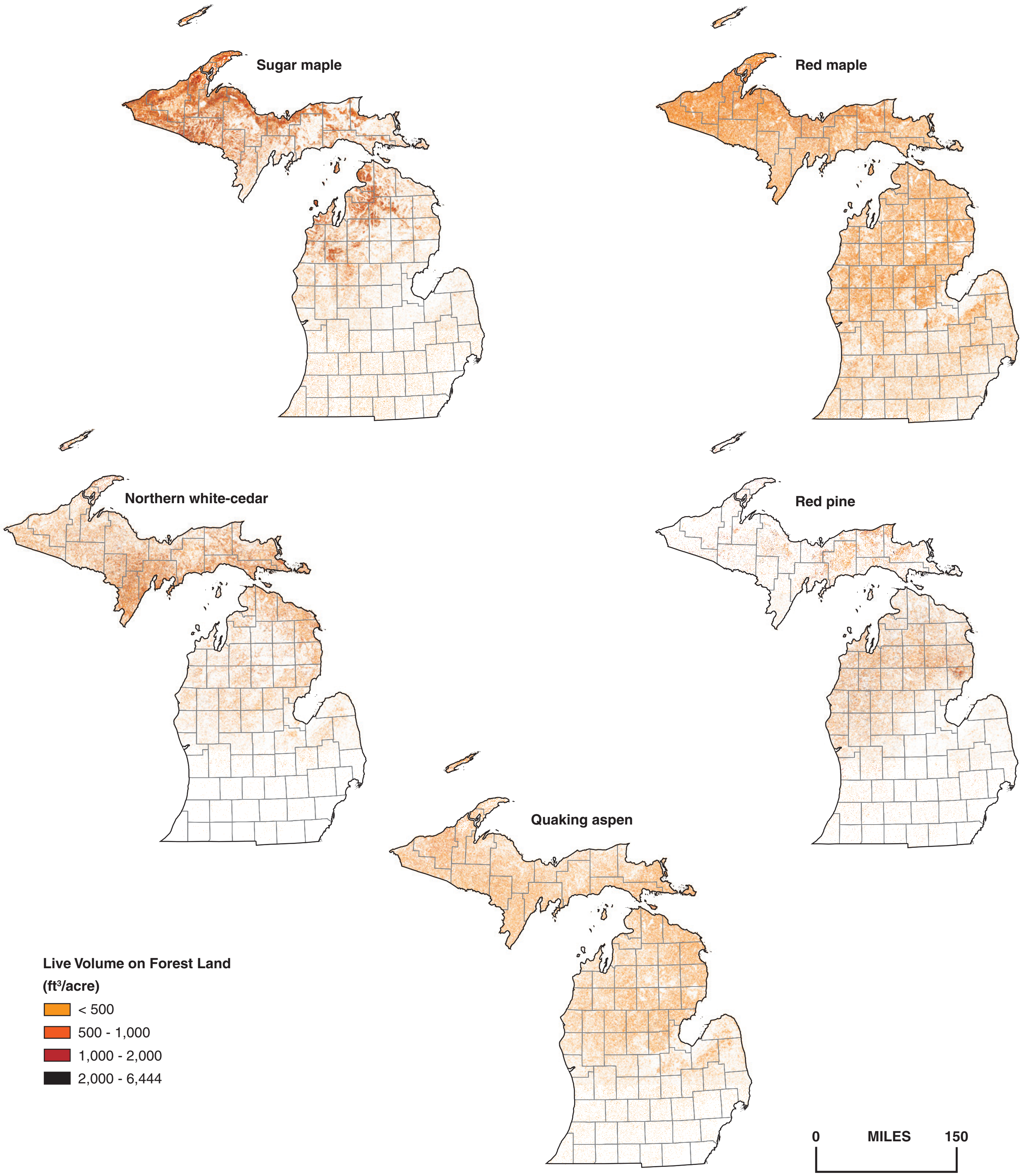

Figure 22.—Volume of live trees per acre (trees at least 5 inches d.b.h.) on forest land for the five most common species by volume, Michigan, 2005 (see Map Descriptions and Acknowledgments in Statistics, Methods, and Quality Assurance).

Lower Peninsula. The distribution of volume for the five most common species by volume varies considerably except for red maple, which is found throughout most of Michigan.

Most of Michigan's tree species have experienced significant increases in growing-stock volume since 1980 (Fig. 23). Eastern white pine, black oak, and red pine at least doubled in volume. Green ash has increased more than any other species on a percentage basis since 1980, but there were only 81 million ft^3 of it in 1980. White and black ash (not shown) also increased by 24 and 38 percent, respectively. Corresponding with gains in volume, species such as red maple and eastern white pine increased in number in all size classes (Table 3).

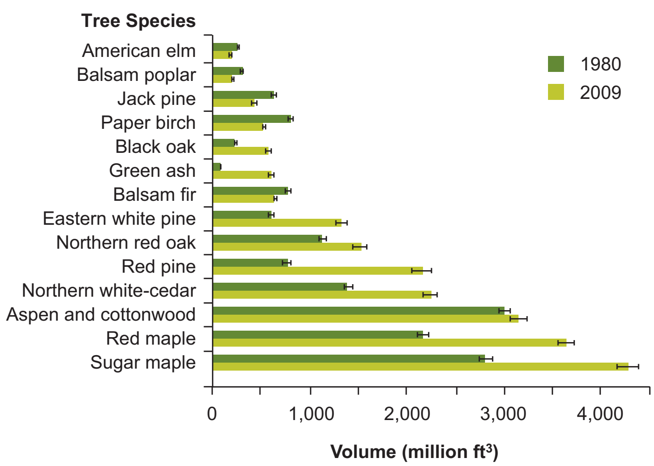

Figure 23.—Volume of growing stock on timberland by species, Michigan, 1980 and 2009; error bars represent 68-percent confidence interval around estimate (selected prominent species).

Balsam fir, balsam poplar, American elm, paper birch, and jack pine experienced significant losses while yellow birch (not shown) remained constant. The aspen/cottonwood species group did not change significantly with gains in cottonwood and bigtooth aspen offsetting a slight decrease in quaking aspen. Although quaking aspen and balsam fir have dropped in growing-stock volume, they have gained significantly over these same years in sapling-size trees (Table 3). The opposite is true for paper birch, which has dropped in the number of sapling and poletimber-size trees. Jack pine has lost in the number of poletimber-size trees.

From 2004 to 2009, growing-stock volume increased for green ash (16 percent), black oak (15 percent), red maple (11 percent), red pine (11 percent), eastern white pine (10 percent), and northern red oak (10 percent). Jack pine (12 percent) and paper birch (10 percent) decreased.

Ash species, especially green ash, have increased in number and growing-stock volume; however, some areas are currently experiencing decreases in ash due to infestation by the emerald ash borer (EAB). Pugh et al. (2011) analyzed FIA data from 2004 through 2009 within 31 miles of the epicenter of the EAB invasion near Detroit, MI, where there was a major decline in live volume and number of ash trees after 2004. This decline was associated with a large increase in the numbers of standing dead as well as harvested ash.

Total growing-stock volume and per-acre growing-stock volume 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 per-acre growing-stock volume (1,788 ft^3/acre) followed by private (1,484 ft^3/acre) and State and local government ownership (1,333 ft^3/acre). Since 1980, the Forest Service has seen the largest gain in growing-stock volume per acre (55-percent increase). Both private ownership and State and local government ownership increased by approximately 30 percent.

The western Upper Peninsula (1,562 ft^3/acre) and southern Lower Peninsula (1,601 ft^3/acre) have significantly higher growing-stock per-acre estimates than the eastern Upper Peninsula (1,351 ft^3/acre) and northern Lower Peninsula (1,461 ft^3/acre). Since 1980, the greatest increase was in the southern Lower Peninsula (53 percent). The smallest increase was in the western Upper Peninsula (17 percent).

From 2004 to 2009 there were some significant changes in growing-stock volume and per-acre growing-stock volume on timberland. Private ownership and State and local government ownership each had increases between 5 to 6 percent in growing-stock volume. The northern Lower Peninsula had increases in total and per-acre estimates of 8 and 7 percent, respectively. The estimate for growing-stock volume in the southern Lower Peninsula increased 14 percent but there was no significant increase per acre. The western Upper Peninsula experienced a 3 percent loss in growing-stock volume per acre. There were no significant changes in per-acre growing-stock volume in any ownership group.

What this means

Since 1980, increases in timberland area and the number of trees, particularly sawtimber-size trees, have led to increases in growing-stock volume. The U.S. Forest Service has the greatest proportion of fully stocked stands (Fig. 14) and the southern Lower Peninsula has the highest proportion of sawtimber-size trees (see Number of Trees).

Although Michigan is still 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. Between the 2004 and 2009 inventories, the estimates of net change were calculated with two different methods. The estimates of net change vary but both indicate a lesser increase in softwoods. The time between the 2004 and 2009 inventories is short considering the periods associated with stand and ecosystem dynamics. Continued monitoring will provide better insight on the future direction of volumes in Michigan.

Sawtimber Volume and Quality

Background

Sawtimber volume is an 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 ¼–inch rule). Softwood sawtimber is valued primarily for dimensional lumber while hardwood sawtimber usually is valued for flooring, kitchen cabinets, 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 with quality inversely related to grade number. Trees not meeting grade 5 requirements are considered cull. Grades 1 through 4 are assigned to trees that contain a 12 feet grading section in the butt 16 feet of the tree. 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. All species of hardwoods are graded 1 through 5 but grades defined for softwoods vary by species. Eastern white pine is graded 1 through 5 but grade 4 is not applied to other pines. Other softwoods, including spruce, fir, hemlock, native tamarack, and cedar, are assigned grades 1 or 5 only. The grading system has changed a number of times. It changed between the 1993 and 2004 inventories and again in 2007. Notable changes in 2007 affected softwood grading (e.g., added grade 5 for all softwoods) while hardwood grading rules have been fairly consistent since 2000. This report's analysis of softwood grades is based only on data from 2007 onward using the most recent grading rules.

What we found

There are 89.3 billion board feet of sawtimber on forest land in Michigan. About 4 percent of the sawtimber volume is on reserved and/or less productive forest land. There are 86.0 billion board feet of sawtimber on timberland. Of this, 64 percent is in hardwood species. Sugar maple (20 percent), red maple (16 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 (27 percent), northern white-cedar (22 percent), and eastern white pine (19 percent) account for 69 percent of softwood sawtimber volume. Considering only timberland, 63 percent of sawtimber occurs on private ownership. Twenty percent is owned by State and local governments and the remainder is in Federal ownership.

Sawtimber volume on timberland has increased in each inventory since 1955 (Fig. 24). 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. From 1980 to 2004, the increase was just over 3 percent per year. Since the 2004 inventory, sawtimber volumes for softwoods and hardwoods have increased by 1 and 2 percent per year, respectively.

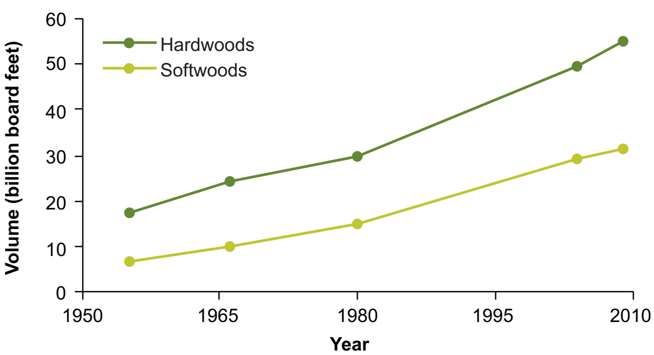

Figure 24.—Sawtimber volume on timberland by species category, Michigan.

By species, the trend in increasing sawtimber volume from 1980 to 2009 followed closely with the trend in growing-stock volume (Fig. 25, Fig. 23). Species such as eastern white pine, northern white-cedar, red pine, and red maple increased at least twofold. Balsam fir (not shown) decreased significantly (23 percent). There was no significant change for jack pine, yellow birch, and paper birch (not shown).

Sawtimber volume has increased significantly for every region and for every major ownership group since 1980. Forest Service land has the greatest sawtimber per-acre volume (5,739 board feet/acre) followed by private (4,397 board feet/acre) and State and local government (3,936 board feet/acre) ownership. Since 1980, the U.S. Forest Service has seen the largest gain in sawtimber per-acre volume (130 percent). State and local government had an 83-percent increase and private ownership had a 62-percent increase.

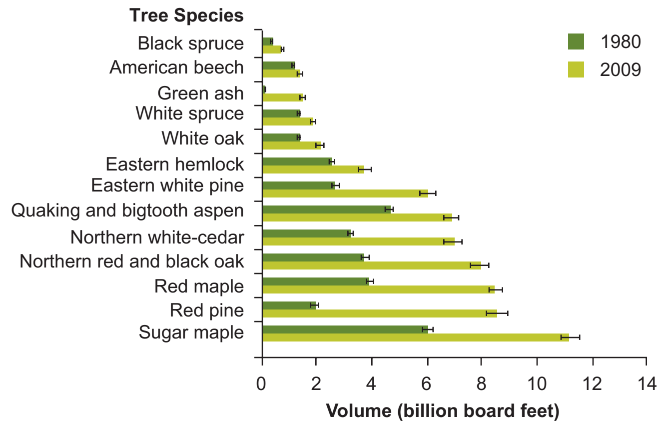

Figure 25.—Sawtimber volume on timberland by species, Michigan, 1980 and 2009; error bars represent 68-percent confidence interval around estimate (selected prominent species).

The southern Lower Peninsula has the greatest sawtimber per-acre volume (5,376 board feet/acre) on timberland followed by the western Upper Peninsula (4,557 board feet/acre), northern Lower Peninsula (4,299 board feet/acre), and eastern Upper Peninsula (3,879 board feet/acre). Since 1980, the greatest increase has been in the northern Lower Peninsula (110 percent). The western Upper Peninsula had the smallest increase (40 percent).

As previously stated, eastern white pine is graded 1 through 5; it has 36 percent of sawtimber volume in grade 3 with 43 percent in grades 1 and 2. Other pines (not assigned grade 4) have 89 percent of sawtimber volume in grade 3. The remaining softwoods (assigned only grades 1 or 5) have 90 percent of their sawtimber volume in grade 1. Hardwood sawtimber volume by grade appears to follow a normal distribution (Fig. 26), with 35 percent of volume in grade 3.

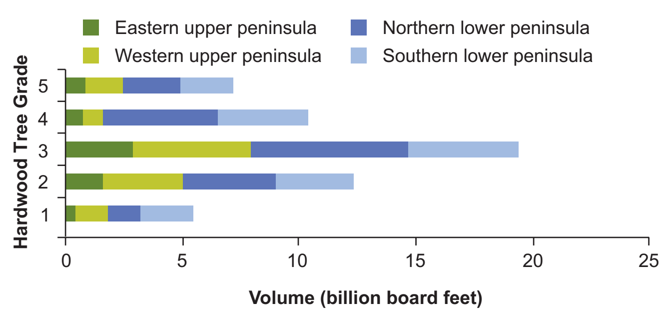

Figure 26.—Hardwood sawtimber volume on timberland by tree grade and region, Michigan, 2009.

The northern Lower Peninsula has the most timberland area and sawtimber volume in hardwoods and softwoods. Even so, the southern Lower Peninsula, with a higher proportion of slightly larger trees, has the most grade 1 hardwood sawtimber volume. For eastern white pine, the Upper Peninsula has 55 percent of its sawtimber volume in grades 1 and 2 versus 32 percent for the northern Lower Peninsula. The western Upper Peninsula has the highest percentage of other pines in grades 1 and 2 at 28 percent. In general, the western Upper Peninsula has a higher percentage of sawtimber volume in grades 3 and better.

The U.S. Forest Service has 73 percent of hardwood sawtimber volume in grades 3 and better compared to the balance of ownerships at 67 percent. The U.S. Forest Service also has a greater percentage of eastern white pine in grades 1 and 2 (58 percent) compared to ownership groups State and local government (43 percent) and private (36 percent).

What this means

The changes in sawtimber volume were similar to those for growing-stock volume. Many late-successional species such as eastern white pine and sugar maple made significant and substantial gains. Red maple is among the species 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; this is due in part to drought and spruce budworm outbreaks (see Insects, Disease, and Decline), the mortality-to-volume rate for this species is one of the highest (Fig. 35).

Grading rules have changed over time but it is certain that we gained volume in higher grades. Given a set number of defects, larger trees receive higher grades and there were increases in the number and size of sawtimber-size trees.

Annual Net Growth

Background

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. The ratio of annual net growth to current volume (percent) is a useful measure for analysis. 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 values vary somewhat by species. A negative number indicates that mortality is exceeding growth. Here, we look at average annual net growth of growing stock on timberland between inventories.

As previously mentioned, estimates of net growth, mortality, and removals were improved after the 2004 inventory (see Background). For some species, the estimates of net growth varied substantially between the 2004 and 2009 methods. Any comparisons between 2004 and 2009 estimates of net growth will be based upon the 2004 methods. Otherwise, 2009 estimates are based on the most recent and improved methods. Differences in estimates for mortality and removals were negligible so no adjustments were applied in comparisons of mortality or removals between the 2004 and 2009 inventories.

Historically, estimates of change (e.g., net growth, removals, and mortality) to current volume have included land-use change. With such changes included, there could be net growth associated with land classified as timberland in the previous inventory but the most current inventory could have no associated volume due to a land-use change to nontimberland. For most analyses, this confounds comparisons of change to volume and can distort interpretations. The most current methods allow us to investigate change to current volume where the condition is timberland in the previous and current inventory. Except for long-term temporal comparisons, this report will focus on timberland-to-timberland estimates. The type of comparison (timberland-to-timberland versus land-use change) will be noted.

Estimates of net growth, mortality, and removals for the 2009 inventory cover measurements from 2000-2004 to 2005-2009, a nominal 5-year window. This is a relatively short time period and differs from the 10 years or more covered in previous inventories. Comparisons between the 2004 and 2009 inventories are made in this report. Estimates of change for the 2004 inventory cover measurements from 1993 to 2000-2004.

What we found

Average annual net growth of growing stock on timberland was 698.4 million ft^3 (687.3 million ft^3 using 2004 methods) for the 2009 inventory (2000-2004 to 2005-2009). Using 2004 methods, this is almost 13 percent less than the estimate of 786.8 million ft^3 for the 2004 inventory (1993 to 2000-2004).

The annual net growth estimate of 698.4 million ft^3 is about 2.5 percent of growing-stock volume on timberland in 2009 (timberland-to-timberland). In comparison, Minnesota and Wisconsin have values of 2.8 and 2.9 percent, respectively. For Michigan, 70 percent of the net growth was in hardwoods and 69 percent was in private ownership.

From 1955 to 1980 annual net growth on timberland increased from 492.6 to 779.1 million ft^3. Between 1980 and 2004, annual net growth changed little. From 2004, annual net growth is estimated to have decreased to 698.4 million ft^3 (Figs. 27, 28). Since the 2004 inventory, private (10 percent decrease), State and local government (20 percent decrease), and the U.S. Forest Service (14 percent decrease) experienced significant decreases in average annual net growth. This appears to be geographically concentrated as there were significant decreases in the eastern Upper Peninsula (18 percent decrease) and western Upper Peninsula (28 percent decrease) but not in the Lower Peninsula.

Average annual net growth of growing stock to current volume varies geographically (timberland-to-timberland) (Fig. 29). The southern Lower Peninsula has the highest rate (3.3 percent) followed by the

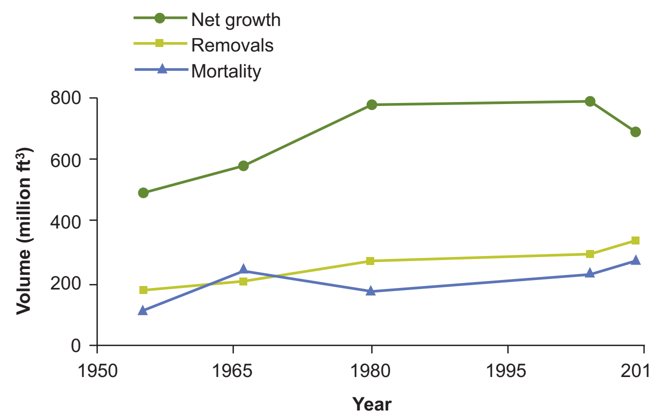

Figure 27.—Net growth, removals (all), and mortality of growing stock on timberland, Michigan. Estimates for net growth and mortality before 1980 and estimates of removals before 1993 are for a single year compared to an average over an inventory period for the more recent inventories.

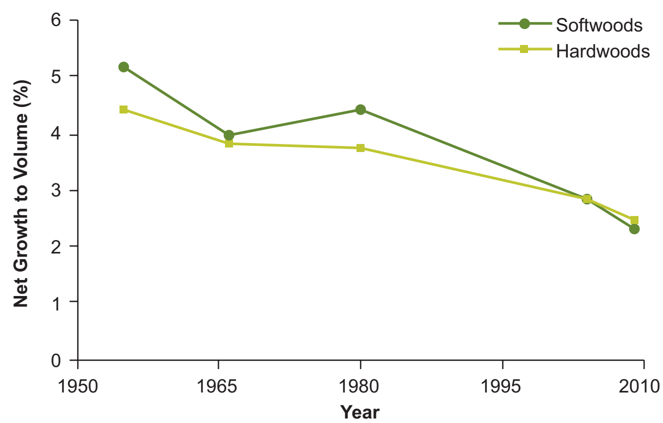

Figure 28.—Ratio (percent) of net growth to current volume for growing stock on timberland by species category, Michigan. Estimates before 1980 are for a single year as opposed to an average over an inventory period for the more recent inventories. Estimates include land-use change into and out of timberland.

northern Lower Peninsula (2.9 percent), eastern Upper Peninsula (2.1 percent), and western Upper Peninsula (1.7 percent). Ash mortality caused by EAB contributed the most to the high mortality in Macomb and Wayne counties (Pugh 2010, Pugh et al. 2011). Each region appears to have experienced a small decrease in net growth to current volume since the 2004 inventory but a precise estimate of change at this level is not possible due to changes in methods. The average annual net growth of growing stock per acre on timberland is highest for the southern Lower Peninsula at 40 ft^3/acre followed by the northern Lower Peninsula at 38 ft^3/acre. The eastern Upper Peninsula (23 ft^3/acre) and western Upper Peninsula (25 ft^3/acre) have lower estimates that are not significantly different from one another.

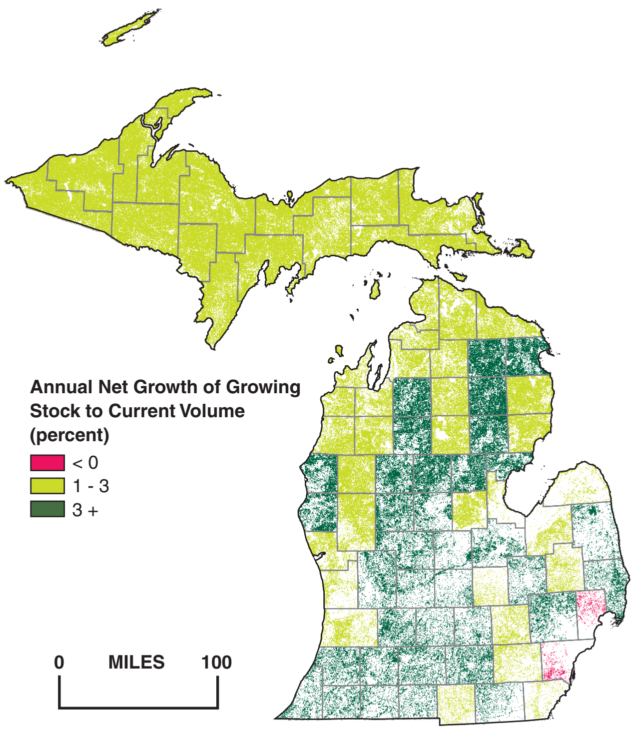

Figure 29.—Ratio (percent) of average annual net growth to current volume for growing stock on timberland by county, Michigan, 2009. Estimates based on timberland to timberland observations (see Map Descriptions and Acknowledgments in Statistics, Methods, and Quality Assurance).

Average annual net growth of growing stock to current volume on timberland varies by ownership group (timberland-to-timberland). Private (2.7 percent) had the highest rate followed by State and local government (2.3 percent) and the U.S. Forest Service (1.8 percent). With respect to changing methodology it appears that estimates dropped slightly for each ownership group from 2004 to 2009. There have been substantial decreases since 1980. For 1980, the best estimates available (include land-use change) are 5.6 percent for the U.S. Forest Service, 3.8 percent for State and local government, and 3.6 percent for private.

The species shown in Figures 30 and 31 accounted for 71 percent of the average annual net growth of growing stock on timberland for the 2009 inventory. Paper birch (not shown) is the only prominent species that experienced negative net growth (-3.8 million ft^3) due to high and increasing amounts of mortality. Every prominent species (including those not shown) had a moderate or high average annual rate of net growth to current volume except for paper birch (-0.8 percent).

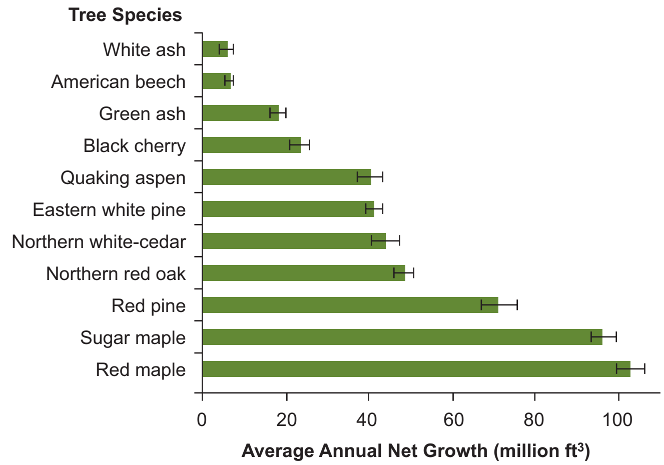

Figure 30.—Average annual net growth for growing stock on timberland by species, Michigan, 2009; error bars represent 68-percent confidence interval around estimate (selected prominent species).

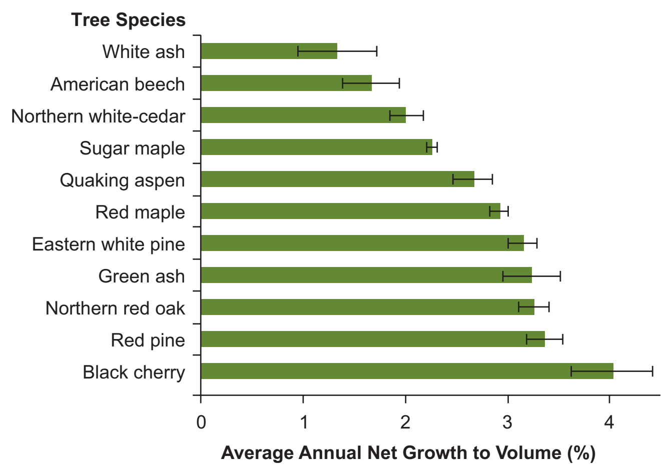

Figure 31.—Ratio (percent) of average annual net growth to current volume for growing stock on timberland by species, Michigan, 2009. Estimates based on timberland-to-timberland observations; error bars represent 68-percent confidence interval around estimate (selected prominent species).

Even though net growth remains moderate to high overall, net growth slowed for a number of species since the 2004 inventory. Average annual net growth of growing stock on timberland decreased significantly for paper birch (213 percent), native tamarack (79 percent), white ash (72 percent), jack pine (68 percent), American beech (59 percent), black spruce (34 percent), white spruce (30 percent), quaking aspen (28 percent), and red pine (20 percent).

What this means

Analyzing growth provides information on forest succession, disturbance, sustainability, and the ability of a species to grow well. Overall, Michigan's forests continue to mature and add volume. With maturation comes a lower rate of growth. Fortunately, net growth to volume remains moderate to high, evidence of the vitality of Michigan's forests.

Increases in mortality, decreases in live net growth, or a combination of each have contributed to decreases in net growth for some species. Mortality increased and live net growth decreased in American beech, white ash, and native tamarack. Significant increases in mortality were observed in paper birch and black spruce. Significant reductions in live net growth were observed in jack pine and white spruce.

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. This is not a surprise given the more productive climate and soils in this region. The southern Lower Peninsula has also experienced significant increases in forest land over the last few decades.

Since the 1980s, the increase in volume and decrease in net growth is most evident on U.S. Forest Service land. 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, U.S. For. Serv. 2002). This is contributing to decreases in 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 (e.g., wind, fire, drought, floods, and air pollution) factors contribute to mortality. Trees cut by harvesting or land clearing are considered removals and are not included in mortality estimates. Mortality can be the result of numerous factors over many years, so it is often difficult to pinpoint the cause of death. Drought can weaken trees and make them susceptible to pests years later. FIA plots are revisited cyclically, 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 growth and regeneration capacity of the forest or it creates potential dangers such as fire.

Here, we look at average annual mortality of growing stock on timberland and compare it to current standing volume (ratio in percent). 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.

What we found

Average annual mortality of growing stock on timberland was 271.8 million ft^3 for the 2009 inventory (Fig. 27). This is about 1.0 percent of growing-stock volume on timberland in 2009 (timberland-to-timberland) and 39 percent of the average annual net growth over the same period. The ratio of average annual mortality to current volume is 1.8 and 1.0 percent for Minnesota and Wisconsin, respectively. For Michigan, 68 percent of the mortality was in hardwoods and 62 percent was in private ownership.

Except for a spike upward in 1966, average annual mortality to current volume has remained fairly constant and low (0.7 to 1.0 percent, excluding 1966 at 1.62 percent) since 1955 (Fig. 32). Average annual mortality to current volume is highest in the southern Lower Peninsula (Fig. 33). An influential factor was ash mortality caused by EAB which contributed to high mortality in Macomb and Wayne counties (Pugh 2010, Pugh et al. 2011). Average annual mortality of growing stock per acre on timberland differs among the regions at 16, 14, 11, and 22 ft^3 for the western Upper Peninsula, eastern Upper Peninsula, northern Lower Peninsula, and southern Lower Peninsula, respectively.

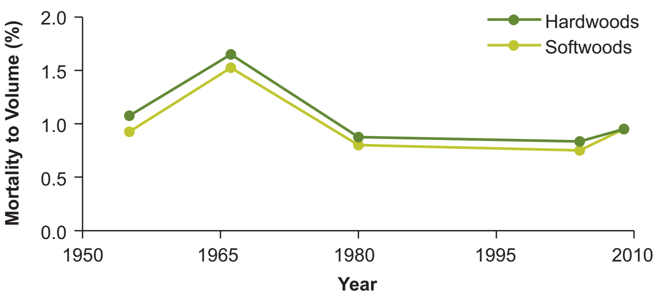

Figure 32.—Ratio (percent) of mortality to current volume for growing stock on timberland by species category, Michigan. Estimates before 1980 are for a single year as opposed to an average over an inventory period for the more recent inventories. Estimates include land-use change into and out of timberland.

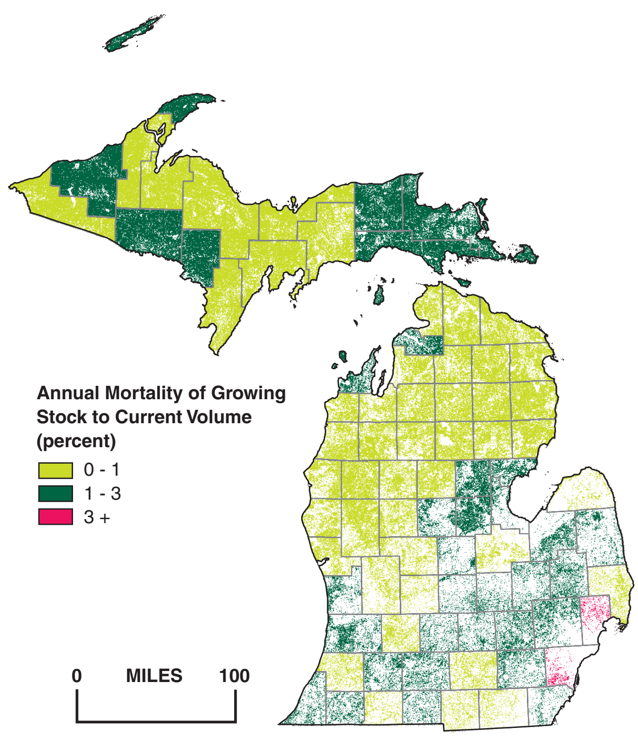

Figure 33.—Ratio (percent) of average annual mortality to current volume for growing stock on timberland by county, Michigan, 2009. Estimates based on timberland-to-timberland observations (see Map Descriptions and Acknowledgments in Statistics, Methods, and Quality Assurance).

Mortality remains low; however, there has been an increase since the 2004 inventory. At the State level, mortality rose 21 percent from 224.5 to 271.9 million ft^3. Except for the northern Lower Peninsula, each region had increases in mortality. The southern Lower Peninsula had the greatest increase (50 percent) followed by the eastern Upper Peninsula (43 percent) and western Upper Peninsula (27 percent). Private (26 percent increase) and State and local government (21 percent increase) experienced significant increases in average annual mortality.

As in past inventories, the primary cause of mortality could not be determined in 78 percent of the instances for the 2009 inventory. In cases where the cause was identified, weather, disease, and insects were most common.

The species in Figures 34 and 35 accounted for 83 percent of the average annual mortality of growing stock on timberland for the 2009 inventory. Quaking aspen had the most average annual mortality but it has a moderate rate of mortality to current volume. American elm, balsam fir, and paper birch had high amounts of average annual mortality and have the highest rates of annual mortality to current volume. Balsam poplar has a high rate of annual mortality to current volume. Jack pine, bigtooth aspen, white ash, black spruce, black ash, and green ash have moderate rates of annual mortality to current volume. White spruce (not shown) has a moderate rate of annual mortality to current volume (1.1 percent).

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 (Fig. 23). These species also had significant reductions in number of trees for certain size classes (Table 3).

Fig. 34 shows a number of species that had increased average annual mortality of growing stock on timberland since the 2004 inventory. The 2009 estimate for mortality of green ash is nearly seven times higher and

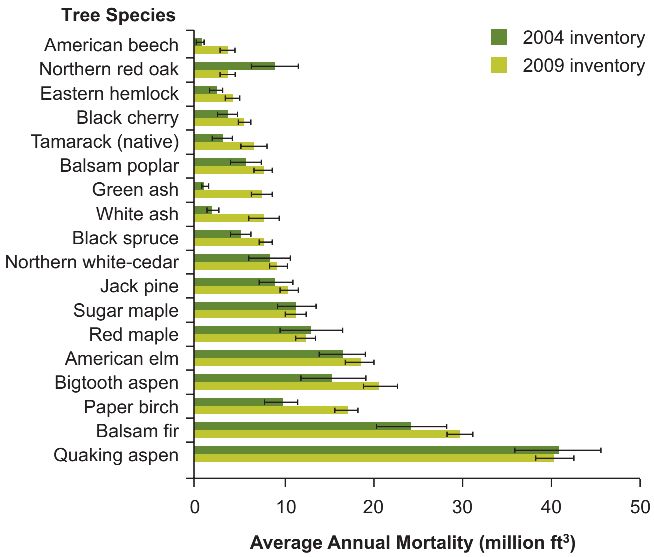

Figure 34.—Average annual mortality for growing stock on timberland by species, Michigan, 2009 and 2004; error bars represent 68-percent confidence interval around estimate (selected prominent species).

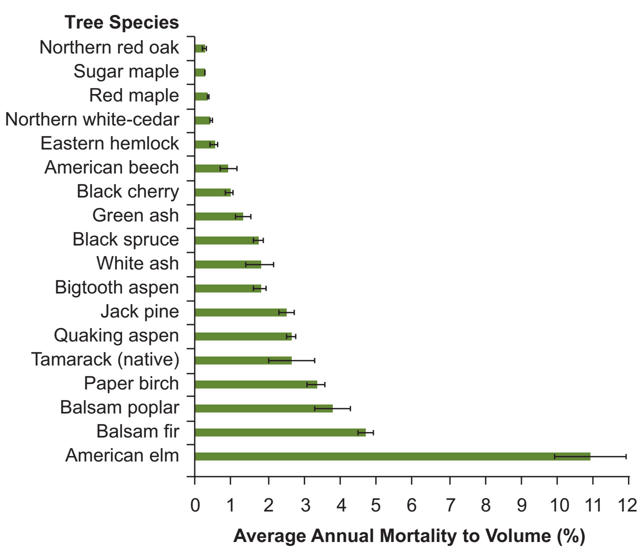

Figure 35.—Ratio (percent) of average annual mortality to current volume for growing stock on timberland by species, Michigan, 2009. Estimates based on timberland-to-timberland observations; error bars represent 68-percent confidence interval around estimate (selected prominent species).

it is more than four times higher for white ash. Much of the green and white ash is succumbing to EAB. Most of the green and white ash is in the Lower Peninsula where EAB is currently having its biggest impact (most black ash is in eastern Upper Peninsula and northern Lower Peninsula). Contributing to mortality in American beech (estimate increased more than 5 times), beech bark disease (BBD) has been spreading throughout much of the Upper Peninsula and the northern Lower Peninsula. The estimate of mortality in native tamarack has doubled with much of the cause attributed to drought, the larch casebearer, and the native eastern larch beetle. Significant increases were also observed for paper birch, eastern hemlock, black spruce, black cherry, and balsam fir. Northern red oak was the only species with a significant decrease.

What this means

Michigan has been fortunate to have low rates of mortality. Factors such as succession, drought, and pathogens contribute to mortality. Higher rates of mortality to volume are expected in short-lived, early successional species such as jack pine, paper birch, and aspens as forests mature. The declines in volume and number of trees might be a management concern from a perspective of wood fiber and maintenance of these types.

In cases where forests are overmature and trees are succumbing to various damage agents, forest types are often associated with species exhibiting moderate or high rates of mortality. Most of the high rate in balsam fir and moderate rates in black and white spruce likely are due to droughts combined with spruce budworm attacks in the late 1990s and mid to late 2000s (see Insects, Disease, and Decline). Wisconsin and Minnesota have about the same rate of average annual mortality to current volume for balsam fir at 5.0 and 4.4 percent, respectively.

The 2009 inventory indicated a 21 percent increase in average annual mortality over the 2004 inventory. Wisconsin had an 18 percent increase over the same period. In Michigan, consecutive years of drought in the late 1990s and 2000s have predisposed species in some areas to higher rates of mortality. Nonnative pests and diseases such as EAB, BBD, larch casebearer, and Dutch elm disease also are contributing to mortality (see Insects, Disease, and Decline).

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 (utilized and not utilized) and diversion removals. Harvest removals include utilized trees and trees cut as a result of harvest operations (including land clearing) but not utilized. Diversion removals occur when living trees are removed from the timberland base due to land-use change. Timberland can change to less productive or reserved forest land or nonforest. Among the estimates of change, we have the least number of nonzero FIA plot observations for removals, so the estimates are inherently less precise.

The Timber Product Output (TPO) study provides another estimate of removals that is based on a survey of 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 Timber Product Output). FIA plot observations provide an alternative measure of growing stock removals from timberland. These alternatives often produce different estimates of growing stock removals from timberland.

When average annual removals are compared to current standing volume (ratio in percent), 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 (all removals) of growing stock from timberland totaled 334.8 million ft^3 for the 2009 inventory (Fig. 27). Ninety-three percent or 311.2 million ft^3 of this total was average annual harvest removals. This harvest estimate is 19 percent more than the estimate of 260.6 million ft^3 for the 2004 inventory.

For the 2009 inventory, the ratio of average annual harvest removals to current volume is approximately 1.1 percent. The average annual harvest removals are about 42 percent of average annual net growth (timberland-to-timberland). Seventy-six percent of the harvest removals were in hardwood and 71 percent was in private ownership. Although harvest removals on public ownership account for only 29 percent of total harvest removals, 41 percent of the softwood harvest removals came from public land. Fifty-one percent of the softwood growing-stock volume is on public timberland.

The TPO estimates of harvest removals (growing stock on timberland) have ranged from 168 million ft^3 in 1965 to 354 million ft^3 in 1994 (see Timber Product Output). TPO estimates generally have been higher than estimates of average annual removals from the 1993 and 2004 FIA plot inventories. The average TPO harvest removals estimate of growing stock from timberland for 2006 and 2008 was 299 million ft^3, very close to the analogous estimate of 311 million ft^3 derived from FIA plot observations for the 2009 inventory.

From 1955 (177.5 million ft^3) to 1980 (274.6 million ft^3), total annual removals (includes land-use change) increased from 1.5 to 2.4 percent per year. From 1980 to 2004, total removals remained steady or increased slightly. During the 2009 inventory, total annual removals increased an average of 3.0 percent per year. The trend since 2004 is contrary to that seen in TPO harvest removals. Total annual removals were the lowest in 1955 but the ratio of removals to volume was at its peak (1.7 percent) (Fig. 36). There was much less volume in 1955.

Average annual harvest removals of growing stock to current volume varies geographically (Fig. 37). The Upper Peninsula (1.2 percent) and northern Lower Peninsula (1.0 percent) have significantly higher estimates of annual harvest removals to current volume than the southern Lower Peninsula (0.7 percent). Average annual harvest removals of growing stock per acre on timberland were 19, 17, 16, and 12 ft^3 for the western Upper Peninsula, eastern Upper

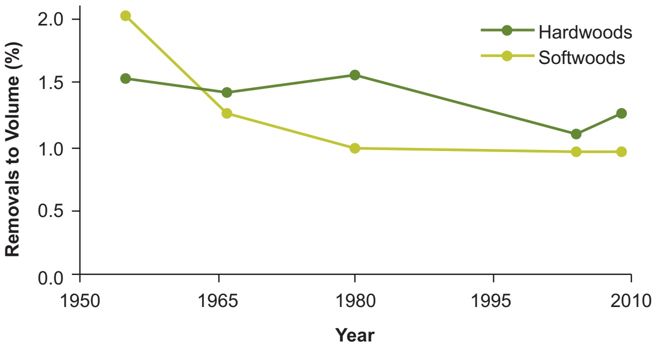

Figure 36.—Ratio (percent) of removals to current volume for growing stock on timberland by species category, Michigan. Estimates before 2004 are for a single year as opposed to an average over an inventory period for the more recent inventories. Estimates include land-use change into and out of timberland.

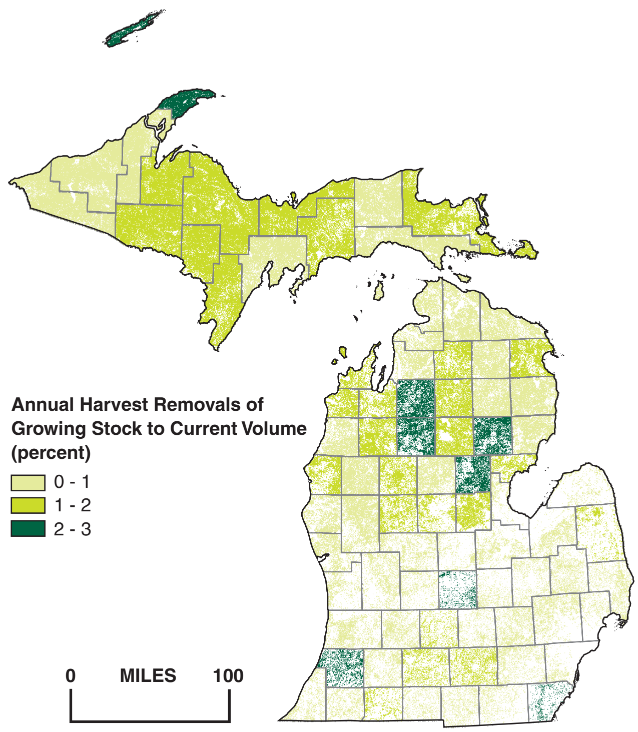

Figure 37.—Ratio (percent) of average annual harvest removals to current volume for growing stock on timberland by county, Michigan, 2009. Estimates based on timberland-to-timberland observations (see Map Descriptions and Acknowledgments in Statistics, Methods, and Quality Assurance).

Peninsula, northern Lower Peninsula, and southern Lower Peninsula, respectively. Harvest removals in the northern Lower Peninsula (112.3 million ft^3) were greater than in other regions. The western Upper Peninsula (88.7 million ft^3) has the next highest harvest removals followed by the eastern Upper Peninsula (66.9 million ft^3) and southern Lower Peninsula (43.3 million ft^3).

Average annual harvest removals to current volume is significantly different among ownership groups. Private (1.2 percent) has the highest rate followed by State and local government (1.0 percent) and the U.S. Forest Service (0.4 percent).

The increase in harvest removals from the 2004 to 2009 inventory was greatest in the western Upper Peninsula (47 percent) and southern Lower Peninsula (62 percent) and in private ownership (30 percent). There were no other significant changes by region or ownership.

Species in Figures 38 and 39 accounted for 75 percent of the average annual harvest removals of growing stock on timberland for the 2009 inventory. Sugar maple had the most average annual harvest removals but its rate of harvest removals to current volume was just above average at 1.3 percent. Jack pine has a high rate of removals to volume (4.0 percent). The more intolerant and/or fast growing, pioneer species such as aspens, birches, and balsam fir have moderate rates. The rate for American beech is higher than rates for most species. Most other prominent species have low rates.

Average annual harvest removals increased for a number of species since the 2004 inventory (Fig. 38). The estimates for green ash and black ash increased by four and six times, respectively. The estimate for yellow birch increased nearly four times. The estimate for black cherry increased nearly three times. Sugar maple and red maple also had significant increases.

As mentioned previously, total removals not only count what was actually removed off site but also include land-use change and trees cut as a result of harvest operations but not utilized. Trees cut as a result of harvest operations but not utilized include those killed by silvicultural or land-clearing activity. Eighty-eight percent of the average annual removals were due to harvesting and removal from the site. Four percent of the

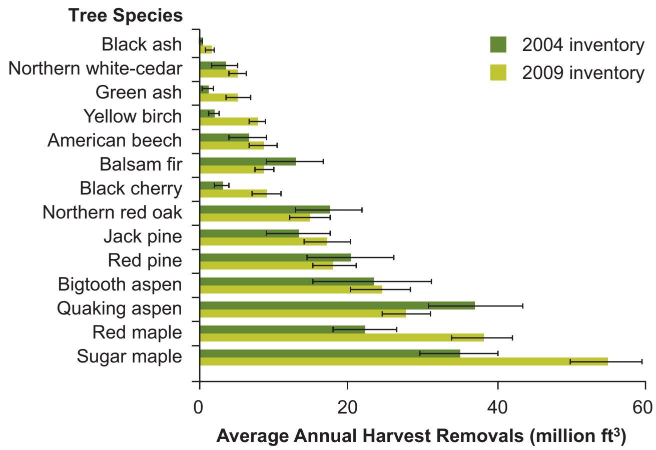

Figure 38.—Average annual harvest removals for growing stock on timberland by species, Michigan, 2009 and 2004; error bars represent 68-percent confidence interval around estimate (selected prominent species).

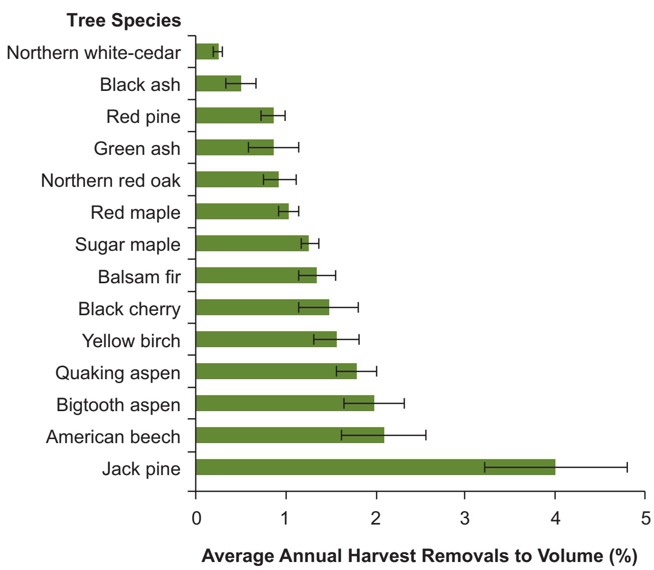

Figure 39.—Ratio (percent) of average annual harvest removals to current volume for growing stock on timberland by species, Michigan, 2009. Estimates based on timberland-to-timberland observations; error bars represent 68-percent confidence interval around estimate (selected prominent species).

average annual removals were in trees not removed but rather left standing as the land was diverted to nonforest. Likewise, diversion to less productive forest land was 3 percent of total removals. No removals were associated with diversion to reserved forest land. Five percent of the removals were cut and not utilized.

What this means

Removals are affected by biological and social factors. Harvesting is not a top priority for most private owners (Butler 2008) or for public owners like the U.S. Forest Service. Since the 1950s, the ratio of harvest removals to volume has been low for Michigan. Even with the 19 percent increase in the estimate for annual harvest removals since 2004, the ratio of harvest removals to volume is 1.1 percent (timberland-to-timberland). Currently, Minnesota and Wisconsin have percentages of 1.6 and 1.4, respectively.

The trend in TPO harvest estimates since 2006 contradict the trend shown by plot-derived estimates. However, the latest TPO and plot-derived estimates are essentially equal. In the past, the plot-derived estimates have been less than the TPO estimates. It is not unexpected that estimates derived from these different methods vary at times but one would expect similar trends. There can be a lag between the current trend and what the plot-derived estimates show. Harvest removals and mortality are events that happen at specific times but the plots are measured within windows of time. Harvests could have occurred in the early 2000s during the 2004 inventory and just recently been recorded in the 2009 inventory from 2005 through 2009. Another consideration is the fact that FIA has the least number of nonzero plot observations for removals, so there is inherently more variability in the estimates. Understanding these factors helps explain how these different methods can show divergent trends.

The ratio of average annual harvest removals to current volume (percent) for different species reflects the attributes and management practices associated with the species. Shade-tolerant species such as sugar maple are expected to have lower rates for removals to volume than intolerant pioneer species such as 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 trees when harvesting to promote regeneration. Species such as balsam poplar, balsam fir, jack pine, and paper birch also have moderate or high rates of mortality. Some of the removals for these species could be an attempt to "capture mortality" or harvest the trees before they die. Likewise, the increase in ash removals is not unexpected given the expectation that much of it will succumb to EAB.

Net Growth to Removals

Background

One measure of sustainability is the ratio of net growth to removals. A ratio greater than 1 indicates the volume of the species is increasing; a ratio less than 1 indicates the volume is decreasing. It is not always beneficial to maintain high ratios of net growth to removals.

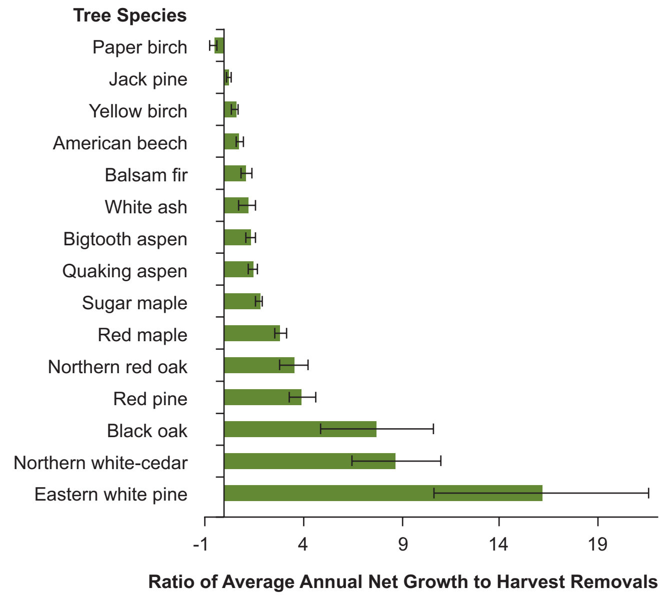

Figure 40.—Ratio of average annual net growth to harvest removals for growing stock on timberland by species, Michigan, 2009. Estimates based on timberland-to-timberland observations; error bars represent 68-percent confidence interval around estimate (selected prominent species).

What we found

The ratio of net growth to harvest removals for the 2009 inventory was 2.4 (timberland-to-timberland), indicating that volume is increasing at a moderate to high rate. For the current inventory, only a minority of species had net growth to removals ratios less than 1 (Fig. 40). Moderate to high mortality and harvest removal rates contribute to lower ratios for aspens, white ash, balsam fir, American beech, jack pine, and paper birch (Figs. 35, 39). Balsam poplar (not shown) has a ratio of 0.3 associated with moderate harvest removals and high mortality. Moderate harvest removals and low net growth rates contribute to the low ratio for yellow birch. Some species have high or very high ratios. In turn, increases in volume for these species have been significantly greater since the 1980 inventory (Fig. 23).

From 1955 to 2004, the net growth to total removals ratio remained nearly constant from 2.7 to 2.8 (includes land-use change; Fig. 41). From 2004 to 2009, net growth decreased by an average 2.5 percent per year and total removals increased by 3.0 percent per year resulting in a lower ratio of 2.1. Except for the 1980 and 2009 inventories, the ratios of net growth to total removals for softwoods and hardwoods have been relatively constant.

Ratios of net growth to harvest removals for the western Upper Peninsula and eastern Upper Peninsula were 1.4 and 1.7, respectively; these ratios were not significantly different from each other. The northern Lower Peninsula

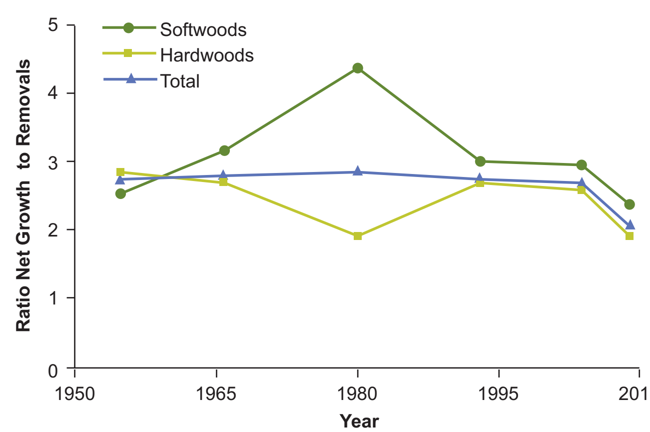

Figure 41.—Ratio of net growth to total removals for growing stock on timberland by species category, Michigan. Estimates include land-use change into and out of timberland.

had a higher ratio (2.8) than the Upper Peninsula and the southern Lower Peninsula had the highest ratio at 4.6. The southern Lower Peninsula has the greatest annual net growth to current volume (3.3 percent) and the lowest annual harvest removals to current volume, thus the large ratio of net growth to harvest removals.

The U.S. Forest Service forest land had the highest ratio of net growth to harvest removals at 5.0. State and local government and private lands had ratios of 2.2. The U.S. Forest Service's significantly lower rate of annual harvest removals to current volume is a major factor in its high ratio of net growth to harvest removals.

Equivalent ratios of net growth to removals can be based on various conditions. Compared to more recent years, the 1955 inventory had the highest ratios of annual net growth and removals to current volume (Figs. 28, 36). The 1955 inventory was also associated with the least amount of growing-stock volume (Fig. 20) on a high amount of forest land (Fig. 2), and mortality was relatively low (Fig.32). Except for the 2009 inventory, the overall ratio has been relatively constant despite changing conditions.

What this means

Even with the small drop from historical levels, the ratio of net growth to removals for this most recent inventory is still at a moderate to high level. Michigan's ratio of net growth to harvest removals (2.4) does not differ from ratios for most Midwestern and Northeastern states. For example, the ratio for Michigan is not significantly different from the ratios for Pennsylvania (2.5), New York (2.3), and Indiana (3.8). Missouri (4.4) and Illinois (8.4) have higher ratios. Minnesota and Wisconsin have significantly lower ratios of 1.9 and 2.0, respectively. At the State level, Michigan has had relatively low removals and mortality rates but high growth rates.

Since the ratios differ substantially by region and owner, it is important to consider these differences in management decisions. The western Upper Peninsula had a low ratio of 1.4. In the western Upper Peninsula, the ratios lower further to 1.2 and 1.3 for State and local government and private ownership, respectively.

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. 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. A high ratio of net growth to removals could result in forest health issues over time, especially for certain species. 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 and some have health issues. For example, jack pine, spruce, balsam fir, birch, and aspen are in high demand for the manufacture of pulp and composite products. These species also have health issues with moderate to high mortality rates. EAB and beech scale have contributed to the low ratios for ash and American beech. Also, nonmarket factors such as wildlife concerns can constrain the supply of species (e.g., northern white-cedar), keeping ratios high.

Forest Health

Bond Falls, Ontonagon County, MI. Photo by Scott A. Pugh, U.S. Forest Service.

Insects, Disease, and Decline

Background

Forest health, structure, and composition are influenced by the interaction of biotic and abiotic elements. Monitoring the status of these factors provides a measure of forest health and is crucial in assessing conditions and trends in Michigan's forests.

Changes to our forest ecosystems often are observed when pests, disease, and other adverse environmental conditions combine. Abiotic environmental factors such as drought, extreme wetness, windstorms, late spring frosts, pollution, and soil properties that affect nutrient availability, moisture content, and aeration influence the effects of pests and disease and predispose trees to decline. A list of insects and diseases mentioned in this report is included in Statistics, Methods, and Quality Assurance.

Frequent drought events since the 1980s have contributed to declines in some susceptible tree species. Severe and extreme droughts as characterized by the Palmer Drought Severity Index were common during the 2009 inventory. For more information, visit http://www.drought.gov/portal/server.pt/community/drought_indicators/223/palmer_drought_severity_index/275. Declines are characterized by a gradual loss of tree growth and vigor usually accompanied by off-color leaves, early leaf drop, and crown dieback and thinning. Trees on xeric (very dry) and hydric (very wet) sites and short-lived species that are at or past maturity are most susceptible.

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 such as 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 (Mack et al. 2000, Mooney and Cleland 2001, Parker et al. 1999). Michigan has been affected by nonnative insects and diseases such as Dutch elm disease, chestnut blight, butternut canker, gypsy moth, and, more recently, EAB, BBD, hemlock wooly adelgid, and sirex woodwasp.

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.

There are a number of groups that focus on monitoring forest health. Information presented in this section is derived from data from the U.S. Forest Service's FIA, National Forest Health Monitoring program, and Northeastern Area, State and Private Forestry; and MIDNR's Forest Health, Inventory, and Monitoring unit. There are many cooperative projects to stop or mitigate forest health issues in Michigan through mandatory and recommended management practices that effectively improve forest health.

What we found

A number of noteworthy insects and disease pathogens were active in Michigan from 2005 through 2009 (Table 6). Several declines were also reported. Damage by some insects is effectively identified with aerial surveys.

Damage reports from aerial surveys are available for jack pine budworm, gypsy moth, forest tent caterpillar, spruce budworm, larch casebearer, eastern larch beetle, and others from the U.S. Forest Service's Forest Health Technology Enterprise Team (U.S. For. Serv. 2011).

Table 6.—Insects, disease, and declines that have caused damage to forests, Michigan, 2009.

Insects, Disease, and Declines	Identified Host
Annosus root disease	Red pine
Ash decline	Ash
Ash yellows	Ash
Aspen decline	Aspen
Beech bark disease	American beech
Diplodia shoot blight	Pine
Dogwood anthracnose	Dogwood
Eastern hemlock looper	Eastern hemlock, balsam fir, spruce
Eastern larch beetle	Native tamarack
Emerald ash borer	Ash
Fall webworm	Hardwoods
Forest tent caterpillar	Sugar maple, aspen, oak, birch, other hardwoods
Gypsy moth	Oak, other hardwoods
Jack pine budworm	Jack pine
Larch casebearer	Native tamarack
Large aspen tortrix	Aspen
Loopers or cankerworms	Sugar maple, other hardwoods
Maple decline	Sugar maple, other maple
Oak decline	Northern pin oak, other oak
Oak wilt	Northern red oak
Pine spittlebug	Pine
Red-headed pine sawfly	Red pine, jack pine
Spruce budworm	Balsam fir, spruce
White pine decline	White pine

The native jack pine budworm is the main pest for jack pine. Budworm defoliation tends to occur in a cyclical fashion, about every 6 to 10 years. Mature stands on low quality sites are most vulnerable. Based on aerial surveys, damage by the native jack pine budworm increased from nearly no detection in 2000 to 329,600 acres in 2003. Damage gradually decreased to 500 acres in 2009.

Oaks are the primary host of the nonnative gypsy moth. After 2 years with little damage in 2001 and 2002, damage by gypsy moth increased to 148,500 acres in 2005. The natural enemy of the gypsy moth, *Entomophaga maimaiga*, thrives in cool wet spring weather. Even with many periods of drought, most years since 2005 have had normal to above normal spring rainfall. Damage has steadily decreased to 4,300 acres in 2009. Northern red oak is the only prominent species that experienced a decrease in mortality for the 2009 inventory.

The native forest tent caterpillar has widespread outbreaks about every 10 to 15 years with its most notable impact on aesthetics. Its hosts include many hardwoods such as sugar maple, aspen, oaks, and birch. The last outbreak peaked in 2001 at 2.5 million acres. Damaged dropped quickly to only small scattered areas in 2004. Damaged remained low until 2009 when it increased to 366,400 acres.

Following drought and repeated defoliations by the nonnative larch casebearer in the early 2000s, the native eastern larch beetle killed 29,400 and 25,700 acres of native tamarack in 2004 and 2005, respectively. Much less damage has been reported since 2005. The estimated average annual mortality for native tamarack doubled after the 2004 inventory.

Mature and overmature balsam fir stands are affected most severely by the native spruce budworm, which prefers balsam fir over spruce. Outbreaks throughout the eastern United States have been periodically causing extensive damage and mortality. These outbreaks are part of the natural life cycle of balsam fir. The last severe outbreak occurred in the Upper Peninsula from the late 1960s to the early 1980s. Spruce budworm damage was around 48,600 acres in 1997. Damage decreased and remained low from 1999 through 2002. Since then it has risen a couple times but remained less than 26,000 acres. In 2009, damage rose to 86,100 acres. With so many drought episodes and no severe outbreak since the early 1980s, we should be watchful for the next episode.

The nonnative EAB was first discovered near Detroit, in 2002. Since then it has been found in 14 other states, Ontario, and Quebec. All major species of ash are susceptible. EAB larvae feed on the inner bark and disrupt the transport of water and nutrients. Almost all exposed trees die. Since the 2004 inventory, the average annual mortality estimate for green ash increased nearly seven times. The estimate rose more than four times for white ash. Slow Ash Mortality Pilot Project or SLAM (http://www.slameab.info/) is a collaborative effort to slow the expansion of ash mortality by reducing EAB numbers in newly infested sites, outside of known infestations.

BBD is the result of a small, sap-feeding insect known as beech scale 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. BBD continues to spread throughout the range of American beech. The estimate of average annual mortality for American beech increased more than five times since the 2004 inventory. A number of groups, including the U.S. Forest Service, MIDNR, Michigan Technological University, and Michigan State University, are monitoring the disease and propagating disease resistant American beech.

Aspen (many areas of the Lake States), white pine (north central Lower Peninsula), and maple (western Upper Peninsula) are experiencing recently reported declines. Drought is a suspected factor in each decline. Repeated defoliations by forest tent caterpillar, gypsy moth, and large aspen tortrix have decreased the vigor of some aspen. With this decreased vigor, these aspen are affected by secondary pests such as Armillaria root rot, bronze poplar borer, aspen leafblotch miner, and *Septoria* leaf spot. Pine spittlebug, *Diplodia scrobiculata*, Armillaria root rot, and other fungi are linked to the white pine decline. Smaller white pine trees are most severely affected. A combination of soil conditions, management practices, and drought are suspected in the maple decline.

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 many cases, trees on poorer soils are at greater risk.

Recommended management practices can mitigate some adverse effects. For example, Pugh (2011) analyzed a Kirtland's warbler management area where jack pine stands are maintained at younger ages to benefit nesting. Net growth was more than double and mortality about half compared to estimates observed for the remaining area of jack pine in the State. It is recommended that harvests occur before jack pine stands reach maturity.

Nonnative species such as EAB and BBD are playing a larger role in affecting Michigan's forest health. Because of the lack of natural enemies and specific plant defense mechanisms, they cause considerable mortality that alters forest structure and composition. The State's forests also face serious potential risk from the introduction of the Asian longhorned beetle (many genera of hosts, including maple, birch, aspen, and ash), sudden oak death or ramorum blight, balsam woolly adelgid, and thousand cankers disease of walnut.

Like many parts of the Nation (Smith et al. 2009), Michigan has recently experienced an increase in mortality (see Annual Mortality). The increase in Michigan is associated with a short period of time. Continued monitoring will provide essential information on emerging issues and trends. Even with the recent increase in mortality, the rate of mortality to current volume at the state level is only about 1 percent of growing-stock volume on timberland. Within forest health circles, a mortality rate less than 3 percent is generally viewed as an acceptable rate of background morality; the rate in Michigan is well within acceptable levels.

Tree Crowns and Standing Dead Trees

Background

The status of tree crowns can indicate the health of the forest. Dieback and crown density help characterize the status of crowns. Like mortality, dieback is a natural part of forest-stand development. Dieback (of live trees at least 5 inches d.b.h.) is measured as the percent of branches in the crown that are dead. Tree crown categories of dieback were created to indicate the severity: none or trace (0-5 percent), light (6-20 percent), moderate (21-50 percent), and severe (51-100 percent). Crown density (of live trees at least 5 inches d.b.h.) is an estimate of crown fullness and represents the amount of foliage, branches, and reproductive structures that block light from going through the crown. Crown density was also categorized into classes: low (0-30 percent), average (31-55 percent), and high (56-90 percent). High amounts of dieback and low crown density signal the potential for lower growth and 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 Phase 3 (P3) inventory, detailed crown information has been collected since 2000 (U.S. For. Serv. 2007). The following analysis is based on information from 205 plots and 5,534 trees for the 2009 inventory and 208 plots and 5,613 trees for the 2004 inventory (see Statistics, Methods, and Quality Assurance).

Standing dead trees are a natural part of forest-stand development and are indicators of forest health, mortality events, wildlife habitat, structural diversity, and carbon storage. The ratio of standing dead basal area to live basal area (percent) on timberland is a metric for standing dead trees. Any tree at least 5 inches d.b.h. and still standing at least 4.5 feet tall that died from one inventory to the next is recorded as standing dead. Estimates of standing dead trees are based on information from all timberland plots (7,998 and 7,295 timberland plots for 1980 and 2009, respectively).

What we found

Dieback is not pronounced overall. Ninety percent of the trees have no or trace amounts of dieback, 8 percent have light dieback, and 2 percent have moderate or severe dieback. This distribution of dieback is similar to the 2004 inventory with equivalent percentages of trees in each category. Thirteen percent of the trees have low crown densities, 68 percent have average densities, and 19 percent have high densities. Likewise, we could not identify a significant difference in crown densities between the 2004 and 2009 inventories. Sixteen percent of the trees had low crown densities, 68 percent had average densities, and 17 percent had high densities in the 2004 inventory. State-level estimates for crown dieback and density in Minnesota and Wisconsin are close to estimates for Michigan. Sample sizes are small making it difficult to identify differences with a high degree of confidence.

Black ash, northern white-cedar, and black spruce have notably higher percentages of trees with moderate or severe dieback (Fig. 42). Black ash and northern white-cedar also have proportionally more low density crowns (Fig. 43). White ash (9.8 percent), native tamarack (3.8 percent), and balsam poplar (2.4 percent), which are not shown, have higher percentages of trees with moderate to severe crown dieback but there are few samples (less than 50 samples per species) of these species. There were no significant differences by species in the moderate or severe crown dieback categories between the 2004 and 2009 inventories.

There are approximately 18 standing dead trees (at least 5 inches d.b.h.) per acre on timberland in Michigan. Minnesota and Wisconsin have 18 and 16 standing dead trees per acre on timberland, respectively. In Michigan, the most abundant standing dead species is balsam fir (three trees/acre). Quaking aspen, paper birch, jack pine, American elm, northern white-cedar, and red maple are also common with one to two standing dead trees per acre. The number of standing dead trees is inversely related to tree size with 45 percent of standing dead trees between 5 and 6.9 inches d.b.h. and only 2 percent larger than 17 inches.

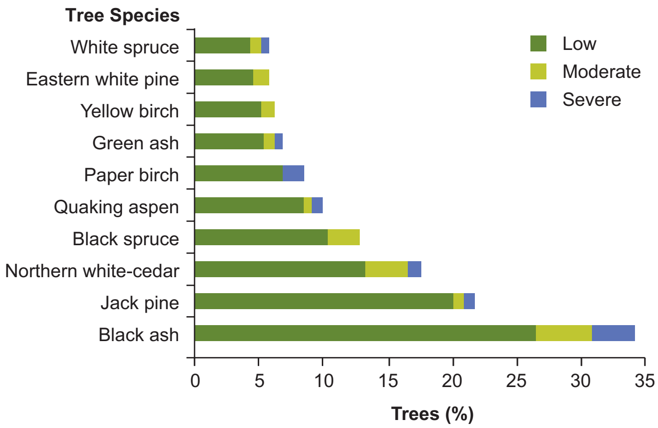

Figure 42.—Percentage of live trees (at least 5 inches d.b.h.) with low to severe crown dieback for select species on timberland, Michigan, 2009 (species with at least 100 samples and at least 1 percent moderate to severe dieback by number of trees).

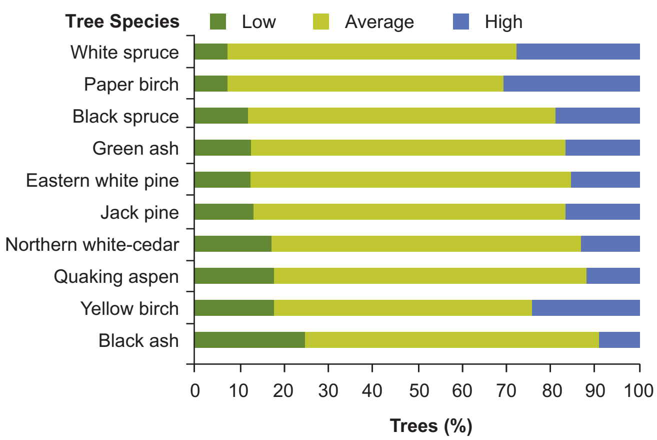

Figure 43.—Percentage of live trees (at least 5 inches d.b.h.) by crown density for select species on timberland, Michigan, 2009 (species with at least 100 samples and at least 1 percent moderate to severe dieback by number of trees).

The overall ratio of standing dead to live basal area is 7.5 percent in Michigan. Wisconsin has the same ratio estimate while the estimate for Minnesota is 10.1 percent. In Michigan, most species with known issues related to succession and health (e.g., balsam fir, native tamarack, quaking aspen, jack pine, balsam poplar, paper birch, and American elm) have higher ratios of standing dead to live basal area (Fig. 44). Northern white-cedar (3.9 percent) and red maple (3.4 percent, not shown) have low percentages even though they rank sixth and seventh by number of standing dead trees, respectively. In most cases, standing dead to live basal area increased from 1980 to 2009. American elm is the only species that showed a decrease in standing dead to live basal area from 1980 to 2009. By 1980, many American elm trees were killed by Dutch elm disease and those standing dead trees have since fallen.

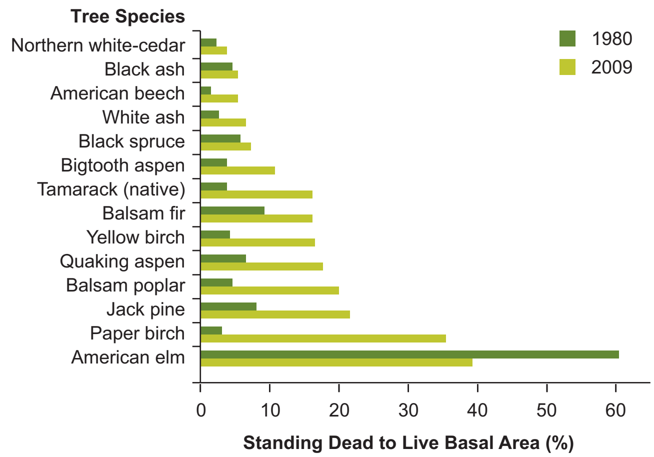

Figure 44.—Ratio (percent) of standing dead to live basal area (trees at least 5 inches d.b.h.) for select species on timberland, Michigan, 1980 and 2009.

The only notable differences in standing dead to live basal area from the 2004 to 2009 inventory were increases in native tamarack (4.9 percent), paper birch (4.8 percent), American elm (3.1 percent), and jack pine (2.9 percent).

What this means

No major health problems are indicated in the crown data. Some crown dieback and standing dead trees are natural and desirable for forest health. Species such as black ash, northern white-cedar, and black spruce have higher numbers with moderate to severe crown dieback partially due to the poorer, hydric sites they occupy.

Even though no issues or significant changes were identified using the crown information, the low number of samples makes it difficult to identify anything but severe health issues. Other variables like mortality (see Annual Mortality) and standing dead to live basal area should be investigated in conjunction with crown information. Species such as black ash and northern white-cedar had more crown dieback but low ratios of standing dead to live basal area (percent). Northern white-cedar has low mortality to volume rates. Black ash and black spruce have moderate mortality to volume rates. As expected, some of the early successional species and others with known health issues have more standing dead to live basal area than other species.

Vegetation Diversity and Invasive Plants

Background

Trees are not the only plants in Michigan's forests. Other vegetation plays a key role in shaping ecosystem processes, such as regulating the microclimate, curtailing erosion, and providing food and wildlife habitat. Data on this other vegetation aids management since such data can inform managers about soil and air quality, moisture and nutrient availability, stand structure and diversity, species abundance, and nonnative and/or invasive vegetation. Native vegetation can be put at risk by nonnative, invasive species. For example, glossy buckthorn invades the understory of forests and shades out native tree seedlings (Fagan and Peart 2004, Frappier et al. 2003). It leafs out earlier and maintains leaves longer than native shrubs.

To gain a better understanding of the flora in Michigan's forests, FIA assessed invasive plant species on Phase 2 (P2) Invasive plots (43 invasive species monitored on approximately 20 percent of field plots or 681 plots) starting in 2007 through 2009 (see Statistics, Methods, and Quality Assurance).

Data on species richness, species abundance, spatial distribution, and forest structure were collected as part of the Vegetation Diversity and Structure Indicator part of P3 plots (approximately 6 percent of field plots or 126 plots) from 2005 through 2009 (see Statistics, Methods, and Quality Assurance). This data was also collected during the 2004 inventory (2000 to 2004). For more information about the goals and methodology associated with the ground flora portion of the P3 plots, see Schulz et al. 2009 and for information on invasive species in Michigan see Michigan Invasive Plant Council (http://invasiveplantsmi.org/) and the National Invasive Species Information Center (http://www.invasivespeciesinfo.gov).

What we found

Michigan's forests support a diverse assemblage of species covering five broad growth habits (forb/herb, graminoid, shrub, tree, and vine) based on classification by the Natural Resources Conservation Service's (NRCS) PLANTS database (NRCS 2011). Comparable to the 813 species found in the 2004 inventory, 790 species were found on P3 plots in the 2009 inventory. Of these 790 species, 373 (almost 50 percent) were in the forb/herb growth habit. Graminoids (grass or grass-like plants, 118), trees (116), and shrubs (110) had similar species counts. There were 32 species of vines. Six hundred and twenty-five (79 percent) of the 790 plant species, were native to the United States and 114 species (14 percent) were introduced. The remaining species were not classified. The most commonly observed species was red maple (107 plots), followed by Canada mayflower (*Maianthemum canadensis*, 86 plots). Of the 26 most commonly observed species, nine were trees. Looking at the 30 most common nonnative species, common dandelion (*Taraxacum officinale*) was observed most often (61 plots), followed by orange hawkweed (*Hieracium aurantiacum*, 31 plots). The majority of nonnative plants fell in the forb/herb category with only a few classified as graminoids and shrubs.

On the P2 Invasive plots there was not a dominant growth habit. Multiflora rose was the most commonly observed species (72 plots, Table 7). Seventy-one percent of the P2 Invasive plots had invasive species and 32 of the 43 invasive species were found. Twenty-five of the 32 invasive species were also found on P3 plots. This result is influenced by the smaller number of P3 plots. Invasive species are widespread but some species are particular to specific regions as shown in Fig. 45 with garlic mustard and common and glossy buckthorn.

Table 7.—Number of plots with invasive plant species recorded on P2 Invasive plots, Michigan, 2007-2009.

Species	No. of Plots
Multiflora rose	72
Reed canarygrass	69
Canada thistle	61
Autumn olive	52
Garlic mustard	33
Bull thistle	32
Spotted knapweed	23
Tatarian honeysuckle	21
Common buckthorn	17
Japanese barberry	15
Glossy buckthorn	15
European privet	8
Showy fly honeysuckle	8
Russian olive	7
Common barberry	6
Common reed	6
Black locust	6
Amur honeysuckle	5
Japanese honeysuckle	4
Oriental bittersweet	3
Siberian elm	3
Creeping jenny	3
Morrow's honeysuckle	3
Tree of heaven	2
Dames rocket	2
Purple loosestrife	2
Norway maple	1
Nepalese browntop	1
Giant knotweed	1
European cranberrybush	1
Japanese knotweed	1
Leafy spurge	1

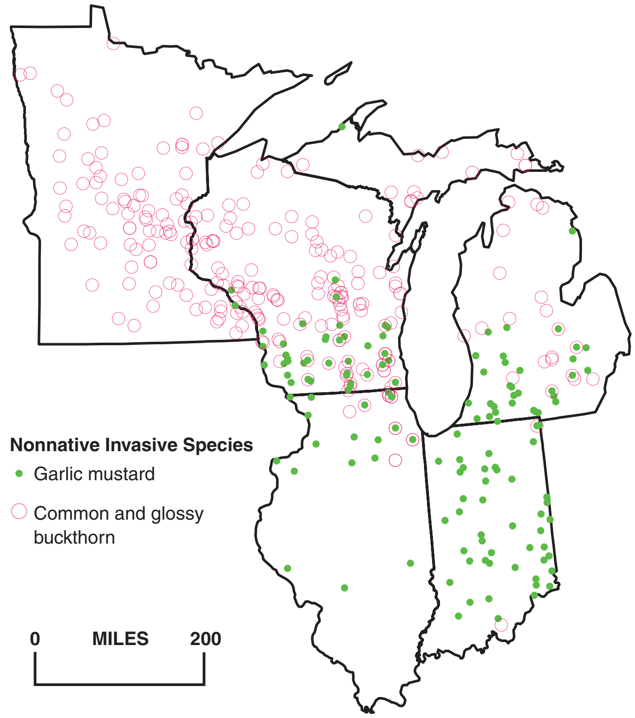

Figure 45.—Distribution of garlic mustard and common and glossy buckthorn on P2 Invasive plots, Michigan and nearby states, 2007-2009 (see Map Descriptions and Acknowledgments in Statistics, Methods, and Quality Assurance).

What this means

The P3 inventory identified many species but it did not sample all the diversity. There are 23 fewer species sampled in the 2009 versus 2004 inventory. The sample size is limited so some species will be missed.

Invasive species are a concern throughout the Midwest because many invasive plants are able to thrive in a variety of habitats. They threaten forested ecosystems by displacing native species and altering resource availability (e.g., water and nutrient levels). Additionally there may be economic implications caused by invasive species such as reduced timber yield and increased management costs. In the future, remeasurement of the P2 Invasive and P3 plots will enable researchers to analyze site and regional characteristics influencing species presence over time.

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 wildlife habitat such as dens for black bears and shelter for small mammals (Harmon et al. 1986). Invertebrates can thrive in their damp, dark environment and the invertebrates are a food source for larger animals. The microclimate of moisture, shade, and nutrients often helps with establishment of floral regeneration (Harmon et al. 1986). DWM are important carbon stocks (Woodall and Liknes 2008) and may be a source of fuel for bioenergy industries. In times of extreme fire weather (e.g., drought), DWM may constitute a fire hazard that should be monitored (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).

Estimates for Michigan are based on observations from 213 P3 plots visited from 2005 thru 2009 (see Statistics, Methods, and Quality Assurance) and are expressed in terms of fuel loadings (biomass) by size and decay classes (Woodall and Monleon 2008). One-hour, 10-hr, 100-hr and 1,000+-hr fuel loadings include fuels that are 0.01-0.24, 0.25-0.99, 1.00-2.99, and 3+ inches in diameter, respectively. Decay class codes are rated according to a five-class scale from 1 to 5 with 1 being the most sound and intact to 5 being the most rotten and dispersed.

What we found

Compared to DWM fuel loadings in the Pacific Northwest (Campbell et al. 2002), loadings are not exceedingly high in Michigan, Wisconsin, and Minnesota (Fig. 46). Compared to Wisconsin and Minnesota, Michigan's fuel loadings are not significantly different across the 1 to 100-hr size-classes. The loadings of the largest fuels (diameter 3.00+ inches) are between those in Minnesota and Wisconsin. The distribution of coarse woody debris (CWD) (diameter 3.00+ inches) by size class is skewed heavily (78 percent) toward pieces less than 8 inches in diameter at point of intersection with plot sampling planes (Fig. 47). The stages of decay of CWD across the State are dominated by the moderate decay classes of 2, 3, and 4 (92 percent) (Fig. 47). There is no apparent trend in volume of CWD by stand density of live trees, though the lowest volumes are associated with stands of little standing live-tree density (Fig. 48). Changes from the 2004 to 2009 inventory were small and it was not possible to confidently identify trends given the small sample size.

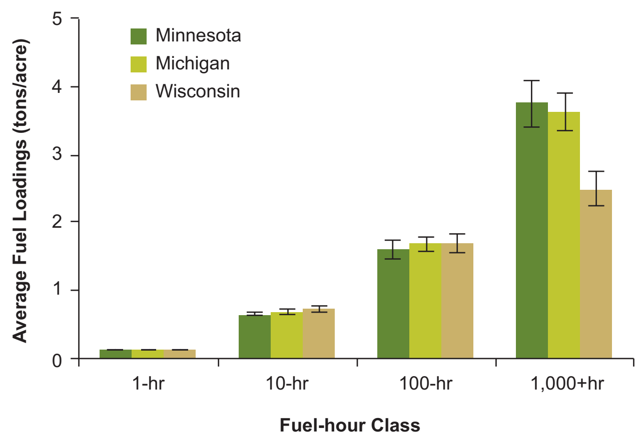

Figure 46.—Average fuel loadings (tons/acre) by fuel-hour class on forest land for Michigan (2005-2009), Minnesota (2005-2008), and Wisconsin (2005-2008); error bars represent 68-percent confidence interval around estimate.

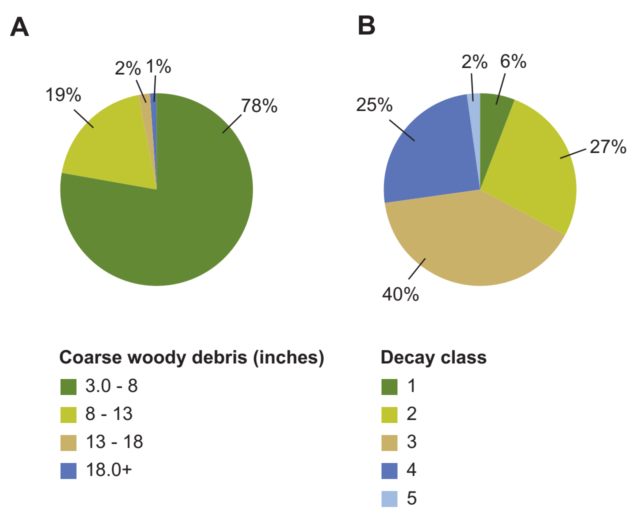

Figure 47.—Percentage of coarse woody debris (pieces/acre) by (A) large-end diameter (inches), and (B) decay class (1 to 5 equals least to most decayed), Michigan, 2009.

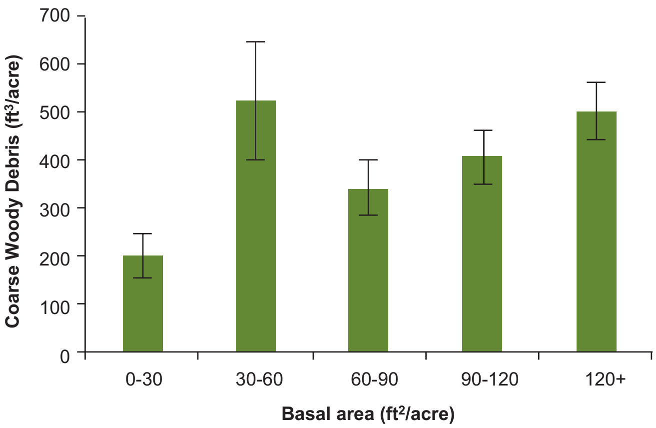

Figure 48.—Average coarse woody volume by stand density of live trees on forest land, Michigan, 2009; error bars represent 68-percent confidence interval around estimate.

What this means

Down woody fuel loadings in Michigan's forests differ little from those in neighboring states. Given that fuels can only pose a fire danger when their moisture levels drop below levels that enable combustion, DWM fuels across Michigan are only fire hazards in certain areas and only in times of extreme drought. Among the woody components, duff comprises the majority of biomass (see Biomass and Carbon), a trait common among the higher latitude forests of the U.S. Although there is an appreciable amount of coarse woody debris habitat in Michigan's forests, most pieces are small (less than 8 inches) and represent a forest resource that may decay rapidly given their small size. In fact, 67 percent of coarse woody pieces are in advanced stages of decay (class 3+). Compared to states with widespread and large-scale wildfire events (e.g., western U.S.), fuel loadings are not exceedingly high across Michigan, so fire danger is low or moderate. Michigan's total woody fuel loadings average less than 7 tons/acre. By contrast, a wind-disturbed area of northern Minnesota averaged nearly 18 tons/acre (Woodall and Nagel 2007).

Ozone

Background

Ozone (O_3) is a natural part of the atmosphere produced primarily through sunlight-driven chemical reactions of nitrogen oxides (by product 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 forests causing visible injury and decreased growth in plants (Karnosky et al. 1996), and changes in ecosystem structure and function (Holton et al. 2003, Karnosky et al. 2005). 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 (EPA 2007). FIA uses the biosite index to measure the severity of ground level-induced foliar injury (Coulston et al. 2003, Smith et al. 2008). The index uses visual indicators to distinguish gradations of healthy and unhealthy leaf tissue.

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 exposures. 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 a leaf's stomates. Stomates often are closed during drought, so injury can remain low in hot weather even when O_3 levels are high.

A number of tree species such as black cherry, quaking aspen, white ash, green ash, sassafras, and yellow-poplar, and other plant species such as common milkweed (*Asclepias syriaca*), blackberry (*Rubus allegheniensis*), and spreading dogbane (*Apocynum andrasefolium*) are sensitive to ozone and useful as bioindicators (Chappelka et al. 1999a, 1999b; Gunthardt-Goerg et al. 2000; Smith et al. 2008; VanderHeyden et al. 2001; Yuska et al. 2003). The condition or health of bioindicator species is one measure of the quality of an ecosystem. When a species is adversely affected by ozone, changes to forest structure and function may follow.

FIA has collected O_3 bioindicator data on biosites in Michigan since 1994. Biosites are wide-open areas, at least 1 acre in size, within or along forested areas. Each site must contain at least 30 individual plants of at least two bioindicator species. Sites are revisited annually but new sample locations are established when minimum site requirements are not present. A base grid of 45 biosites was established in Michigan when the national O_3 grid was implemented in 2002. The location and number of biosites can vary but there must be at least one biosite in each grid cell. FIA's biomonitoring program assessing O_3 leaf damage of bioindicators is unique with its national scale and standardized implementation. For more information on the O_3 biomonitoring program see http://www.nrs.fs.fed.us/fia/topics/ozone/.

What we found

O_3 induced foliar injury has been verified every year since FIA started collecting data in 1994 but 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 with only 0.3 percent of the evaluated plants showing injury from 2000 through 2009. In the same time period, 1.1 and 2.3 percent of evaluated plants showed injury in the northern Lower Peninsula and southern Lower Peninsula, respectively.

Biosite index values below 5 indicate no risk and little or no injury. Values from 5 to 14 represent low risk and light to moderate injury. The eastern Upper Peninsula (0.4 average biosite index) and western Upper Peninsula (0.0 average biosite index) each had low biosite index values from 2000 through 2009 with no detected injury or risk in most years. The northern Lower Peninsula (1.3 average biosite index) also had low biosite index values except in 2006 which had a value of 5. The southern Lower Peninsula (2.6 average biosite index) has low to moderate biosite index values.

The results for the southern Lower Peninsula from 2000 through 2009 are presented in Table 8. The average biosite index and injury caused by O_3 have fallen during the 2009 inventory. Even so, three biosites had biosite index values representing moderate to severe injury (range 18 - 21) and one biosite had severe injury (value 26).

Table 8.—Bioindicator O_3 injuries for the southern Lower Peninsula, Michigan, 2000-2009.

Parameter	2000	2001	2002	2003	2004
Biosites	21	27	23	24	24
Biosites with injury (%)	81	77.8	56.5	20.8	37.5
Plants evaluated	1,750	2,366	2,389	2,380	2,324
Plants with injury (%)	9.0	5.3	1.7	1.1	1.9
Average biosite index	6.3	3.1	1.7	0.1	5.7
Parameter	**2005**	**2006**	**2007**	**2008**	**2009**
Biosites	24	24	24	22	22
Biosites with injury (%)	37.5	41.7	25	22.7	18.2
Plants evaluated	2,372	2,514	2,531	2,159	2,072
Plants with injury (%)	1.2	1.4	0.6	1.4	1.0
Average biosite index	3.3	1.9	0.3	2.4	1.0

In the southern Lower Peninsula, FIA evaluated eight bioindicator species for foliar injury and seven species (black cherry, blackberry, common milkweed, white ash, spreading dogbane, sassafras, and yellow-poplar) exhibited O_3 injury. No injury was found on pin cherry. Six percent of yellow-poplar and 3 percent of blackberry were injured. Injury was 1 percent or less for each of the other species. In the 2004 inventory, injury was more common; 24 percent of yellow-poplar and 7 percent of black cherry were affected.

What this means

The biosite index values and foliar injury levels indicate that O_3 is a stress agent for some forests in southern Michigan. Data from the Michigan Department of Environmental Quality showing severity and duration of O_3 exposures exhibit notable year-to-year variability (http://www.michigan.gov/deq/0,1607,7-135-3310_4195-151319—,00.html). Peak hourly O_3 values exceed 0.1 parts per million along Lake Michigan in southwest Michigan and exceed the threshold required to cause injury in some bioindicator species (Bennett et al. 2006).

O_3 sensitive species such as 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 has only 6 percent of its live volume on forest land in the southern Lower Peninsula. Yellow-poplar (nearly 100 percent in southern Lower Peninsula), green ash (65 percent), and black cherry (61 percent) have most of their live volume on forest land in the southern Lower Peninsula. Yellow-poplar has little live volume at 66 million ft^3 on forest land. White ash (33 percent) has a moderate amount of live volume on forest land in the southern Lower Peninsula.

Ground-level O_3 exposure in Michigan is influenced by local and regional pollution sources. Michigan's northern forests are at low risk of O_3-induced visible foliar injury because sources are limited, though regional transport events to the north occur from the urban areas in the southern Lake Michigan basin.

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.

Forest Products

Red pine stand adjacent to clearcut. Photo by Scott Pugh, U.S. Forest Service.

Timber Product Output

Background

Michigan's wood-products and paper industries directly employ nearly 25,000 workers with an output of approximately $7.4 billion annually (North American Industry Classification System codes 321 and 322, U.S. Census Bur. 2007). These primary wood-using industries include sawmills, pulp and paper manufacturers, and veneer and plywood manufacturers. Additional Michigan wood-product jobs and economic outputs are in logging, transportation, trade, and wood furniture industries. 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.

Since the late 1970s, the Forest Service and the MIDNR have conducted biennial surveys of all primary and wood using mills in Michigan. These surveys typically result in assessment reports on timber product output and use. Timber product output is the volume of industrial roundwood products produced. Industrial roundwood products include saw logs, pulpwood, veneer logs, poles, commercial posts, pilings, cooperage logs, particleboard bolts, shaving bolts, lath bolts, charcoal bolts, and chips from roundwood used for pulp or board products. In addition to surveys from Michigan, the assessments also include mill survey results from other states that processed wood harvested from Michigan, and regional harvest utilization studies (FIA unpublished). Here, production considers only wood coming from the forests of Michigan and processed in the State or other locations.

The most recent survey for Michigan was conducted in 2008 (Fig. 49); the assessment report is pending.[1] Data from the 2008 survey is included in this report. The latest published assessment (Piva and Weatherspoon 2010) is for 2006.

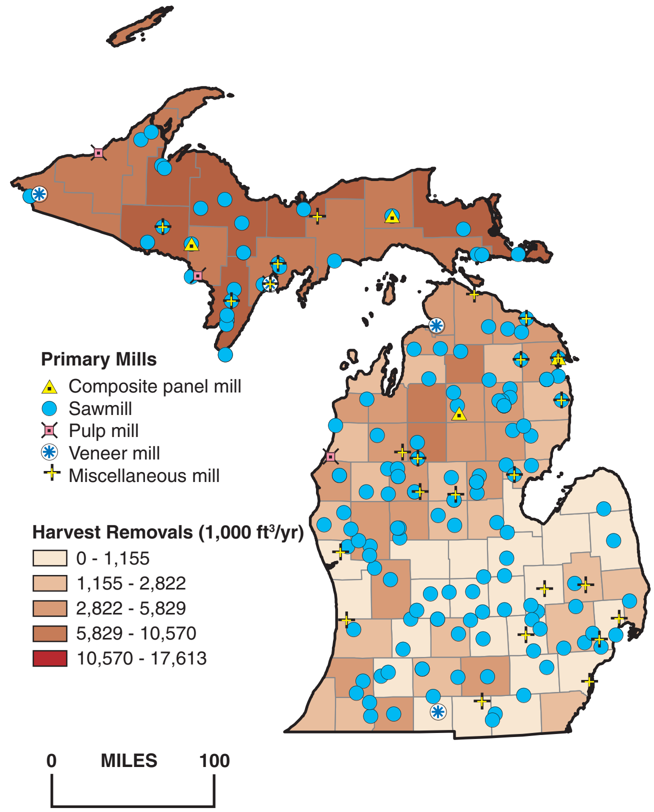

Figure 49.—Location and type of primary wood-using mills in Michigan (2008) overlaid on average annual harvest removals (2005-2009) from FIA plot data (see Map Descriptions and Acknowledgements in Statistics, Methods, and Quality Assurance).

The TPO mill surveys determine the total industrial wood usage in the State from all land. From this total wood usage, regional harvest utilization studies are used to make estimates 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.

The average annual removals estimate (see Annual Removals) derived from FIA plot observations can differ from the TPO survey estimate. Average annual removals are based on FIA plot observations and include harvest removals, unutilized removals (trees killed in the harvesting process and left on site), and diversion removals (see Annual Removals). The TPO survey estimate is based on data from a single year. The average annual removals estimate is a yearly average from one inventory to the next. Both the TPO and plot

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[1]Haugen, D.E.; Neumann, D. In Preparation. Michigan timber industry: an assessment of timber product output and use. 2008. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station.

observations can be used to derive estimates of harvest removals for growing stock from timberland, but because of different approaches and time periods, the estimates may be quite different. The TPO estimates for 2006 and 2008 averaged 299 million ft^3. The nearly analogous estimate from plot observations was 311 million ft^3 for the 2009 inventory (2000-2004 to 2005-2009).

What we found

In the process of harvesting industrial roundwood from Michigan's forests in 2008, 409 million ft^3 of woody material was removed. This woody material includes any tree (e.g., dead tree or sapling) and aboveground volume (1-foot stumps not included for pole and sawtimber-size trees unless mill indicates processing of stumps). Seventy-eight percent of the woody material removed was used for industrial roundwood, 5 percent was logging residues (merchantable material left on site), and 17 percent was logging slash (unmerchantable material left on site). About 38 percent of the roundwood produced in Michigan was from the northern Lower Peninsula (Fig. 50).

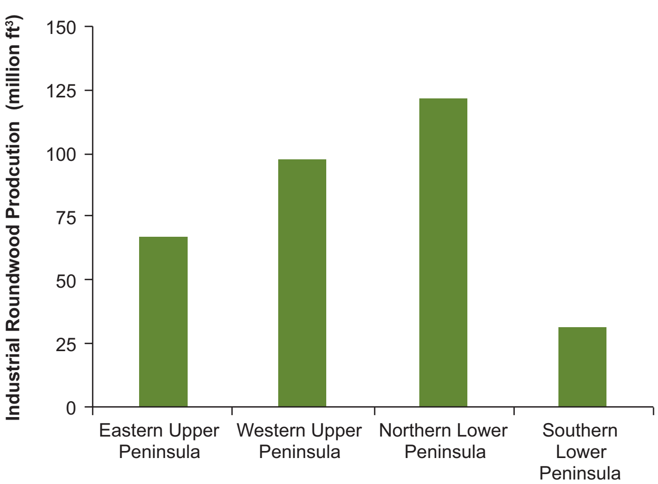

Figure 50.—Industrial roundwood production by region, Michigan, 2008.

Aspen accounted for nearly 20 percent of the total industrial roundwood produced in 2008. Other important species or species groups harvested were hard maple (14 percent), soft maple (10 percent), red pine (10 percent), jack pine (5 percent) and red oaks (5 percent) (Fig.51).

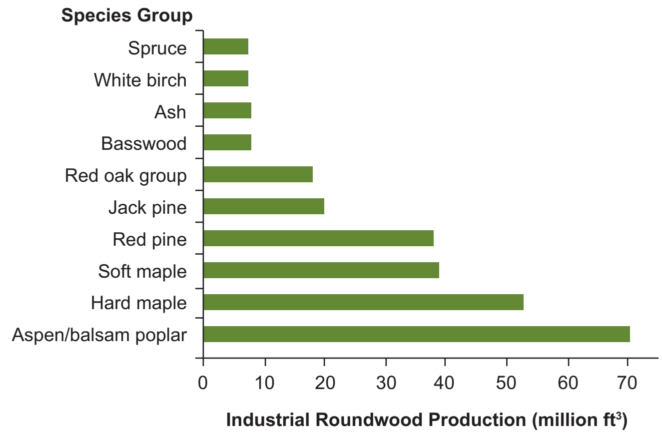

Figure 51.—Industrial roundwood production by prominent species group, Michigan, 2008.

By product, pulpwood accounted for 54 percent of all the roundwood produced, saw logs represented 31 percent, and veneers, industrial fuelwood, and other miscellaneous items accounted for 15 percent (Fig. 52).

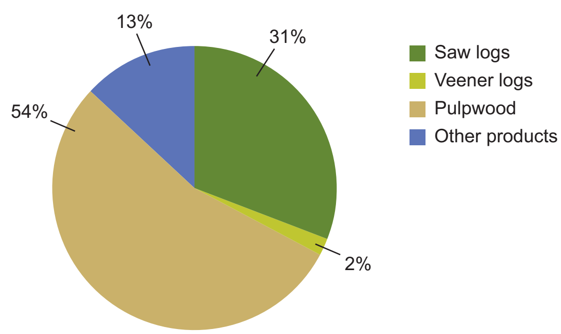

Figure 52.—Distribution of industrial roundwood production by product, Michigan, 2008.

Michigan's saw-log production was 574.0 million board feet in 2008 and 91 percent of this was processed by Michigan mills. The remaining 9 percent was exported to mills in Wisconsin, Indiana, Ohio, and Canada or other countries (Fig. 53). Michigan mills processed about 574.5 million board feet. Ninety-one percent of this was from Michigan's forests. The rest is imported from Wisconsin (8.6 percent), Illinois, Indiana, Minnesota, and Canada.

More than 2.2 million cords of pulpwood (mill residue not included) were produced from Michigan forest lands in 2008, of which 2.0 million cords (88 percent)

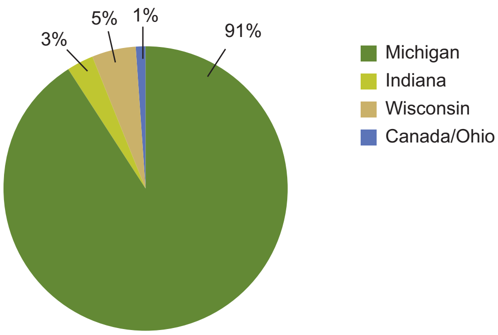

Figure 53.—Distribution of saw-log production by state/country of destination, Michigan, 2008.

remained in Michigan. Michigan exported 207,500 cords of this pulpwood to Wisconsin and 52,600 cords to Minnesota. The remaining 22,600 cords went to mills in Canada and Ohio (Fig. 54). Michigan mills processed 2.2 million cords of pulpwood. As previously mentioned, 2.0 million cords originated from Michigan. Another 223,100 cords of pulpwood were imported from Wisconsin and Canada by Michigan pulp and composite panel mills.

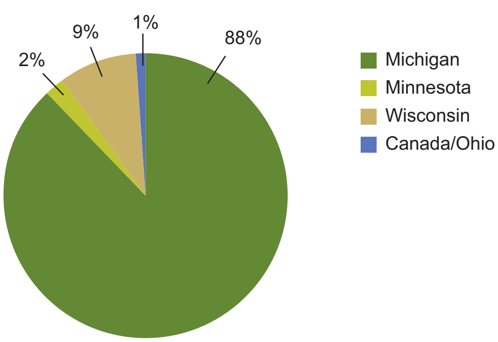

Figure 54.—Distribution of pulpwood production by state/country of destination, Michigan, 2008.

Between 2004 and 2008, industrial roundwood production declined by 10 percent (Fig. 55). Both saw logs and pulpwood decreased by nearly 20 percent. Four of the 12 pulp and composite panel mills in the State closed between 2004 and 2006. However, industrial roundwood used for other products has more than doubled since 2004 from 22.6 to 48.7 million ft³.

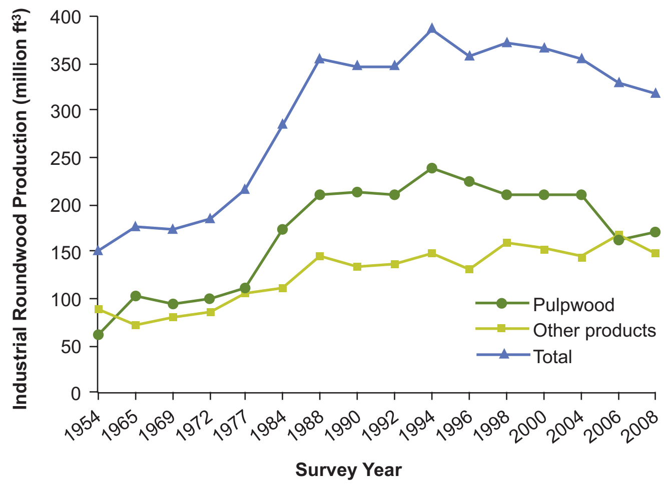

Figure 55.—Production of industrial roundwood by product, Michigan.

According to previous mill surveys, the number of active primary wood-using mills decreased from 288 mills in 2004 to 248 mills in 2006, and to 201 mills in 2008 (Table 9). However, preliminary results from the 2010 TPO survey indicate the decline was less severe.

What this means

As in the past, the northern Lower Peninsula was the largest producer of roundwood with more than 121 million ft³ (38 percent of total); the western Upper Peninsula produced 98 million ft³ (31 percent of total). This is not surprising as the northern Lower Peninsula and western Upper Peninsula account for the majority of timberland with 10.6 and 7.3 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 is likely a function of both its availability and its desirability as a commercial species (lumber, veneer, and pulpwood). Nearly 727,000 cords of maple (hard and soft) were harvested for pulpwood in 2008, nearly 6,000 more cords than aspen harvested for pulpwood.

Michigan is processing most of its own wood resources. More than 90 percent of the roundwood harvested in Michigan is processed by Michigan mills. Production

Table 9.—Active primary wood-using mills in Michigan by survey year (pulp mills include particle board plants, OSB, and waferboard; other mills include posts, poles, piling, cooperage, shavings, and mine timber).

Mill type	Size	1990	1996	2000	2004	2006	2008
	million board ft	*number of mills*					
Sawmill	More than 5	39	27	34	36	38	30
Sawmill	1 to 5	105	94	74	83	61	43
Sawmill	Less than 1	200	152	138	127	107	92
Pulp mill		11	12	12	12	8	8
Veneer mill		7	4	5	4	4	4
Other mill		43	29	31	26	30	24
Total mills		405	318	294	288	248	201

and total mill output has remained fairly steady while the number of mills appears to have declined. The pulp and composite panel mills appear to be steady. While saw log production decreased more than 20 percent between 2006 and 2008, pulpwood production increased nearly 5 percent. Increases in industrial fuelwood and mulch contributed to the increase from 22.6 to 48.7 million ft^3 in the other miscellaneous items category. For example, chipping and grinding of ash trees removed due to EAB can readily be used for these products.

There is an abundance of sustainable wood resources in the State based on the ratio of net growth to removals (see Net Growth to Removals) and current volumes (see Volume; Sawtimber Volume and Quality). Net growth, removals, and volume indicate that an increase in the harvest of timber products in Michigan would be biologically sustainable. This opportunity to increase harvest is influenced by difficult-to-measure factors such as landowner objectives, accessibility, parcelization, and stumpage price and market volatility, all of which make it more difficult to increase the harvest level in Michigan.

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Pugh, Scott A.; Pedersen, Lawrence D.; Heym, Douglas C.; Piva, Ronald J.; Woodall, Christopher W.; Barnett, Charles J.; Kurtz, Cassandra M.; Moser, W. Keith. 2012. **Michigan's Forests 2009**. Resour. Bull. NRS-66. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 68 p. [DVD included].

The seventh inventory of Michigan's forests, completed in 2009, describes more than 19.9 million acres of forest land. The data in this report are based on visits to 7,516 forested plots from 2005 to 2009. Timberland accounts for 97 percent of this forest land, and 62 percent is privately owned. The sugar maple/beech/yellow birch forest type accounts for 18 percent of the State's forest land, followed by aspen (13 percent) and white oak/red oak/hickory (7 percent). Balsam fir, red maple, and sugar maple are the three most common species by number of trees. Growing-stock volume on timberland has continued to increase totaling about 28.7 billion cubic feet (ft^3). The associated net growth, harvest removals, and mortality totaled 698, 311, and 272 million ft^3/year, respectively. In addition to information on forest attributes, this report includes data on forest health, biomass, land-use change, and timber-product outputs. Detailed information on forest inventory methods, data quality estimates, and important resource statistics can be found in Statistics, Methods, and Quality Assurance on the DVD in the back of this publication.

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

DVD Contents

Michigan's Forests 2009 (PDF)

Michigan's Forests 2009: Statistics, Methods, and Quality Assurance (PDF)

Michigan Inventory Database (CSV file folder)

Michigan Inventory Database (Access file)

Field guides that describe inventory procedures (PDF)

Database User Guides (PDF)

Michigan's Forests, 2009: Statistics, Methods, and Quality Assurance

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Resource Bulletin NRS-66

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