United States Department of Agriculture

West Virginia Forests 2013

Forest Service

Northern Research Station

Resource Bulletin NRS-105

Publication Date September 2016

Abstract

The annual inventory of West Virginia's forests, completed in 2013, covers nearly 12.2 million acres of forest land with an average volume of more than 2,300 cubic feet per acre. This report is based data collected from 2,808 plots located across the State. Forest land is dominated by the oak/hickory forest-type group, which occupies 74 percent of total forest land area. Seventy-eight percent of forest land area consists of a plurality of large diameter trees, 15 percent contains medium diameter trees, and 7 percent contains small diameter trees. The volume of growing stock on timberland has been rising since the 1950s and currently totals over 25 billion cubic feet. The average annual net growth of growing-stock trees on timberland from 2008 to 2013 is approximately 519 million cubic feet per year. Important species compositional changes include increases in sapling numbers of yellow-poplar, American beech, and noncommercial species, which coincide with decreases in numbers of trees and saplings of oak species. Additional information is presented on forest attributes, land use change, carbon, timber products, species composition, regeneration, and forest health. Detailed information on forest inventory methods, data quality estimates, and summary tables of population estimates, are available at http://dx.doi.org/10.2737/NRS-RB-105.

Acknowledgments

The authors would like to thank West Virginia's inventory crew members over the 2004-2013 inventory cycle: Thomas Albright, Phil Bergsrud, James Connolly, Chris Coolbaugh, Michael Effinger, Adrienne Evans, Jeff Fulgham, Ted Goodnight, Jason Gould, Marlin Gruver, Paul Kelley, Karen Kubly, Nicholas Larson, Chris Mate, Cade Mitchel, Paul Natiella, Paul Neubauer, Mitch Pennabaker, Stephen Potter, Matt Powell, Kirk Ramsey, Jason Reed, Todd Renninger, Todd Roffe, Ty Ryen, Richard Starr, Katherine Tillman, Chris Tucci, Roell Wayne, Michael Whitehill, Thomas Willard, Ron Yaworsky, Jessica Yeagle, Ashley Zickefoose, Lewis Zimmerman. Thanks also to George McCaskill and Randy Dye for serving as reviewers and providing insightful, constructive comments.

Cover: Fall foliage as seen from the viewing tower at Kumbrabow State Forest. Photo by West Virginia Department of Commerce, used with permission.

Manuscript received for publication August 2015.

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

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

September 2016

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

Printed on recycled paper

West Virginia Forests, 2013

Randall S. Morin, Gregory W. Cook, Chuck J. Barnett, Brett J. Butler, Susan J. Crocker, Mark A. Hatfield, Cassandra M. Kurtz, Tonya W. Lister, William G. Luppold, William H. McWilliams, Patrick D. Miles, Mark D. Nelson, Charles H. Perry, Ronald J. Piva, James E. Smith, James A. Westfall, Richard H. Widmann, and Christopher W. Woodall

About the Authors

Randall S. Morin, Tonya W. Lister, James A. Westfall, and William H. McWilliams are research foresters with the Forest Inventory and Analysis (FIA) program, Northern Research Station, Newtown Square, PA.

Gregory W. Cook is Deputy State Forester for the West Virginia Division of Forestry, Department of Commerce, Charleston, WV.

Chuck J. Barnett and Richard H. Widmann are foresters with the FIA program, Northern Research Station, Newtown Square, PA.

Brett J. Butler is a research forester with the FIA program, Northern Research Station, Amherst, MA.

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

Mark A. Hatfield is a forester with the FIA program, Northern Research Station, Durham, NH.

Ronald J. Piva is a forester with the FIA program, Northern Research Station, St. Paul, MN.

Cassandra M. Kurtz is a natural resources specialist with the FIA program, Northern Research Station, St. Paul, MN

William Luppold is a research economist with the Northern Research Station, Princeton, WV.

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

Christopher W. Woodall is a research forester and Project Leader with the Northern Research Station, Durham, NH, and formerly with the FIA program.

Foreword

On October 12, 2008, I received a letter from the Forest Management Review Commission, an interim committee of the West Virginia Legislature, which cited twelve issues of concern. The committee's number one issue was Forest Inventory and Analysis. No single document is more important to the sustainability of West Virginia's forests than this, our seventh forest inventory. This document was prepared by the Forest Inventory and Analysis program of the U.S. Department of Agriculture, Forest Service, Northern Research Station, with assistance from the West Virginia Division of Forestry, Department of Commerce. The sound scientific information contained within allows one to look at the evolution of our forest over the past seventy years, identify trends, and thus project the future condition of our forest. The ability to know the present condition of our forest and project the future is essential to ensure the sustainability of our forest.

A forest is many things to many different people. Today's society requires forest managers to recognize and balance the many ecological, social and economic issues. This inventory and analysis report is comprehensive and formatted in a way that addresses many issues. A forest provides clean water, clean air, carbon storage, scenic landscapes, recreational opportunities, wildlife habitat and, last but not least, jobs for those employed in the forest products industry.

Forests are dynamic and forever changing. This inventory indicates that we have not lost or gained forested acreage; the average tree size, quality, and total volume have all increased since the last inventory in 2008. However, this trend cannot continue indefinitely and there are issues that need to be monitored closely. The most notable issue is that oaks make up to 47 percent of the trees 20 inches and larger in diameter, but only 8 percent of the trees less than 10 inches in diameter. Oaks have historically been a high value species in the world lumber markets and, therefore, the decline of this species would most likely have a negative impact on the forest products industry. Of equal importance is the fact that numerous wildlife species would be negatively impacted if this important food source were reduced. This is just one example of the many challenges this report highlights.

This report will not be put on the shelf. It is a valuable tool that will enable the West Virginia Division of Forestry and other resource managers to recognize potential issues and develop strategies to address those issues, thus ensuring the sustainability of West Virginia's forest resource.

C. Randy Dye

Director/State Forester

Contents

Rock outcrop at Coopers Rock State Forest. Photo by Randall Morin, U.S. Forest Service.

Highlights

On the Plus Side

- West Virginia's forest land base remains stable at about 79 percent since 2008, making it the third most forested state in the United States based on the percentage of land area.
- Timberland makes up 97 percent of West Virginia's forest land.
- The small amount of forest land lost over the past 5 years has been more than offset by the forest land gained.
- Most of the forest carbon in the region is found in medium aged stands dominated by relatively long-lived species. This suggests that forest carbon stocks will continue to increase in the State as stands mature and accumulate carbon in aboveground and belowground components.
- Due to the continuing increases in volume, West Virginia's timber resources are at record levels since the first forest inventory in 1949.
- The ratio of growth to removals remains above 2:2 indicating that forests in the State are growing twice as much wood volume annually than is being cut.
- In addition to the increase in overall board-foot volume of sawtimber material, the quality of saw logs in West Virginia has improved since 2000.
- The 0.9-percent mortality rate from 2009 to 2013 is slightly higher than what was reported for the previous inventory period (0.7 percent). There is substantial variation by species.
- Tree crowns remain generally healthy and stable based on the low occurrence of crown dieback.
- Many of the wood-processing facilities in West Virginia are sawmills processing primarily saw logs. These mills provide woodland owners with an outlet to sell timber locally and provide jobs in rural areas.
- Hardwood exports and wood production employment began to increase in 2013 after major declines that began in 2007.

Areas of Concern

- Only 38 percent of West Virginia's timberland is well stocked with trees of commercial importance and may indicate that forest harvesting practices over the past decade have changed the general stocking condition across the State.
- Nearly 3.8 million acres of forest land has undergone an intergenerational transfer, foreshadowed by the advanced age of many owners.
- While timber volume in West Virginia has increased to record levels, the rate of growth has leveled off as the forest continues to mature and this trend is likely to continue into the future.
- Current species composition of saplings foretells a future forest overstory with more red maple, sugar maple, blackgum, yellow-poplar, and black birch and less oak than exists today. Long-term changes in forest composition will alter wildlife habitats and affect the value of the forest for timber products.
- The presence of nonnative, invasive plant species is common across much of the State. The most abundant invasive plant is multiflora rose.

Issues to Watch

- Commercial and residential development of forest land, particularly around Morgantown and Martinsburg, could reduce forest cover.
- The trend toward small parcels held by many landowners will continue to complicate the economics of forest management and the delivery of government programs.
- The area of medium diameter stands has decreased and area of large diameter stands has increased over the past three decades.
- West Virginia's forests continue to accumulate biomass as the forests mature. Because most of the biomass is contained in the boles of growing-stock trees, and most of the gains in biomass stocks are found in these higher value sawtimber-size trees, only a fraction of the accumulated material is available for use as fuel.
- Although the proportion of high-grade wood volume has remained stable in West Virginia, changes in species composition point toward potential reductions in overall sawtimber quality in the future.

- The number of wood-processing mills has steadily declined across the region. This could present a hardship for landowners that need pulp mills, sawmills, and veneer mills to market their harvested timber.
- Invasive insect pests that may increasingly impact tree species in West Virginia in the future include hemlock woolly adelgid and emerald ash borer.
- More extreme weather-related events, including hurricanes, droughts, and floods caused by a changing climatic regime, could lead to catastrophic economic and ecological loss of the State's forest resource.
- The State's maturing forest structure will continue to limit pioneer and other shade-intolerant species that thrive in sunnier forested conditions.
- Frequent tree damage and internal decay on 20 percent of trees in West Virginia may indicate reduced tree health or timber quality.

Background

Seneca Rocks, West Virginia. Photo by Randall Morin, U.S. Forest Service.

Overview of Forest Inventory

The forests of West Virginia are valuable assets due to their importance to the economy and quality of life for residents. Accurate information is critical for understanding the current conditions, interpreting trends over time, and projecting future scenarios.

The Forest Inventory and Analysis program, commonly referred to as FIA, is the nation's forest census. It was established by the U.S. Congress to "make and keep current a comprehensive inventory and analysis of the present and prospective conditions of and requirement of the forest and range lands of the United States" (Forest and Rangeland Renewable Resources Planning Act of 1974; 16 USC 1601 [note]). FIA has been collecting, analyzing, and reporting on the nation's forest resources for over 80 years with the first FIA inventory of West Virginia's forests completed in 1949. Information is collected on the status and trends of the extent, composition, structure, health, and ownership of the forests. This information is used by policy makers, resource managers, researchers, and the general public to better understand forest resources and to make more informed decisions about their fate.

Data for this survey were collected between 2009 and 2013, but throughout this report, we refer to 2013 as the inventory year. Previous forest inventories, completed in 1949 (Wray 1952), 1961 (Ferguson 1964), 1975 (Bones 1978), 1989 (DiGiovanni 1990), and 2000 (Griffith and Widmann 2003), were collected under a different inventory system where states were inventoried periodically with no measurements made between inventories. An annualized system was implemented in West Virginia in 2004 to provide updated forest inventory information every year based on a 5-year cycle; results of that survey are reported in Widmann et al. 2013.

This report is divided into chapters that focus on forest features, forest health, and forest economics. Details about the data collection, estimation procedures, and statistical reliability are included in the section "Statistics, Methods, and Quality Assurance," at http://dx.doi.org/10.2737/NRS-RB-105. The section also includes a glossary (e.g., growing-stock trees, ingrowth, etc.) and numerous tables summarizing the results reported here.

A Guide to the FIA Forest Inventory

What is a tree?

The FIA program of the U.S. Forest Service defines a tree as a perennial woody plant species that can attain a height of at least 15 feet at maturity. Growing-stock trees include live trees of commercial species having a diameter at breast height (d.b.h.) of 5.0 inches and larger meeting specified standards of quality or vigor. A complete list of tree species measured in West Virgina during this inventory is included in the appendix.

What is a forest?

A forest can come in many forms depending on climate, quality of soils, and the available gene pool for the dispersion of plant species. Forest stands can range from very tall, heavily dense, and multi-structured, to short, sparsely populated, and single layered. FIA defines forest land as land that has at least 10 percent crown cover by live trees or formerly had such tree cover and is not currently developed for a nonforest use. The area with trees must be at least 1 acre in size and 120 feet wide.

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

FIA classifies forest land into three categories:

- Timberland is unreserved forest land that meets the minimum wood volume productivity requirement of 20 cubic feet per acre per year.
- Reserved forest land is land withdrawn from timber utilization through legislative regulation.
- Other forest land is commonly found on low-lying sites or high craggy areas with poor soils where the forest is incapable of producing 20 cubic feet per acre per year. In earlier inventories, FIA measured trees only on timberland plots and did not report volumes on all forest land. Since the implementation of the new annual inventory in West Virginia in 2004, FIA has been reporting volume on all forest land.

In West Virginia, about 97 percent of all forest land is classified as unreserved and productive timberland, 2 percent is reserved and productive forest land, and 1 percent is other forest land.

This report is the culmination of the first complete remeasurement of the inventory of West Virginia's forests using FIA's annualized forest inventory system. With remeasurement completed, comparison of two sets of growth, mortality, and removals data as well as trends on forest land is now possible. However, since some of the older periodic inventories only reported on timberland, much of the trend reporting is still focused on timberland.

How many trees are in West Virginia?

West Virginia's forest land contains approximately 1,801 million live trees that are at least 5-inches d.b.h. We do not know the exact number of trees because the estimate is based upon a sample of the total population. The estimates are calculated from field measurements of 2,808 plots classified by ownership. For information on sampling errors, see Statistics, Methods, and Quality Assurance section of this report found at http://dx/doi/org/10.2737/NRS-RB-105.

How do we estimate a tree's volume?

Statistical models are used to predict volumes within a species group or for a specific species. Individual tree volumes are based upon species, diameter, and merchantable height from trees within the region. Tree volumes are reported in cubic feet or board feet based on the International ¼-inch log scale rule.

How is forest biomass estimated?

Specific gravity values for each tree species or group of species were developed at the U.S. Forest Service's Forest Products Laboratory (Miles and Smith 2009) and applied to FIA tree volume estimates for developing merchantable tree biomass (weight of tree bole). To calculate total live-tree biomass, we have to add the biomass for stumps, limbs and tops, and belowground stump and coarse roots (Woodall et al. 2011). We do not currently report live biomass for foliage. FIA inventories report biomass weights as oven-dry short tons. Oven-dry weight of a tree is the green weight minus the moisture content. Generally, 1 ton of oven-dry biomass is equal to 1.9 tons of green biomass.

Forest Inventory Sample Design

FIA has established a set of permanent inventory plots across the United States that are periodically revisited. Each plot consists of four 24-foot subplots for a total area of approximately one-sixth of an acre. Each plot is randomly located within a hexagon that is approximately 6,000 acres in size. Therefore, each plot represents about 6,000 acres of land and can be used to generate unbiased estimates and associated sampling errors for attributes such as total forest land area. Full details of sample design and estimation procedures are available in Bechtold and Patterson (2005) and a summary explanation is included in the Statistics, Methods, and Quality Assurance section of this report found at http://dx.doi.org/10.2737/NRS-RB-105.

The inventory is conducted in phases. In Phase 1 (P1), the population of interest is stratified and plots are assigned to strata to increase the precision of estimates. In Phase 2 (P2), tree and site attributes are measured for forested plots established in each hexagon. Phase 2 plots consist of four 24-foot fixed-radius subplots on which standing trees are inventoried. This sampling design results in 2,808 long-term inventory plots in West Virginia. The Northern Research Station FIA is currently transitioning its forest health indicator monitoring from the Phase 3 (P3) protocols of the past to the Phase 2 plus (P2+) protocols of the future. The general approach is to reduce the amount the data collected on each plot while increasing the number of forest health plots. For example, the P3 protocols required five tree crown health variables whereas the P2+ protocols only include two crown health variables: crown dieback and uncompacted live crown ratio.

How do we compare data from different inventories?

New inventories are commonly compared with older datasets to analyze trends or changes in forest growth, mortality, removals, and ownership acreage over time (Powell 1985). A pitfall occurs when the comparison involves data collected under different schemes or processed using different algorithms. Recently, significant changes were made to the methods for estimating tree-level volume and biomass (dry weight) for northeastern states, and the calculation of change components (net growth, removals, and mortality) was modified for national consistency. These changes have focused on improving the ability to report consistent estimates across time and space—a primary objective for FIA. Regression models were developed for tree height and percent cull to reduce random variability across datasets.

Before the component ratio method (CRM) was implemented, volume and biomass were estimated using separate sets of equations (Heath et al. 2009). With the CRM, determining the biomass of individual trees and forests has become simply an extension of our FIA volume estimates. This allows us to obtain biomass estimates for growth, mortality, and removals of trees from our forest lands, not only for live trees, but also for their belowground coarse roots, standing deadwood, and down woody debris.

Another new method, termed the “midpoint method,” has introduced some differences in methodology for determining growth, mortality, and removals to a specified sample of trees (Westfall et al. 2009). The new approach involves calculating tree size attributes at the midpoint of the inventory cycle (2.5 years for a 5-year cycle) to obtain a better estimate for ingrowth, mortality, and removals. Although the overall net change component is equivalent under the previous and new evaluations, estimates for individual components will be different. For ingrowth, the midpoint method can produce a smaller estimate because the volumes are calculated at the 5.0-inch threshold instead of using the actual diameter at time of measurement. The actual diameter could be larger than the 5.0-inch threshold. The estimate for accretion is higher because growth on ingrowth, mortality, and removal trees are included. As such, the removals and mortality estimates will also be higher than before (Bechtold and Patterson 2005).

A word of caution on suitability and availability

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

Forest Features

Fog fills the valleys below Snowshoe Mountain. Photo by Randall Morin, U.S. Forest Service.

Dynamics of the Forest Land Base

Background

West Virginia's diverse forests are dominated by oak/hickory and maple/beech/birch forest-type groups, but spruce/fir and pine types also provide important ecological niches and diversity, particularly at high elevations. Because forests are so important for wood products, tourism, clean water, clean air, wildlife habitat, and wood energy, evaluating change in the status and condition of those forests is important. The amount of forest land and timberland are vital measures for assessing forest resources and making informed decisions about their management and future. Gains or losses in forest area are an indication of forest sustainability, ecosystem health, and land use practices, and they have a direct effect on the ability of forests to provide goods and services. Additionally, these measures are the basis for FIA's estimates of numbers of trees, wood volume, and biomass.

Most of West Virginia falls into four ecoregion sections (Fig. 1): Southern Unglaciated Allegheny Plateau, Northern Cumberland Mountains, Allegheny Mountains, and Northern Ridge and Valley (Cleland et al. 2007). Areas within ecoregions have similar combinations of soil and landform that tend to contain distinct assemblages of natural communities.

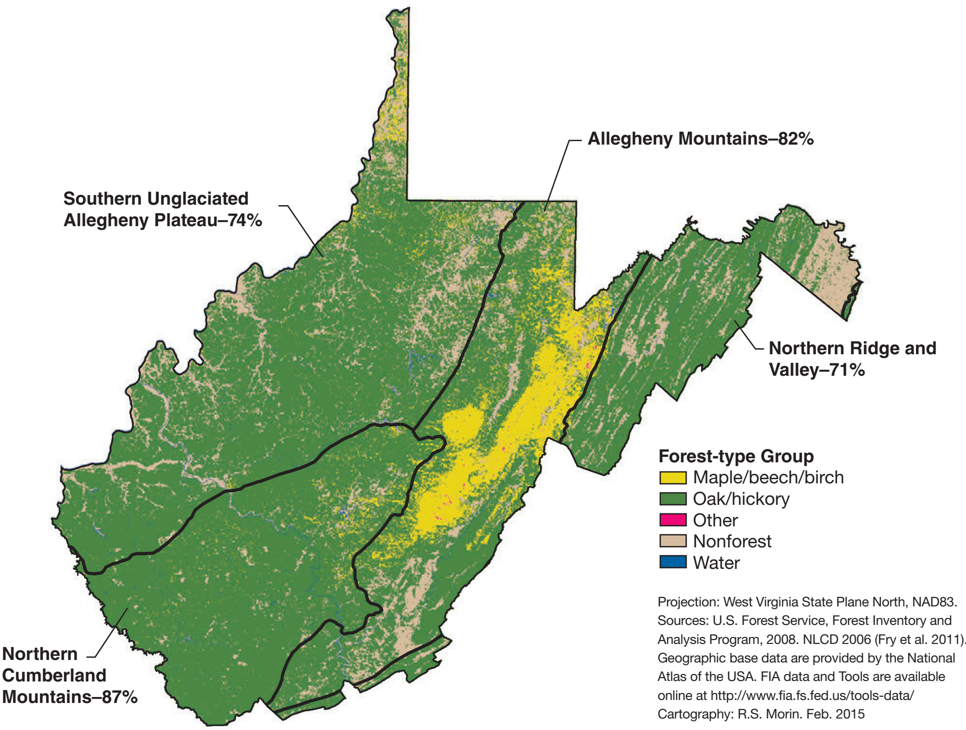


Figure 1.—Distribution of forest-type groups, West Virginia. Labels indicate ecoregion sections and proportion of area in forest land.

Forest type is determined by the stocking (relative density) that tree species contribute to a sampled condition. The forest types used by FIA are based on the types presented by Eyre (1980). Related forest types are combined into groups. A modeled spatial distribution of the forest-type-groups in West Virginia is presented in Figure 1. The dataset used to create Figure 1 is available at http://data.fs.usda.gov/geodata/rastergateway/forest_type/index.php.

What we found

Forests are the dominant land cover across most of West Virginia. The percentage of forest cover ranges from 70 percent in the Northern Ridge and Valley ecoregion to 87 percent in the Northern Cumberland Mountains ecoregion (Fig. 1). When FIA completed its first inventory (1949) of West Virginia, only 64 percent of the State's area was forested. Subsequent inventories showed a steady increase in forest cover as lands were reforested due to the abandonment of farmland. West Virginia's forested land base increased rapidly between 1949 and 1989 (Fig. 2).

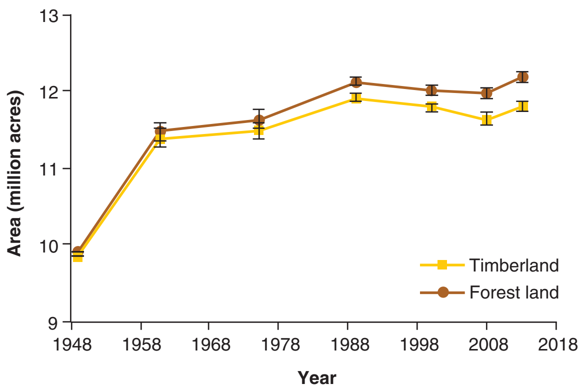


Figure 2.—Area of forest land and timberland, West Virginia, by inventory year. Error bars represent 68 percent confidence intervals around the estimate.

The forest land base in West Virginia is composed of predominately hardwood forest types. Most forest land is classified as the oak/hickory forest-type group (Fig. 3), but the proportion of forest land in oak/hickory varies by ecoregion, ranging from 54 percent in the Allegheny Mountains ecoregion to 85 percent in the Northern Cumberland Mountains ecoregion. The second most abundant forest-type group is maple/beech/birch; it varies from 9 percent in the Northern Cumberland Mountains ecoregion to 35 percent in the Allegheny Mountains ecoregion. The white pine forest-type group is present at low levels across all ecoregions. By contrast, the oak/pine and spruce/fir forest-type groups are concentrated in the Northern Cumberland

Mountains and Allegheny Mountains ecoregions, respectively. The spruce/fir forest-type group is only present at elevations above 3,000 feet and 58 percent occurs at above 4,000 feet.

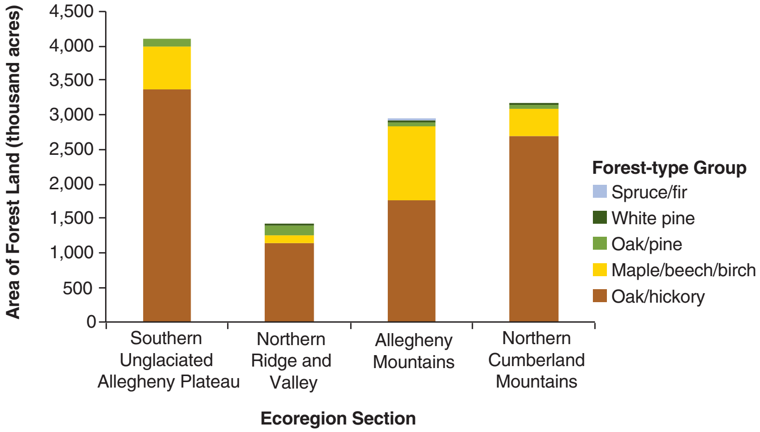


Figure 3.—Area of forest land by major forest-type group and ecoregion section, West Virginia, 2013.

What this means

West Virginia is the third most forested state, with 79 percent of its land base forested. The current statewide estimates of forest land have remained stable since 1988 (Fig. 2). Future changes in West Virginia's forest land base will depend on the pace of land development as well as the economics of farming and the oil and gas industries. Due to inadequate oak regeneration and increasing numbers of maple, the distribution of forest-type groups may shift slowly from oak/hickory to maple/beech/birch in the future (see Regeneration Status section on page 76).

Availability and Productivity of Forest Land

Background

As previously mentioned, FIA divides forest land into three categories—timberland, reserved forest land, and other forest land—to clarify the availability of forest resources and facilitate forest management planning. Two criteria are used to make this determination: reserved status (unreserved or reserved) and site productivity (productive or unproductive). Forest land that is capable of growing trees at a rate of at least 20 cubic feet per acre per year and that is not legally restricted from being harvested is classified as timberland. If harvesting is restricted on forest land by statute or administrative decision, then it is designated as reserved regardless of its productivity class. The harvesting intentions of private forest land owners are not used to determine the reserved status. The other forest land category is made up of forest land that is unreserved and low in productivity.

What we found

Ninety-seven percent of West Virginia's forest land meets the definition of timberland, and 89 percent of that timberland is in private ownership. The current estimates of timberland have remained unchanged since 1989 (Fig. 2). Most of the land in the reserved class is designated natural areas on the Monongahela National Forest. Forest land classified as "other" is rare and only accounts for less than 1 percent of total land (Fig. 4).

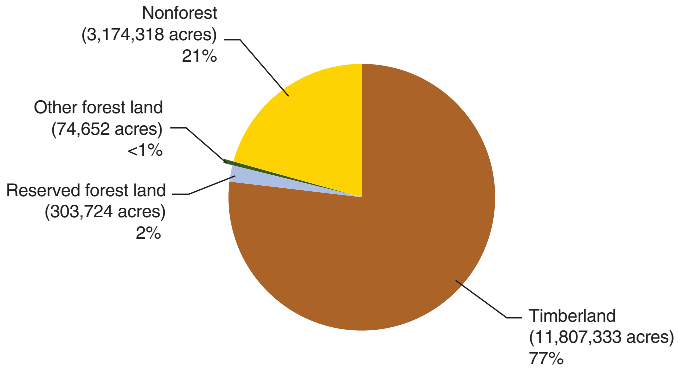


Figure 4.—Sampled land area by major category, West Virginia, 2013.

What this means

Because most of West Virginia's forest land is classified as timberland, it is potentially available for harvesting timber or other forest products. It also means that trends observed on timberland are likely to apply to forest land as well. The demand for forest products will increase with an expansion in the number of industries that utilize these products. Therefore, the balance of supply and demand for these forest products needs to be closely monitored. Later sections in this report provide more details on how much forest land is actively managed for forest products and a more accurate estimate of how much timberland is truly available for harvesting.

Ownership of Forest Land

Background

How private land is managed is primarily the owner's decision. To a large extent, the availability and quality of forest resources, including recreational opportunities, timber supply, and protection of wildlife habitat, are determined by the landowners. By understanding the priorities of forest land owners, leaders of the forest conservation community can better help owners meet their needs, and in so doing, help conserve the state's forests for future generations. The National Woodland Owner Survey (NWOS) (Butler et al. 2016a), conducted by the FIA, collects information about private forest landowners' attitudes, management objectives, and concerns. The survey focuses on the diverse and dynamic group of owners that is the least understood—families, individuals, and other unincorporated groups, collectively referred to as "family forest owners." The NWOS data reported here are based on the responses from 249 family forest ownerships from West Virginia that participated between 2011 and 2013. For complete results of the NWOS of West Virginia forest landowners, see Butler et al. (2016b).

What we found

Eighty-seven percent of the forest land of West Virginia is privately owned (Figs. 5, 6). This level of private ownership has been stable since the late 1980s (Fig. 7). Most of these private acres are owned by family forest owners who control an estimated 6.5 million acres; details about this group are discussed below. Corporations own an estimated 4.0 million acres; this group includes traditional forest industry companies, timber investment management organizations, mining companies, and numerous other types of companies. Other private owners, including conservation organizations, unincorporated clubs and partnerships, and Native American tribes, own an estimated 150,000 acres of forest land in the State.

Public agencies control an estimated 1.6 million acres of West Virginia's forest land (Fig. 6). The Federal government manages an estimated 1.2 million acres of forest land, much of this in the Monongahela National Forest. State forest, park, and wildlife agencies are stewards of another 300,000 of forest land. Local government agencies control an estimated 53,000 acres of forest land in the State.

According to the Butler et al. (2016b), there are an estimated 101,000 family forest ownerships across West Virginia that each own at least 10 acres of forest land, owning collectively 6.1 million acres. The average forest holding size of this group is 60 acres;

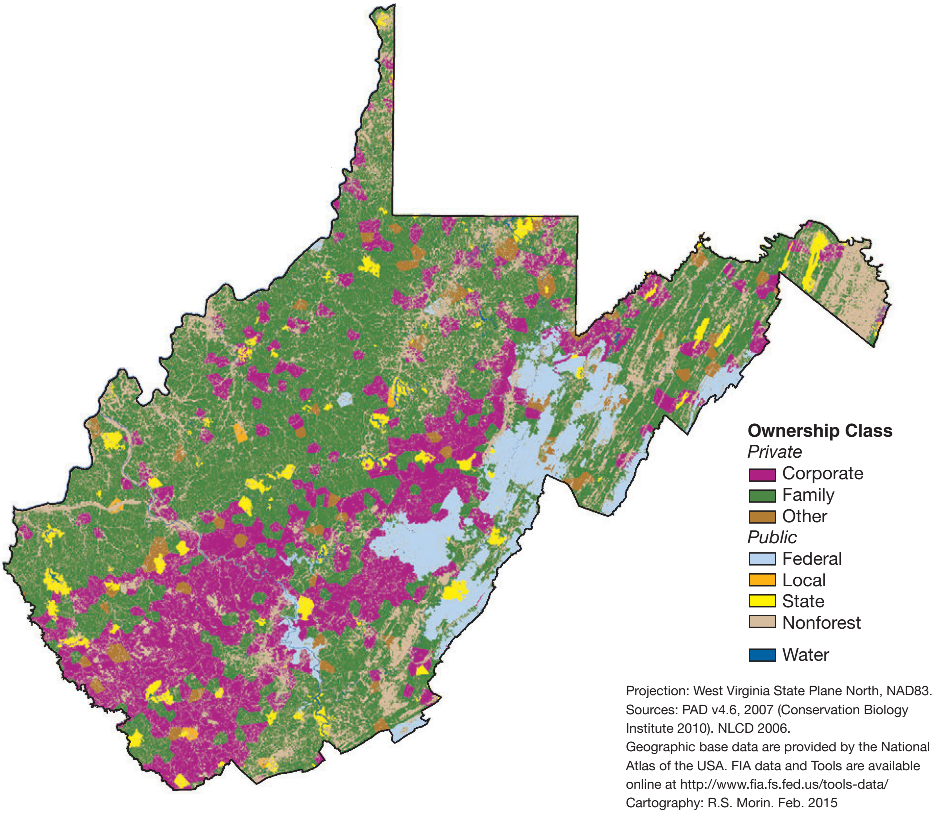


Figure 5.—Distribution of forest land by owner class, West Virginia.

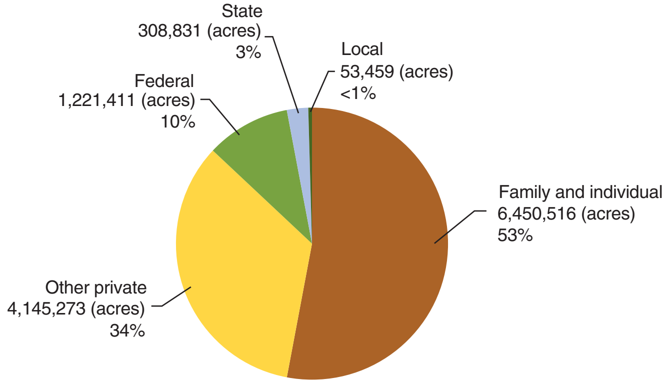


Figure 6.—Forest land area by major ownership category, West Virginia, 2013.

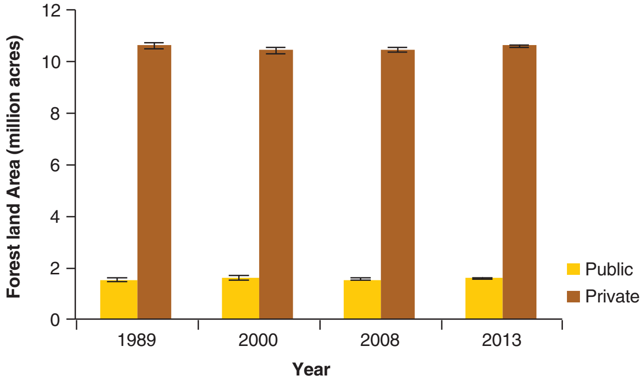


Figure 7.—Forest land area by major ownership category and inventory year, West Virginia. Error bars represent 68 percent confidence intervals around the estimate.

66 percent of these family forest ownerships own less than 50 acres of forest land, but 76 percent of the family forest land is in holdings of at least 50 acres (Fig. 8). The primary reasons for owning forest land are related to beauty, wildlife, legacy, and privacy (Fig. 9). The most common activities on their land are personal recreation, such as hunting and hiking, and cutting trees for personal use, such as firewood (Fig. 10). Few family forest ownerships have participated in traditional forestry management and assistance programs in the past 5 years (Fig. 11). Fewer than 15 percent of the ownerships have a written forest management plan, which happens to be the most common form of forest management assistance. The average age of family forest owners in West Virginia is 64 years with 50 percent of the family forest land owned by people who are at least 65 years of age (Fig. 12).

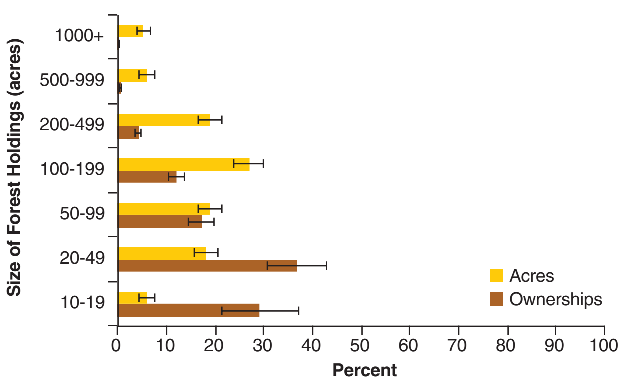


Figure 8.—Percentage of family forest ownerships and acres of forest land by size of forest land holdings, West Virginia, 2013. Error bars represent 68 percent confidence intervals around the estimate.

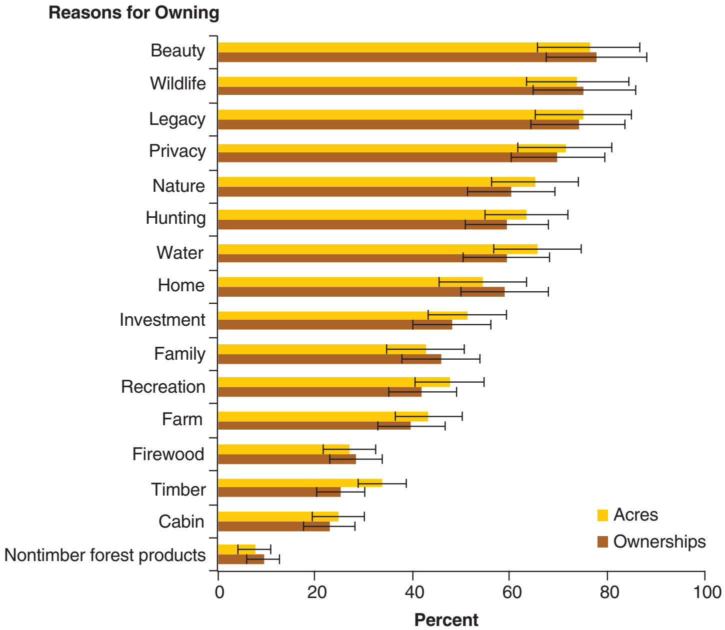


Figure 9.—Percentage of family forest ownerships and acres of forest land by reasons given for owning forest land ranked as very important or important, West Virginia, 2013. Categories are not exclusive. Error bars represent 68 percent confidence intervals around the estimate.

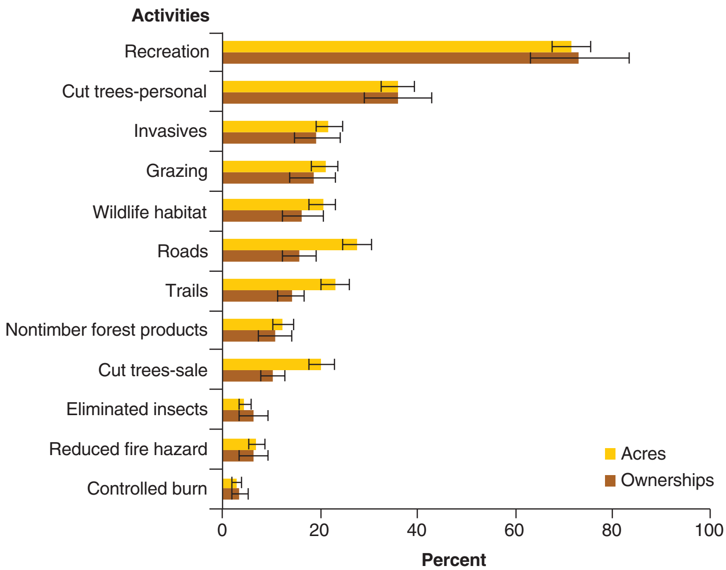


Figure 10.—Percentage of family forest ownerships and acres of forest land by activities in the past 5 years, West Virginia, 2013. Categories are not exclusive. Error bars represent 68 percent confidence intervals around the estimate.

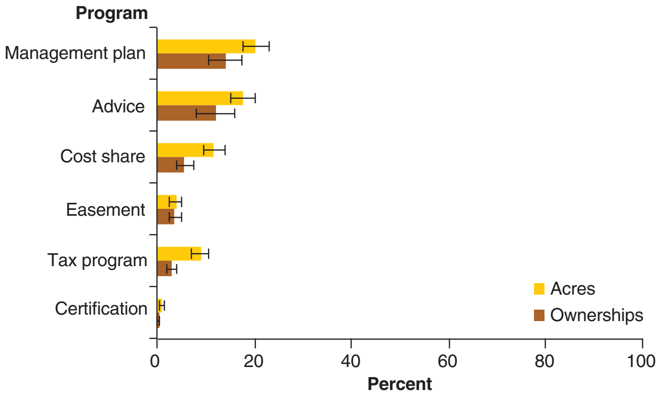


Figure 11.—Percentage of family forest ownerships and acres of forest land by participation in forest management programs, West Virginia, 2013. Categories are not exclusive. Error bars represent 68 percent confidence intervals around the estimate.

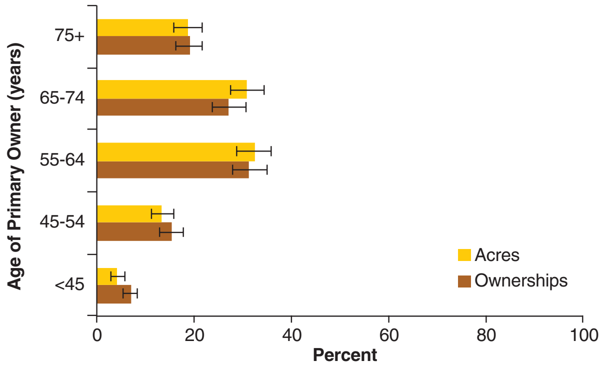


Figure 12.—Percentage of family forest ownerships and acres of forest land by age of primary owner, West Virginia, 2013. Error bars represent 68 percent confidence intervals around the estimate.

What this means

The fate of the forests lies primarily in the hands of those who own and control the land. It is therefore critical to understand forest owners and what policies and programs can help them conserve the forests for current and future generations. Looking particularly at family forest ownerships, the group that is the least understood and the fate whose land is arguably the most uncertain, they own their land primarily for amenity reasons, but many are actively doing things with their land. That being said, more than 85 percent of them do not have a management plan nor have they participated in most other traditional forest management planning or assistance programs. There are significant opportunities to help these owners increase their engagement and stewardship of their lands. Programs such Tools for Engaging Landowners Effectively (http://www.engaginglandowners.org) can help the conservation community develop and implement programs more effectively and efficiently. Another important trend to watch is the aging of the family forest owners. With many of them being relatively advanced in age, this portends many acres of land passing on to the next generation in the not too distant future. There are programs such as Your Land Your Legacy (http://masswoods.net/monthly-update/your-land-your-legacy-deciding-future-your-land) and Ties to the Land (http://tiestotheland.org) that can help owners meet their bequest goals, but it is uncertain who the future forest owners will be and what they will do with their land.

Land Use Change

Background

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

FIA characterizes the area of the State using several general land use categories: forest, agriculture (including pasture and cropland), developed land, rights-of-way, water, and other nonforest land. The conversion of forest land to other uses is referred to as gross forest loss, and the conversion of nonforest land to forest is known as gross forest gain. The magnitude of the difference between gross loss and gain is defined as net forest change. By comparing the land uses on current inventory plots with the land uses recorded for the same plots during the previous inventory, we can characterize forest land use change dynamics. Understanding land use change dynamics is essential for monitoring the sustainability of West Virginia's forest resources and helps land managers make informed policy decisions.

What we found

The dominant land use in West Virginia is forest land, which covers 78 percent of the State's area (Fig. 13). Agricultural uses cover 10 percent of the area and include pasture (5 percent), cropland (4 percent), and other agricultural land (1 percent). When rights-of-way are included in the developed land classification, this class accounts for 11 percent of West Virginia's area. Developed land is primarily concentrated in and around the largest cities in West Virginia including Charleston, Huntington, Parkersburg, and Morgantown.

Most of the FIA plots in West Virginia either remained forested or stayed in a nonforest use (77 percent and 20 percent, respectively), and only the remaining 3 percent of plots experienced either a forest loss or gain from 2008 to 2013 (Fig. 14).

According to the FIA remeasurement data, West Virginia lost 177,000 acres (1.5 percent) of forest land from 2008 to 2013 which was more than offset by a gain of approximately 289,000 acres (2.4 percent) during the same time period (Fig. 15). Thirty-four percent of forest gains come from former pasture and this proportion rises to over half when all agricultural land uses are included. The remaining 48 percent of gains in forest comes from developed land (19 percent), rights-of-way (26 percent), water (2 percent), and other nonforest land (1 percent). Most of the forest loss was a result of forest land converting to developed uses (30 percent) and rights-of-ways (39 percent). There was a greater proportion of forest gained from the conversion of agricultural uses than was lost to agricultural uses (Fig. 16).

FIA data can be used to characterize the forest land that has been lost and gained to see if it differs from forest land that remained forested. The forests of West Virginia are dominated by stands in the large diameter-size class (78 percent) with only 7 percent of forests in small diameter stands. However, the forest land that has been gained has a greater proportion of small diameter stands (27 percent) than in West Virginia as a whole.

Figure 17 shows the distribution of remeasured plots across West Virginia, highlighting plots on which 25 percent or more of the area has experienced a lost or gain in forest land. Forest loss appears to be more prevalent in the northern and southern regions of the State. There is very little forest loss in eastern West Virginia, which corresponds to the area containing the Monongahela National Forest.

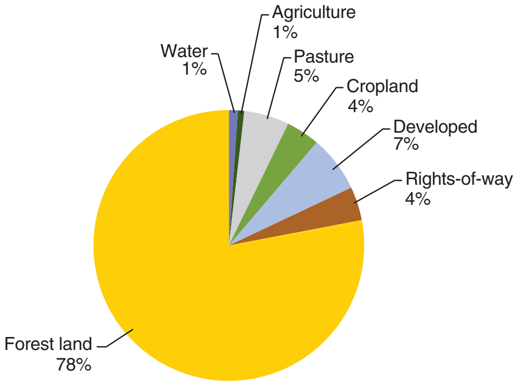


Figure 13.—Land use composition of remeasured FIA plots, West Virginia, 2013.

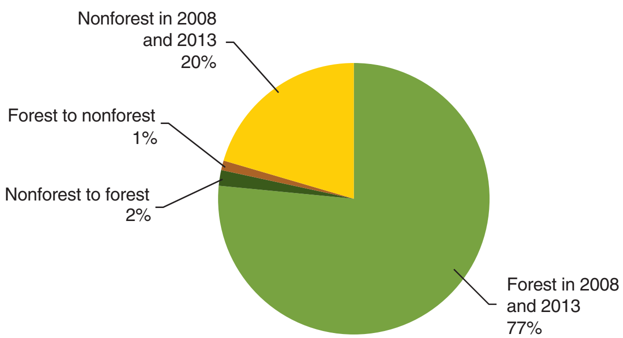


Figure 14.—Land use change, West Virginia, 2008 to 2013.

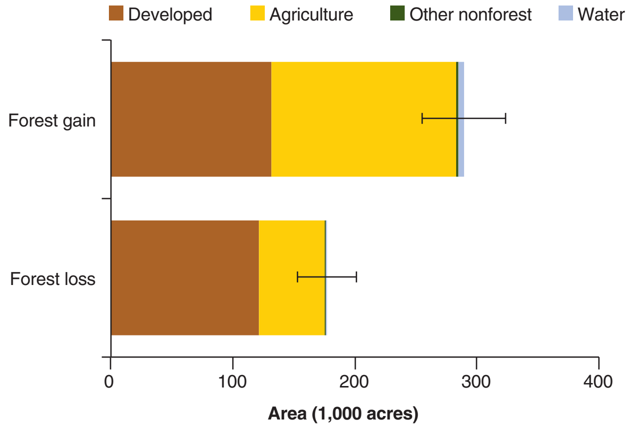


Figure 15.—Area of forest loss and forest gain by land use category, West Virginia, 2008 to 2013. Error bars represent 68 percent confidence intervals around the estimate.

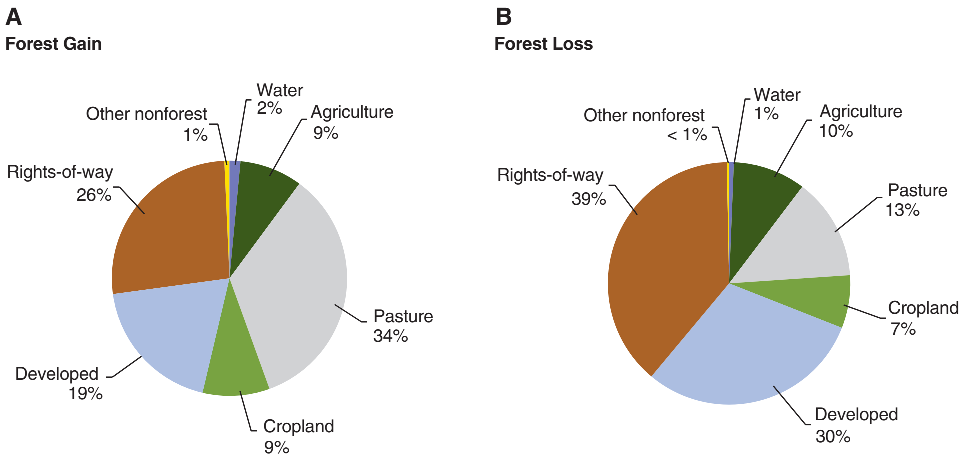


Figure 16.—Forest gain (A) from former land use, and forest loss (B) to current land use, West Virginia, 2008 to 2013.

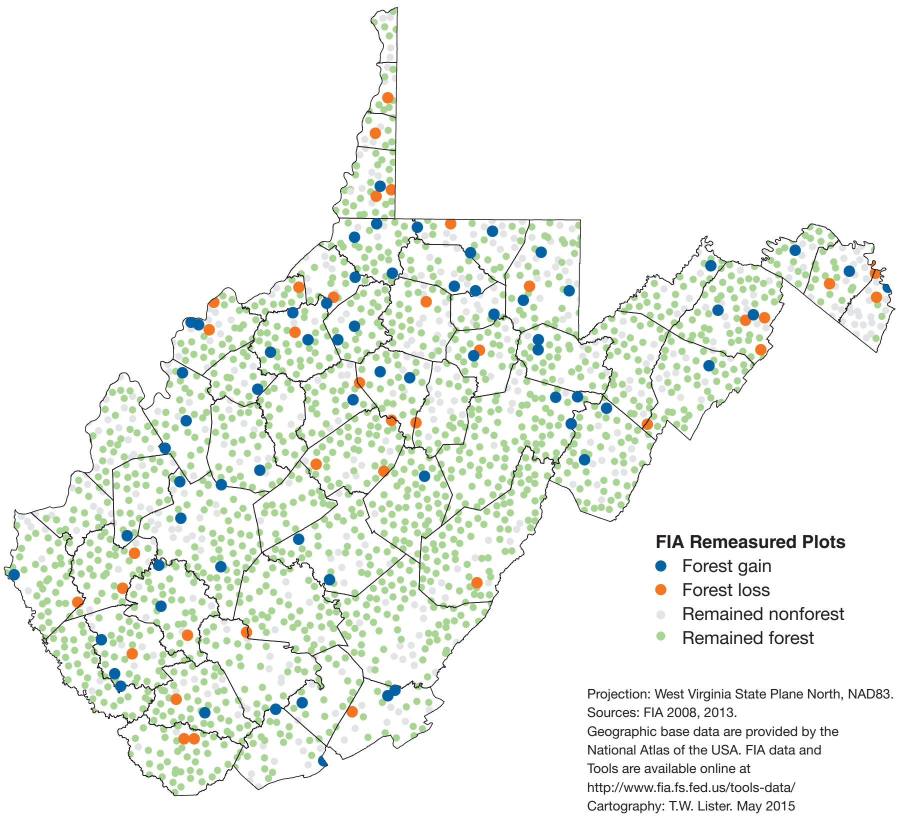


Figure 17.—Distribution of remeasured inventory plots showing forest gains and losses, West Virginia, 2008 to 2013. Plot locations are approximate.

What this means

Overall, there was a small net gain in forest land in West Virginia from 2008 to 2013, which suggests a continued conservation and valuation of the State's forest resources. Historic gains in forest land from the 1950s to the 1990s were likely due to the conversion of agricultural land to forest. Agricultural land still appears to be the greatest source of new forest land in the State as more than 50 percent of forest gains come from former agricultural land, most of which was pasture.

Some of the gains and losses of forest land in West Virginia may be from marginal forest land moving into and out of the forest land base. This movement between forest and nonforest classifications may be a result of land meeting or not meeting FIA's definition of forest land due to small changes in understory disturbance, forest extent, or forest cover. These fluctuations likely contribute to the losses from and gains in developed land and rights-of-way.

Permanent forest loss to development may also be occurring, especially near West Virginia's growing cities, including Morgantown and Martinsburg, where population has increased by 6.4 percent and 2.6 percent, respectively, over the past 3 years. Other potential causes of forest loss in West Virginia include the further development of surface mining and natural gas exploration and extraction due to an increased demand for domestic energy production. For the State as a whole, however, the area of forest lost is relatively small. Forest losses are being outpaced by gains in forest land due in part to the continued afforestation of former farm land and forest land conservation efforts.

Urbanization and Fragmentation of Forest Land

Background

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

Spatial landscape pattern metrics help quantify these different characteristics of fragmentation. Metric values are sensitive to the resolution of the land cover data source used (Moody and Woodcock 1995), similar to the way that animal species see the landscape very differently depending on the scale at which they operate—e.g., the same patch that supplies interior forest conditions for one species is viewed as an unsuitable fragment by another. Since important forest ecosystem processes operate at different scales, in this report we examine current levels of fragmentation at two scales. We have adapted a spatial integrity index (SII) developed by Kapos et al. (2002) for the global Forest Resources Assessment (FRA). The SII integrates three facets of fragmentation affecting some aspect of forest ecosystem functioning—patch size, local forest density, and patch connectivity to core forest areas—to create a single metric for comparison where a value of 1 indicates an area that is highly fragmented while a value of 10 is used for an area of highest forest spatial integrity. Since even acceptably low misclassification rates in the source land cover data can be magnified into substantial errors in metric values (Langford et al. 2006, Shao and Wu 2008), we have calculated spatial integrity at the two scales corresponding to two of the most reliable and widely available sources of data—the 30 m (98.4 feet) scale of the 2011 National Land Cover Dataset (NLCD 2011) (Homer et al. 2015), and the 250 m (820 feet) scale of the 2009 FIA forest cover dataset (Wilson et al. 2012). Both scales fall within the 10 to 1000 square km (2,471–247,091 acres) scale at which pattern process linkages are often of greatest management interest (Forman and Godron 1986).

In the SII calculation, core forest is defined by patch size and local forest density within a defined local neighborhood area. An unconnected forest fragment is defined by its patch size, local forest density, and distance to a core forest area. The spatial integrity of all other forest lands are scaled between the 'core' and 'unconnected fragment' ends. At the 250 m scale, a forested grid cell must be part of a forest patch that is greater than 1,544 acres (2.41 square miles) in size in order to be considered core forest, and all forest land with a patch size of less than 30 acres is considered an unconnected fragment. At the 30 m scale, forest patch size must be greater than 22 acres in order to be considered core forest, and forest land with a patch size of less than 2.5 acres is considered an unconnected fragment. The local forest density criterion is based on a circular area with a radius of 0.78 miles (1,222 acres) for the 250 m scale and on a circular area with a radius of 0.09 miles (16 acres) for the 30 m scale. Ninety percent of the respective neighborhoods must be classified as forest for a location (e.g., grid cell) to qualify as core forest (Table 1). These two scales capture a relatively broad range of definitions for core forest and spatial integrity that should encompass the scales appropriate for understanding impacts on a wide range of wildlife species and ecosystem processes affected by forest fragmentation.

Table 1.—Spatial integrity index (SII) parameters used in calcuations at each scale

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

The population of West Virginia increased by 2.2 percent between 2000 and 2010 (up to 1.85 million). During that same time period, the number of housing units increased by 4.8 percent (U.S. Census Bureau 2010). Stated another way, between 2000 and 2010 housing units increased at a pace 2.2 times the rate of increase in population, a trend not unique to West Virginia. This is a decrease from the period between 1990 and 2000, when the population only increased by 0.8 percent, but the number of housing units increased by 7.7 percent (9.6 times the rate of increase in population). In recent decades across the United States, this housing growth has occurred not only in increasing suburban rings around urban areas but also in rural areas. Lepczyk et al. (2007), Theobald (2005), and Hammer et al. (2004) observed that among the areas facing rapid increases in housing density now and predicted into the future are amenity-rich rural areas around lakes and other forested recreation areas. The 17 percent increase in the number of reported second homes from 2000 to 2010 could be a partial reflection of this trend in West Virginia (U.S. Census Bureau 2010). This can put additional pressure on forested areas even above the general increases in population.

What SII identifies as core does not represent completely intact forest conditions because it is calculated from forest canopy and does not consider underlying house densities or proximity to roads. Using the definition of wildland-urban interface (WUI) intermix from Radeloff et al. (2005) (greater than 15.5 houses per square mile [6 per square km]), we identified how much forest, particularly core or intact forest land, coincided with these areas. The WUI is described as the zone where human development meets or intermingles with undeveloped wildland vegetation. It is associated with a variety of human-environment conflicts. Radeloff et al. (2005) have defined this area in terms of the density of houses (WUI "intermix" areas), the proximity to developed areas (WUI "interface" areas), and percentage of vegetation cover. We used WUI intermix maps intersected with forest land in NLCD 2011 (Homer et al. 2015) to examine changes in the amount of forest land co-occurring with WUI house densities.

Roads are another important urbanization impact affecting forest lands that is not completely captured by either of the previous two indices. In West Virginia, 42 percent of the forest land was within 650 feet of a road of some sort, and 69 percent was within 1,310 feet (calculated from NLCD 2006 forest [Fry et al. 2011] and U.S. Census Bureau [2000] roads). Roads have a variety of effects: direct hydrological, chemical, and sediment effects; serving as vectors for invasive species; facilitating human access and use; increasing habitat fragmentation; and wildlife mortality. Actual impacts will vary depending on road width, use, construction, level of maintenance, and hydrologic and wildlife accommodations (e.g., Charry and McCollough 2007, Forman et al. 2003). Generally, when more than 60 percent of the total land area in a region is within 1,310 feet of a road, cumulative ecological impacts from roads should be an important consideration (Riitters and Wickham 2003).

What we found

Considering SII classes at the 250 m scale, with 1,544 acres or greater considered core forest, 81 percent of the forest land in West Virginia is core forest, 17 percent has high integrity, 1 percent has medium integrity, 0 percent has low spatial integrity, and 1 percent of the forest is in unconnected fragments. At the 30 m scale, with 22 acres or greater considered core forest, 82 percent of the forest land in West Virginia is core forest, 15 percent has high spatial integrity, 2 percent has medium integrity, and 1 percent of the forest is in unconnected fragments. Table 2 shows a breakdown of SII values by FIA unit for both scales.

Table 2.—Breakdown of SII values by FIA unit for 30 m and 250 m spatial integrity classes. See Figure 18 for boundaries of FIA units.

Unit	Fragment	Low	Medium	High	Core	Fragment	Low	Medium	High	Core
Northeastern	1	0	2	13	84	1	0	1	19	78
Southern	1	0	2	14	83	0	0	1	12	87
Northwestern	1	0	2	18	78	0	0	2	20	77
State	1	0	2	15	82	1	0	1	17	81
State, after incorportating WUI areas	1	0	2	31	65	1	0	2	32	64

Forest connectivity is very high across West Virginia when examined at either the 250 m scale (Fig. 18) or the 30 m scale. At the 30 m scale, the lower threshold of 22 acres for defining core forest means that more forest patches are considered core than at the 250 m scale in the Northeastern Unit, which is a typical situation in many areas. However in the Southern Unit, there are fewer areas considered to be core at the 30 m scale than at the 250 m scale. This latter situation is relatively unique to West Virginia, and occurs in areas where there is predominately fine-scale fragmentation in a generally forested landscape. Figure 19 compares the SII classes between the two scales for part of the Northeastern Unit including Clarksburg (in the Northeastern Unit), and provides examples of both types of fragmentation. It is important to note that for the above calculations the forest landscape data used are depicting tree cover only and do not incorporate the presence of development that might be associated with or underlying this tree cover.

Forest land with sufficient underlying housing density to qualify as WUI areas has been steadily increasing in many areas of the Nation, including West Virginia. In 1990, 22 percent of the forest land in West Virginia was in low and medium density WUI. In 2000 this increased to 25 percent of the forest land, and in 2010 it remained 25 percent. The spatial distribution of forested WUI is depicted in Fig. 20. Two of the three FIA units have close to 30 percent of forest in WUI (Table 3). These underlying housing densities are poorly captured by the tree canopy cover data used in the calculation of spatial integrity above. When we integrate SII results with WUI areas, 17 percent of West Virginia's forest

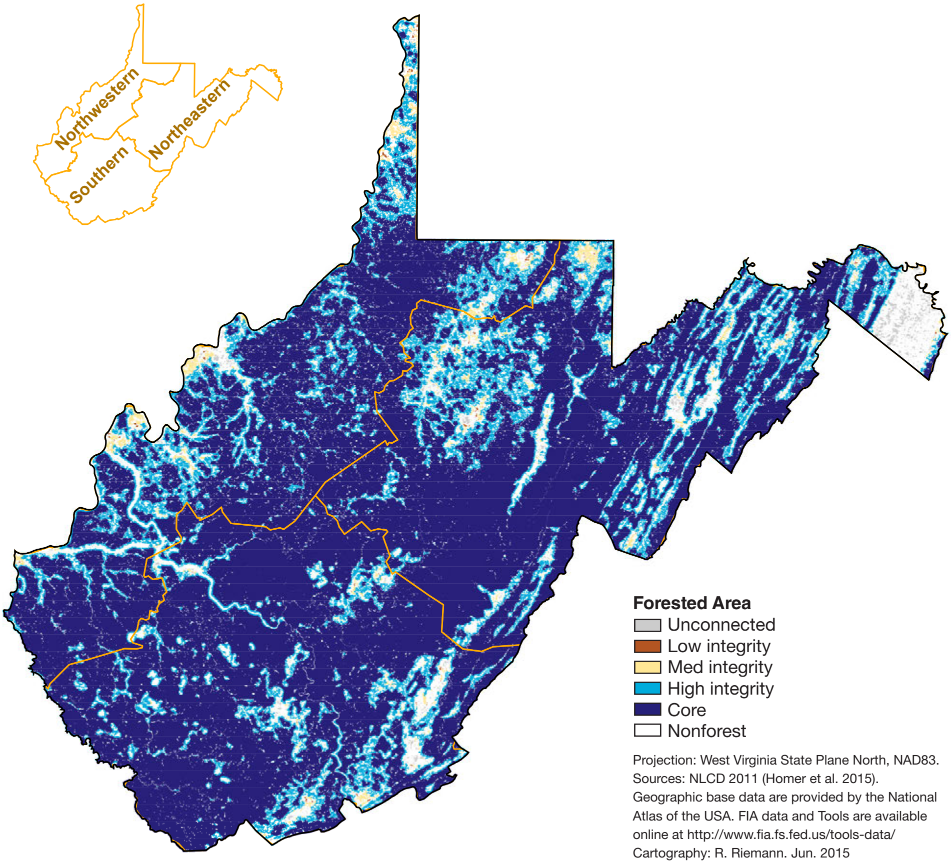


Figure 18.—Spatial integrity index (SII) of forest land at the 250 m scale, West Virginia, 2011.

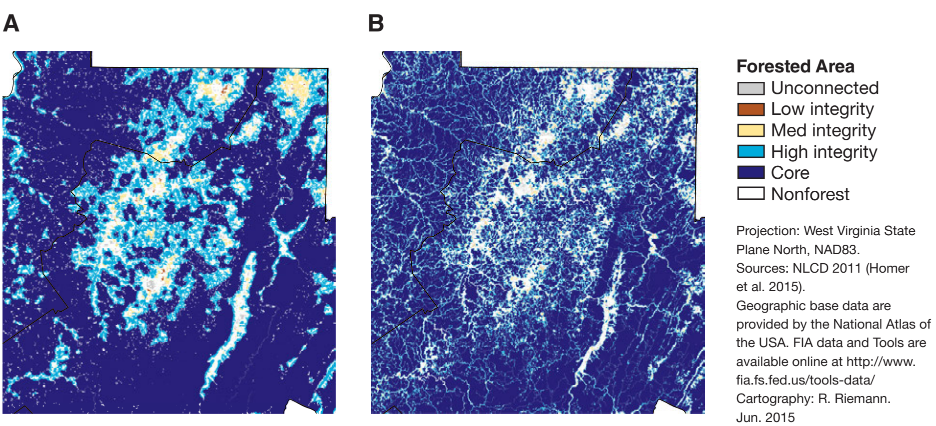


Figure 19.—Spatial integrity index (SII) of forest land at the 250 m scale (A), and 30 m scale (B) in the area around Clarksburg, West Virginia, 2011.

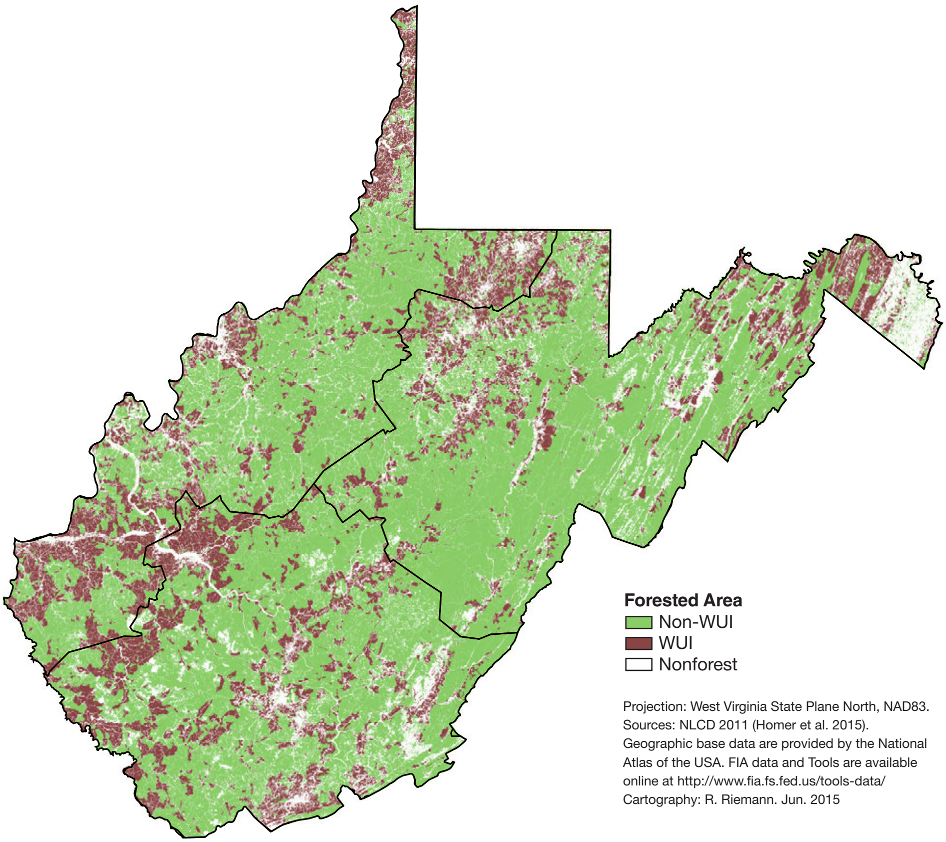


Figure 20.—Wildland-urban interface (WUI) of West Virginia.

Table 3.—The distribution of forest land with respect to several urbanization and fragmentation factors, expressed as a percentage of the forest land in each FIA unit, West Virginia. See Figure 18 for boundaries of FIA units.

FIA Unit	% of Area in forest[a]	% of Forest land in WUI[b]	% of Forest land <650 feet from road[c]
Northeastern	81	19	40
Southern	82	27	39
Northwestern	80	30	47
State	81	25	42
State total	34	10	25

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

[b] Approximating the forest land potentially affected by underlying or nearby development (U.S. Census Bureau 2010).

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

land moves from being core forest to lower spatial integrity classes, decreasing the proportion of forest land in the core class from 81 percent to 64 percent at the 250 m scale, and by almost identical numbers at the 30 m scale. In Fig. 21 it is evident how substantially WUI house densities affect many areas that would otherwise be core forest.

Roads remain pervasive in the landscape, existing even in areas that appear to be continuous forest land from the air. In 2000, 39 percent of the forest area in the Southern Unit is within 650 feet of a road, and 47 percent of the forest land in the Northwestern Unit is within 650 feet of a road (Fig. 22). Often, this area coincides with WUI areas of housing development. It is also worth noting that the roads included in the U.S. Census Bureau (U.S. Census Bureau 2000) data (TIGER files) do not include many minor roads that are not associated with housing development. If the analysis would include these minor roads, the road densities double, similar to what exists in areas like northern Wisconsin (Hawbaker and Radeloff 2004).

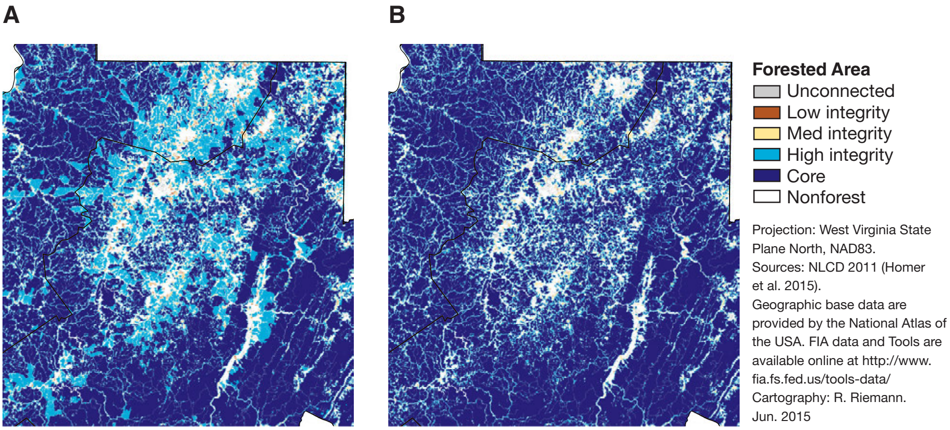


Figure 21.—Spatial integrity index (SII) of forest land at the 30 m scale with (A) and without (B) incorporating WUI status, in the area around Clarksburg, West Virginia.

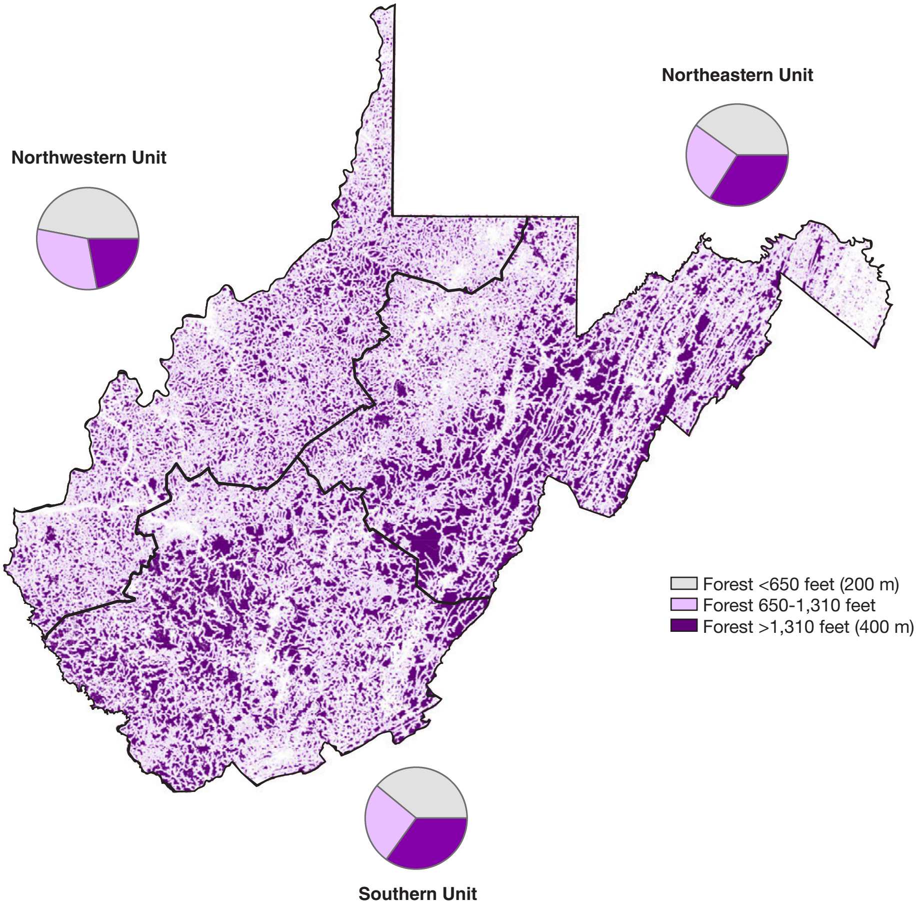


Figure 22.—Distance to the nearest road of forest land, West Virginia, 2000. Pie charts display the proportion of forest area in each distance class by FIA unit.

What it means

Whether we consider the 250 m or the 30 m scales, if we incorporate the WUI areas into our definition of spatial integrity, about 65 percent of the forest land in West Virginia meets the definition of core forest, and almost all of the remaining areas of forest have high spatial integrity. Roads are pervasive throughout the area and are over the threshold at which cumulative ecological impacts from roads can begin to occur.

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

Urbanization increases the proximity of people, development, and other anthropogenic pressures to natural habitats. Both urbanization and forest fragmentation change the way in which humans use forest land, frequently decreasing the likelihood that it will be managed for forest products and increasing its use for outdoor recreation, although urbanization has also been observed to increase the incidence of "posting" forested land, which decreases outdoor recreation opportunities and alters local cultural use of forest (Butler 2008, Kline et al. 2004, Wear et al. 1999). Continuing fragmentation, parcelization, and urbanization can be barriers to stewardship if the result is forest tracts that are too small or too isolated for effective management (Tavernia et al 2016).

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

West Virginia retains large areas of core forest cover, however increasing urbanization of forest land in the form of WUI areas and roads may begin to affect how forests function. Such fragmentation and urbanization can diminish the benefits and services forests provide and make forest management more difficult. If West Virginia's population continues to expand into rural areas, fragmentation of forest land could become a concern to land managers. Planning can be used to limit development incursions into core forest areas. In addition, the characteristics and maintenance of roads and development can also play a role in their actual impact on the resilience of forest land and its ability to continue to supply the forest products and ecosystem services we expect and need.

Stand Size and Structure

Background

Tree diameter measurements are used by FIA to assign one of three stand-size classes to sampled stands to give a general indication of stand development. The categories are determined by the size class that accounts for the most stocking of live trees per acre. Small diameter stands are dominated by trees less than 5 inches in d.b.h. Medium diameter stands have a majority of trees at least 5 inches d.b.h. but less than the large diameter stands. Large diameter stands consist of a preponderance of trees at least 9 inches d.b.h. for softwoods and 11 inches for hardwoods.

Stocking is a measure of relationship between the growth potential of a site and the occupancy of the land by trees. The relative density (or stocking) of a forest is important for understanding growth, mortality, and yield. Five classes of stocking are reported by FIA: nonstocked (0-9 percent), poor (10-34 percent), moderate (35-59 percent), full (60-100 percent), and overstocked (>100 percent). Stocking levels are examined using all live trees and growing-stock trees only to identify the amount of growing space that is being used to grow trees of commercial value as opposed to the amount that is occupied by trees of little to no commercial value. For a tree to qualify as growing stock, it must be a commercial species and not contain large amounts of cull (rough and rotten/missing wood). The growth potential of a stand is considered to be reached when it is fully stocked. As stands become overstocked, trees become crowded, growth rates decline, and mortality rates increase. Poorly stocked stands can result from harvesting practices or forest growth on abandoned agricultural land; in contrast to moderately stocked stands, poorly stocked stands are not expected to grow into a fully stocked condition within a practical amount of time for timber production.

What we found

West Virginia has a growing and maturing forest. The distribution of forest land by stand-size class continues to trend toward larger diameter stands in the State. A significant decrease in area of medium diameter stands and a significant increase in area of large diameter stands have occurred since 2000 (Fig. 23). The trend of increasing areas of large diameter stands is even more pronounced when current timberland estimates are compared with those from the 1949 inventory (Wray 1952). Timberland area in large diameter stands now makes up nearly 80 percent of timberland area (Fig. 24).

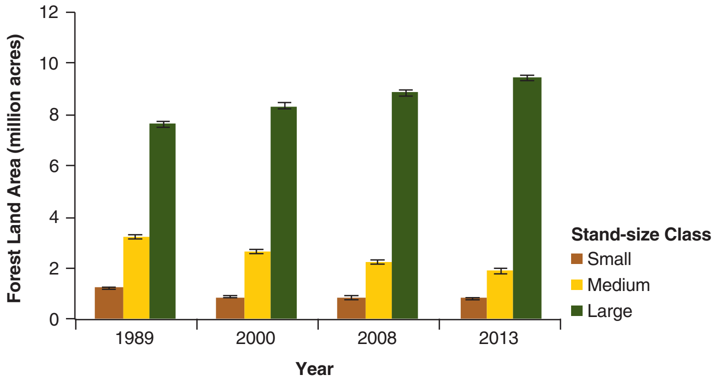


Figure 23.—Area of forest land by stand-size class by inventory year, West Virginia. Error bars represent 68 percent confidence intervals around the estimate.

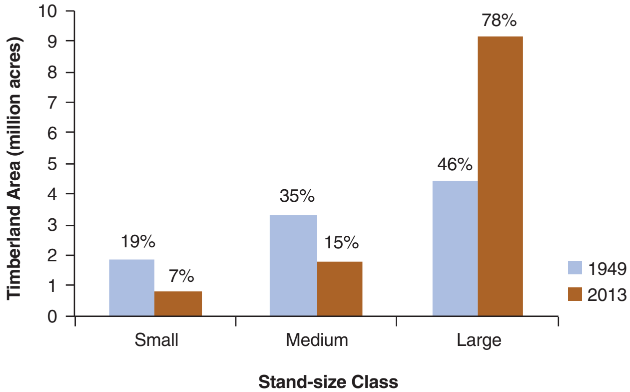


Figure 24.—Area of timberland by stand-size class, West Virginia, 1949 and 2013. Percentage of area in each inventory is shown above the bars.

Since 2000, timberland area in the poorly and moderately stocked classes for all live trees and growing-stock trees has increased while fully stocked area has decreased (Figs. 25, 26). In 2013, only 38 percent of stands are fully stocked or overstocked with growing-stock trees, which is an 8 percent decrease since 2000. Comparing nonstocked and poorly stocked stands for live versus growing-stock trees in 2013 reveals that the growing-stock area is 1 million acres greater than live tree area (2.2 million to 1.2 million acres) (Figs. 25, 26). This indicates that West Virginia has more than 2 million acres of timberland that are poorly stocked or nonstocked with growing-stock trees (Fig. 26) but nearly half of those acres are moderately, fully, or overstocked when noncommercial species and cull trees are included. Nearly 21 percent of poorly or nonstocked timberland acres are less than 40 years old and 82 percent are less than 80 years old (Fig. 27). The distribution of age classes is explored further in a subsequent section on forest habitats.

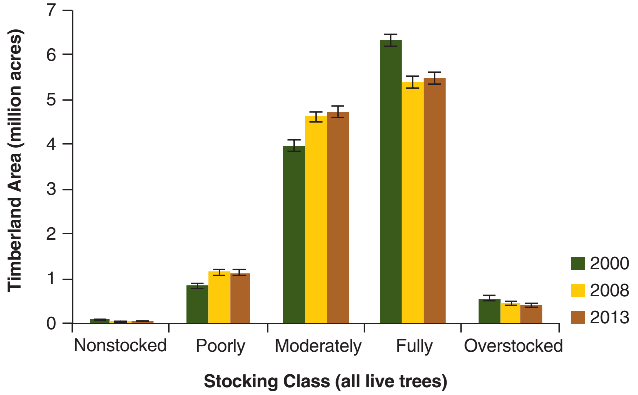


Figure 25.—Area of timberland by stocking class of all live trees by inventory year, West Virginia. Error bars represent 68 percent confidence intervals around the estimate.

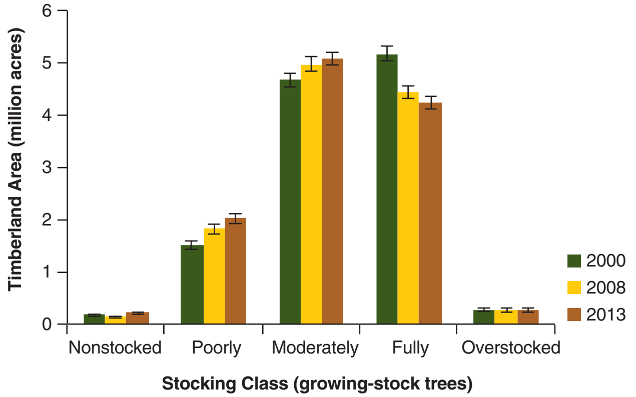


Figure 26.—Area of timberland by stocking class of growing-stock trees and inventory year, West Virginia. Error bars represent 68 percent confidence intervals around the estimate.

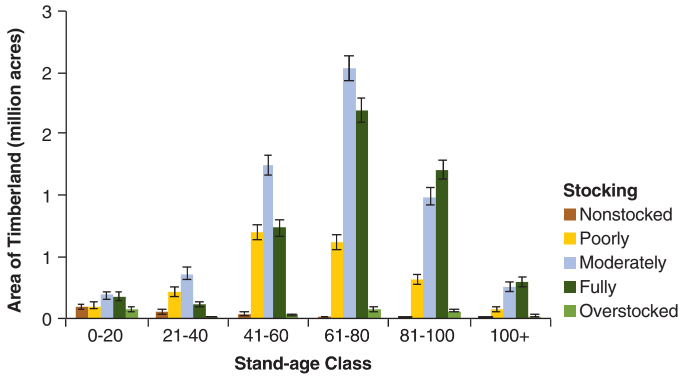


Figure 27.—Area of timberland by stocking class of growing-stock trees and stand-age class, West Virginia, 2013. Error bars represent 68 percent confidence intervals around the estimate.

What this means

The trend of increasing forest land area in large diameter stands demonstrates the continuing maturation of West Virginia's forests to stands of larger, older trees. An important component of forest biodiversity is complex structural features. Although the area of forest in smaller diameter stands is decreasing, mature stands do provide diverse structures due to gap dynamics and the presence of shade tolerant species in the understory. The diversity of tree ages and sizes present in mature forests provides a broad range of habitats for wildlife and other organisms and makes forests more dynamic and better able to recover from disturbance.

The shifts in timberland area out of fully stocked stands into poor (56 percent) and moderately stocked (44 percent) stands since 2000 may indicate that forest harvesting practices over the past decade may have changed the general stocking condition across West Virginia. Only 38 percent of timberland is well stocked with tree species of commercial importance. From a commercial perspective, management practices to increase stocking of growing-stock species may be needed in poorly stocked stands. Although the 1 million acres of timberland that is poorly or nonstocked with commercially important species represents a loss of potential growth, these forests do contribute to biodiversity. However, the higher light levels and open growing conditions in these poorly or nonstocked stands may make them more susceptible to invasion by nonnative plant species (e.g., common barberry [*Berberis vulgaris*], multiflora rose [*Rosa multiflora*]).

Numbers of Trees

Background

A basic component of forest inventory is the number of trees; these estimates are simple, reliable, and comparable with estimates from past inventories. When combined with species and size, estimates of numbers of trees are valuable for showing the structure of forests and changes that are occurring over time. Young forests generally have many more trees per acre than older forests, but the latter usually have much more wood volume (or biomass) than younger forests.

What we found

Since 1997, the number of trees in the 10-inch and smaller d.b.h. classes has decreased while the number of trees in the larger classes increased (Fig. 28). In general, the percentage increase in the number of trees by diameter class increased with diameter class up to the 18-inch class (Fig. 29).

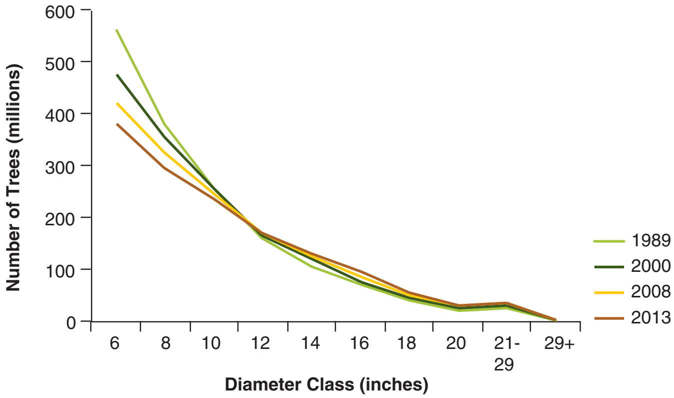


Figure 28.—Number of growing-stock trees on timberland by diameter class and inventory year, West Virginia. Value shown on x axis represents the midpoint of the 2-inch diameter class, i.e., 6 inches refers to trees with diameters of 5 to 6.9 inches.

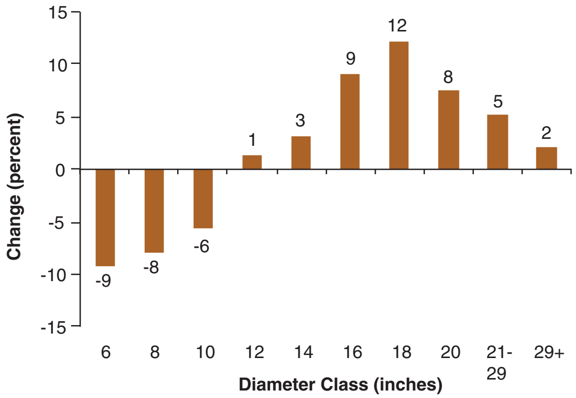


Figure 29.—Percentage change in numbers of growing-stock trees by diameter class, West Virginia, 2008 to 2013.

When we look at growing-stock trees, red maple, sugar maple, and yellow-poplar continue to be the most numerous tree species in West Virginia. Many species decreased slightly in overall numbers between 2008 and 2013—chestnut oak, red maple, northern red oak, black cherry, American beech, and hickory. White oak and black/scarlet oak showed larger decreases in growing-stock numbers at 8 and 5 percent, respectively. By contrast, yellow-poplar and sugar maple increased slightly in numbers of growing-stock trees (Fig. 30).

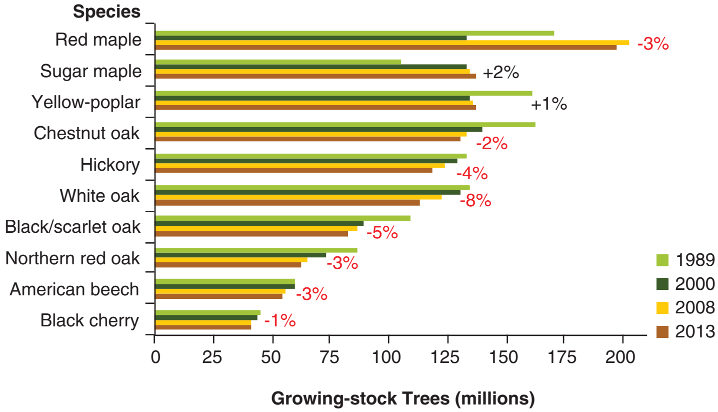
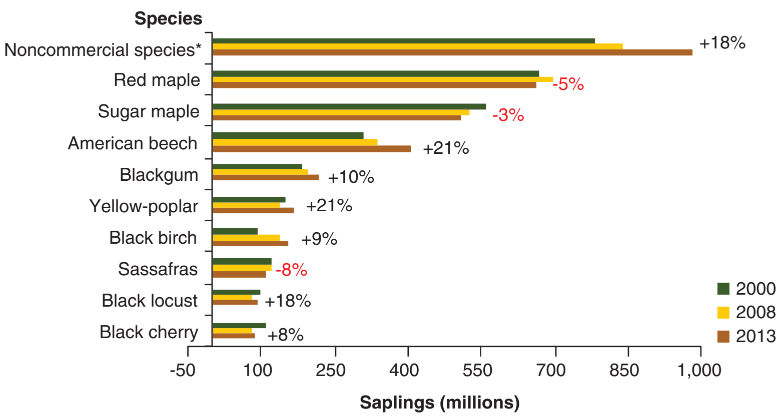


Figure 30.—Number of growing-stock trees on timberland by species and inventory year, West Virginia. Percentage change between 2008 and 2013 is shown to the right of the bars.

Noncommercial species continue to be the most abundant sapling-size trees (d.b.h. of 1 to 4.9 inches) when grouped together, and they increased in numbers by 18 percent between 2008 and 2013. Red maple is the most abundant individual species in West Virginia; it showed a 5 percent decrease in number of saplings during that period. The largest proportional increase in number of saplings are American beech and yellow-poplar (21 percent). Other important species that increased in number are blackgum, black birch, black locust, and black cherry. Species for which number of saplings decreased are red maple, sugar maple, and sassafras (Fig. 31).



*Includes striped maple, eastern hophornbeam, pin cherry, and other species with poor form.

Figure 31.—Number of saplings (1 to 4.9 inches d.b.h.) on timberland by species and inventory year, West Virginia. Percentage change between 2008 and 2013 is shown to the right of the bars.

What this means

Since 1989, the number of large diameter trees has been increasing steadily in West Virginia. More recently, the number of trees in the 6- through 10-inch d.b.h. classes has been decreasing, indicating that as trees grow into larger size classes they are not being replaced by smaller trees growing into the medium diameter classes (Fig. 32).

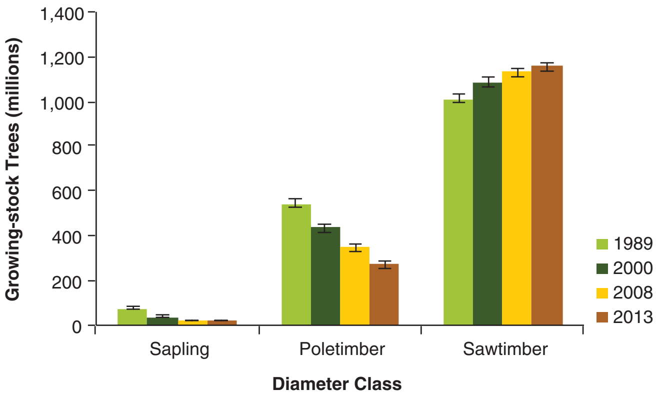


Figure 32.—Number of growing-stock trees on timberland by size class and inventory year, West Virginia. Error bars represent 68 percent confidence intervals around the estimate.

Saplings in today's forest are a prime indicator of the composition of the future forest. Saplings eventually replace large trees that are harvested or killed by insects, diseases, or weather events. The dominance of red and sugar maple, increasing dominance of American beech and yellow-poplar, and lack of oak saplings will have an impact on the future species composition of West Virginia's forests. Additionally, the relatively high sapling abundance of noncommercial species may be a concern for timber management. Projections of future compositional changes are complicated by the potential impacts of climate change on the distributions of different tree species.

Carbon Stocks

Background

Forests sequester carbon from the atmospheric greenhouse gas carbon dioxide, which is linked to global climate change. Consequently, carbon has increasingly become a part of forest resource reporting in recent years. Among terrestrial ecosystems, forests contain the largest reserves of sequestered carbon. Regional and national greenhouse gas reporting forums include forest carbon stocks because increases in these stocks represent quantifiable partial offsets to other greenhouse gas emissions. For example, carbon sequestration by U.S. forests represented an offset of over 11 percent of total U.S. greenhouse gas emissions in 2013 (US EPA 2015) and the continuing increase in West Virginia forest carbon stocks contributes to this effect.

Carbon accumulates in growing trees via the photosynthetically-driven production of structural and energy containing organic (carbon) compounds that primarily accumulate in trees as wood. Over time, this stored carbon also accumulates as dead trees, woody debris, litter, and organic matter in forest soils. For most forests, the understory grasses, forbs, and nonvascular plants as well as animals represent minor pools of carbon stocks. Within soils, the larger woody roots are readily distinguished from the bulk of soil organic carbon so the roots are generally reported as the belowground portion of trees and not included in the soils estimates. Carbon loss from a forest stand can include mechanisms such as respiration (including live trees and decomposers), combustion, runoff or leaching of dissolved or particulate organic particles, or direct removal, such as the harvest and utilization of wood. From the greenhouse gas reporting perspective, it is important to note that not all losses result in release of carbon dioxide to the atmosphere; some wood products represent continued long-term carbon sequestration.

The carbon pools discussed here include living plant biomass (live trees ≥1-inch d.b.h. and understory vegetation), dead wood and litter (standing dead trees, down dead wood, and forest floor litter—i.e., nonliving plant material), and soil organic matter exclusive of coarse roots and estimated to a depth of 1 meter. Carbon estimates, by ecosystem pool, are based on sampling and modeling; for additional information on current approaches to determining forest carbon stocks see US EPA (2015), U.S. Forest Service (2014), and O'Connell et al. (2014). The level of information available for making the carbon estimates varies among pools. For example, the greatest confidence is in the estimate of live tree carbon due to the level of sampling and availability of allometric relationships applied to the tree data. Limited data and high variability associate lower confidence in the soil organic carbon estimates and for this reason interpretation of these estimates is limited. Ongoing research is aimed at improving the estimates (US EPA 2015). The carbon estimates provided here are consistent with the methods used to develop the forest carbon reported in the U.S. Environmental Protection Agency's Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2013 (published in 2015). However, the 2013 inventory summarized here includes some newer data relative to the West Virginia forest contribution to US EPA (2015).

What we found

Carbon stocks in West Virginia forests are estimated at 913 million tons carbon, a 4 percent increase since 2008. Live trees and soil organic carbon account for 90 percent of forest carbon stocks and 33 percent of carbon is in the wood and bark of the bole of trees at least 5 inches d.b.h. (Fig. 33). There is greater accumulation of carbon in the aboveground biomass of trees, and carbon stocks increase with stand age (Fig. 34). Eighty-eight percent of total aboveground carbon stocks are represented by the three age classes spanning stand ages of 41 to 100 years (i.e., tons per acre from Fig. 34 multiplied by total acres); in contrast, the youngest and oldest age classes together account for 8 percent of total forest carbon stocks.

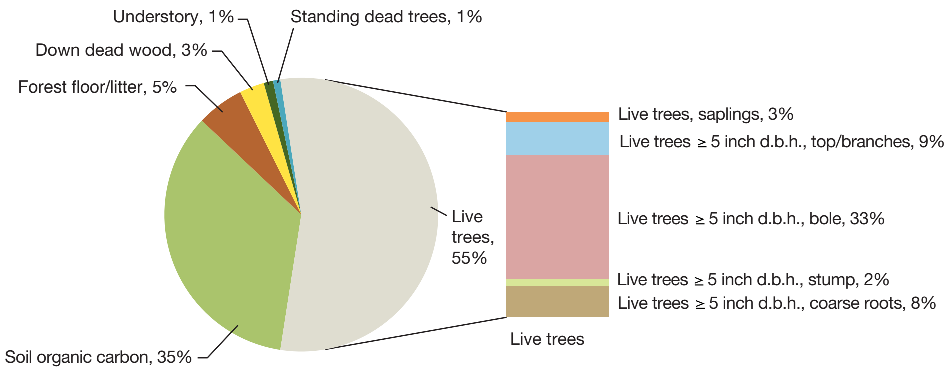


Figure 33.—Estimated carbon stocks on forest land by forest ecosystem component, West Virginia, 2013.

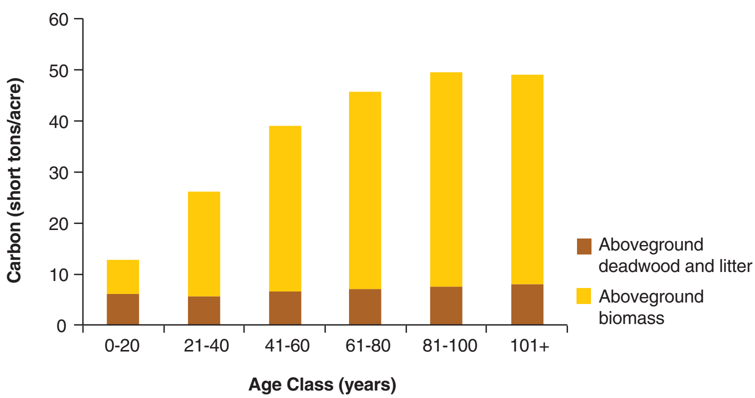


Figure 34.—Aboveground live and nonliving carbon stocks per acre by stand-age classes, West Virginia, 2013.

Species composition can affect carbon stocks. Seventy-two percent of total forest carbon stocks are in the oak/hickory forest-type group with the largest single pool as aboveground biomass within the oak/hickory forest-type group—388 million tons carbon or about 42 percent of all West Virginia forest carbon stocks.

Figure 35 illustrates the carbon density component of total stock with average tons of carbon per acre available from the common West Virginia forest-type groups. Carbon per acre is further classified into biomass (live trees and understory), dead wood (standing dead trees and down dead wood), litter, and soil. Note that the variability among forest-type groups is most closely associated with variability in biomass (which is essentially live trees, see Fig. 23).

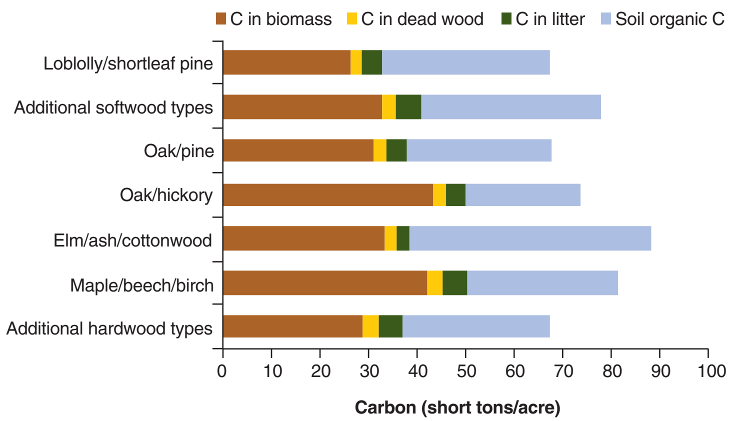


Figure 35.—Average carbon stock per acre by forest-type group and component, West Virginia, 2013. The less common forest-type groups are pooled as additional softwood or hardwood types.

Actual stocks for a particular stand will depend on a combination of influences—site history, management, stand age, or component species for example—so that individual sites can vary about the summaries provided in Figures 33, 34, or 35. As an example, the statewide average carbon per acre for live trees is 51 (tons carbon per acre) for stands that are identified as fully stocked, but the site-to-site variability is such that 50 percent of measured plots fell between 42 and 62 tons carbon per acre with greater carbon per acre in the top 25 percent and lower levels in the remaining 25 percent.

The current carbon estimation methods and data were also applied to the 2008 West Virginia forest inventory (data not shown) to produce summaries consistent with those provided here for the 2013 inventory. Overall forest carbon per acre increased by 2.1 percent relative to 5 years ago, and live tree carbon values increased by 3.0 percent. In addition, total forest area increased over the same period so that total carbon stocks in 2013 are 3.9 percent greater than the equivalent values calculated for 2008.

What this means

Forest carbon stocks or differences in stocks broadly reflect other measures of forest resources such as stand age, volume, or stocking. However, these summaries are useful in order to have some reference measure of carbon stocks for the State relative to published regional or national forest carbon reports and to provide a ready estimate of the role of West Virginia forests. In brief, the carbon summaries show: 1) most of the carbon is in live trees (closely followed by soils); 2) most carbon is in stands of 40 to 100 years; 3) specific stand-level carbon varies by forest-type group; and 4) overall forest carbon in West Virginia has increased over the past 5 years.

Biomass

Background

Tree biomass is a measure of how much carbon is being stored in trees on forest land. The increasing interest in carbon dynamics for questions related to carbon sequestration, emission reduction targets, production of biofuels, and forest fire fuel loadings makes biomass estimates a critical component of the FIA program. Because of increases in tree volume, West Virginia's forests contribute significantly to carbon sequestration. Aboveground biomass is defined by FIA as the weight of live trees composed of the boles, aboveground portion of stumps, tops, and limbs (but excluding foliage).

What we found

The forest land of West Virginia has an estimated 823.8 million dry tons of aboveground tree biomass with an average biomass of 67.6 tons per acre. Biomass density (tons per acre) is highest in the Allegheny Mountain region of the State; the statewide distribution of biomass per acre on forest land is displayed in Figure 36.

Sixty-eight percent of the aboveground biomass is in the boles of growing-stock trees; this is also the part of the tree resource that can be converted into valuable wood products. The other 32 percent of the biomass is in tops, limbs, stumps, cull trees, or trees of noncommercial species (Fig. 37).

On timberland, biomass has increased by 26 percent since 1989 (589.2 to 793.6 million dry tons). This increase is primarily due to the increasing size of sawtimber trees in West Virginia. By contrast, biomass decreased in sapling- and poletimber-size trees during this period (Fig. 38).

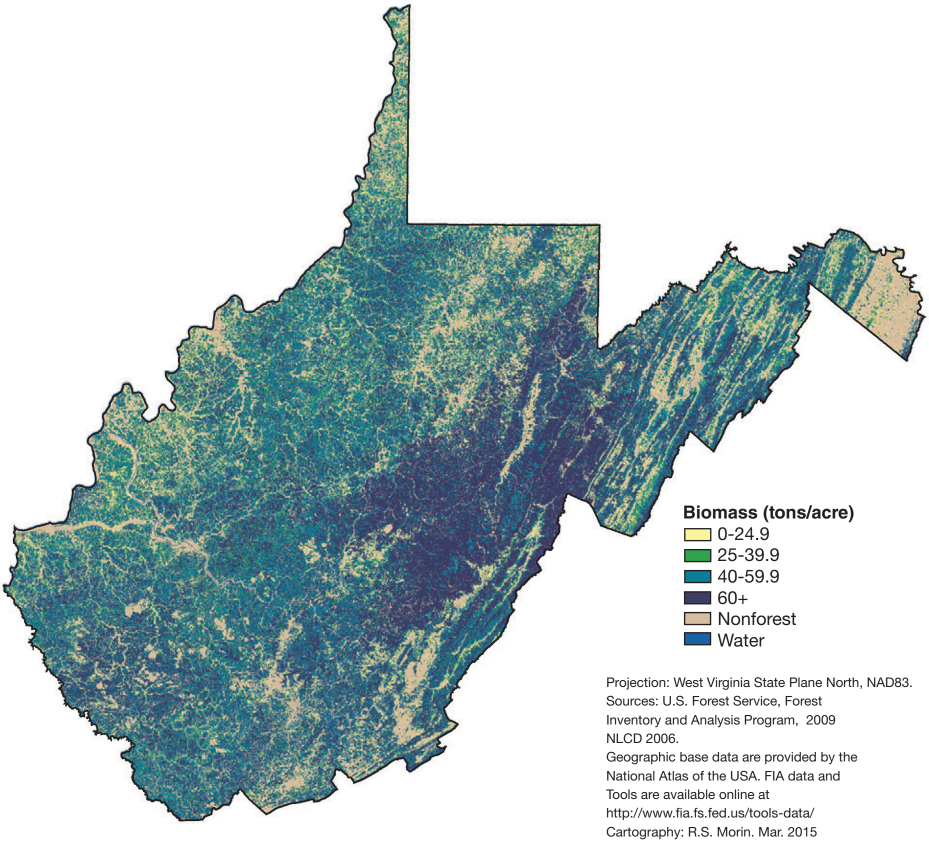


Figure 36.—Live tree biomass density of trees at least 1 inch d.b.h., West Virginia, 2009.

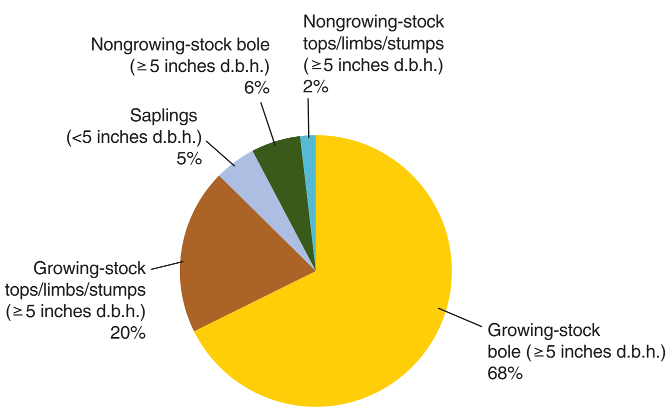


Figure 37.—Proportion of live-tree biomass (trees 1 inch d.b.h. and larger) on forest land by aboveground component, West Virginia, 2013.

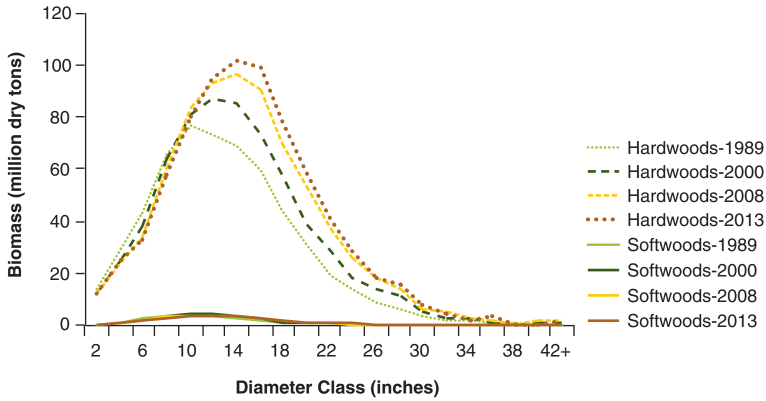


Figure 38.—Distribution of live-tree biomass (trees at least 1 inch d.b.h.) on timberland by species group, diameter class, and inventory year, West Virginia.

What this means

West Virginia's forests are continuing to accumulate biomass as the forests mature. Because most of the biomass is contained in the boles of growing-stock trees, and most of the gains in biomass stocks are found in these higher value sawtimber-size trees, only a fraction of the accumulated material is available for use as whole tree chips for large wood fuel users. If the demand for biomass increases with increases in heating, power production, and (potentially) the production of liquid fuels, the wood-using market would become more competitive. This creates an opportunity for enhancing forest management practices to benefit both traditional forest products supplies and those for bioenergy.

Private forest landowners hold 84 percent of West Virginia's biomass, thus they play an important role in sustaining this resource. Currently, forest landowners are not financially compensated for the carbon sequestration service by the trees on their land but this scenario could change in the future if markets for forest carbon sequestration continue to grow. If carbon trading and biomass production become more common, reliable estimates of biomass and carbon in forests, both in the aboveground biomass and in soils, will become more important. The future of this scenario depends on political decisions and prices for energy producing fuels including crude oil and natural gas.

Volume of Growing-stock Trees

Background

To assess the amount of wood potentially available for commercial products, FIA estimates growing-stock volumes for trees that meet requirements for size, straightness, soundness, and species, that are growing on timberland. Growing-stock volume includes only trees at least 5 inches d.b.h. and does not include rough, rotten, and dead trees, or noncommercial tree species. The forest products industry relies on growing-stock volume as its resource base. Current volumes and volume changes over time can reveal important resource trends in forests. This is especially important with respect to trend information because many past FIA inventories provided only growing-stock estimates.

What we found

The growing-stock volume in West Virginia has increased steadily since 1949. The 2013 estimate of 25.4 billion cubic feet is an increase since the 2000 inventory (Fig. 39). Distributions of growing-stock volumes by diameter class from the current and three previous inventories reveal a steady shift toward larger diameter trees (Fig. 40). Volume increased in all d.b.h. classes greater than 10 inches, but decreased in the 6-, 8-, and 10-inch diameter classes in the 2013 inventory (Fig. 41).

Per-acre volumes vary by species (Fig. 42). The per-acre volumes for all species, and specifically for red and sugar maple, is greatest in the Allegheny Mountains ecoregion. Per-acre volume of yellow-poplar is greatest in the central part of the State and decreases across the eastern panhandle. Chestnut oak and northern red oak are concentrated in the eastern panhandle, and white oak occurs at high levels in the eastern panhandle as well as in the southern and western portions of the State.

Growing-stock volume on timberland in West Virginia averages 2,152 cubic feet per acre. Of this volume, 95 percent is in hardwood species. Yellow-poplar (17 percent), chestnut oak (10 percent), red maple (10 percent), white oak (9 percent), northern red oak (9 percent), and sugar maple (7 percent) make up over 60 percent of the hardwood growing-stock volume. Eastern white pine (28 percent), Virginia pine (24 percent), eastern hemlock (22 percent), and red spruce (11 percent) account for over 85 percent of softwood growing stock.

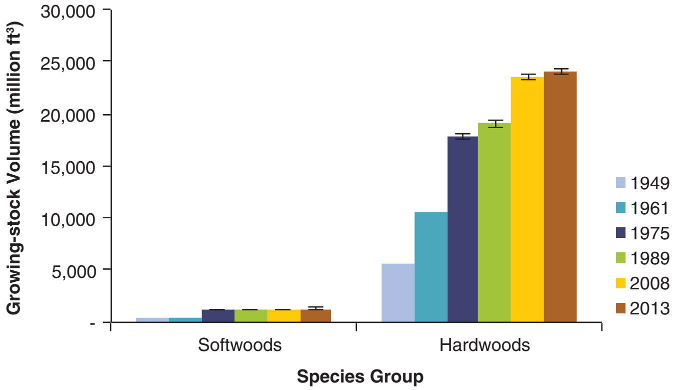


Figure 39.—Growing-stock volume on timberland by species group and inventory year, West Virginia. Error bars represent 68 percent confidence intervals around the estimate.

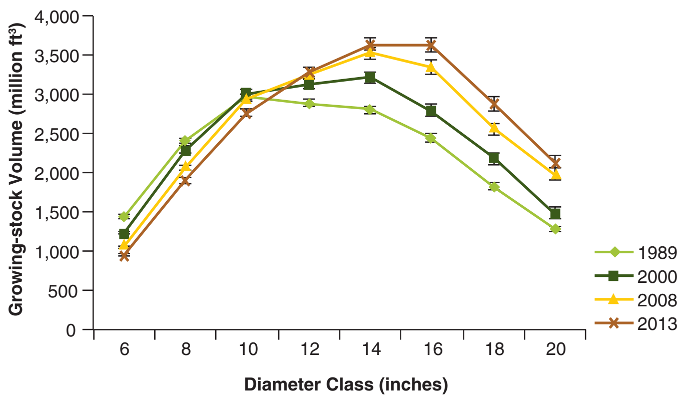


Figure 40.—Growing-stock volume on timberland by diameter class and inventory year, West Virginia. Error bars represent 68 percent confidence intervals around the estimate.

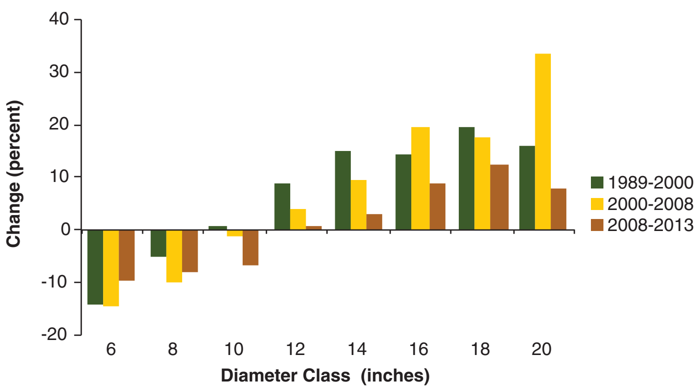
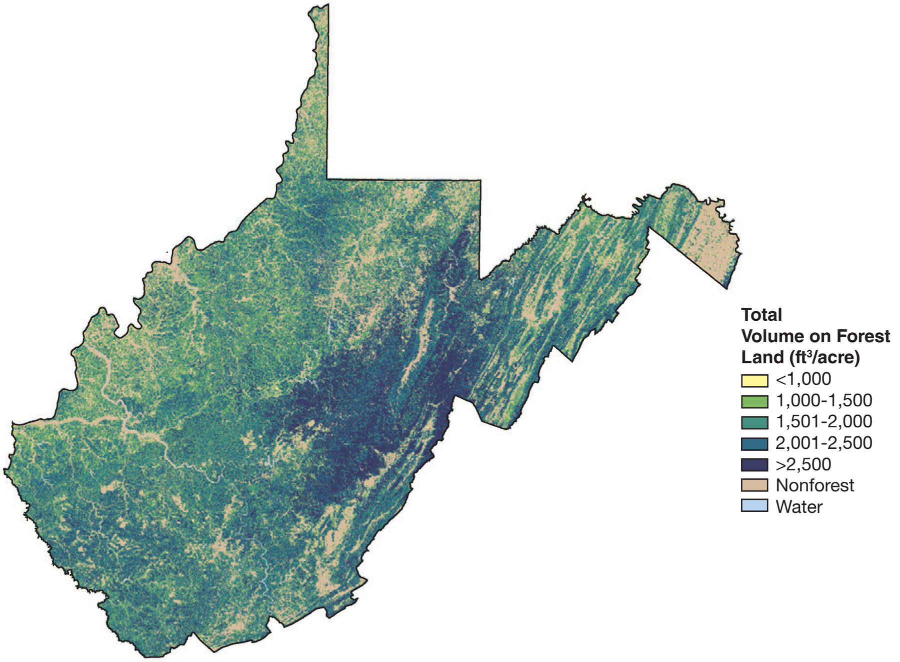
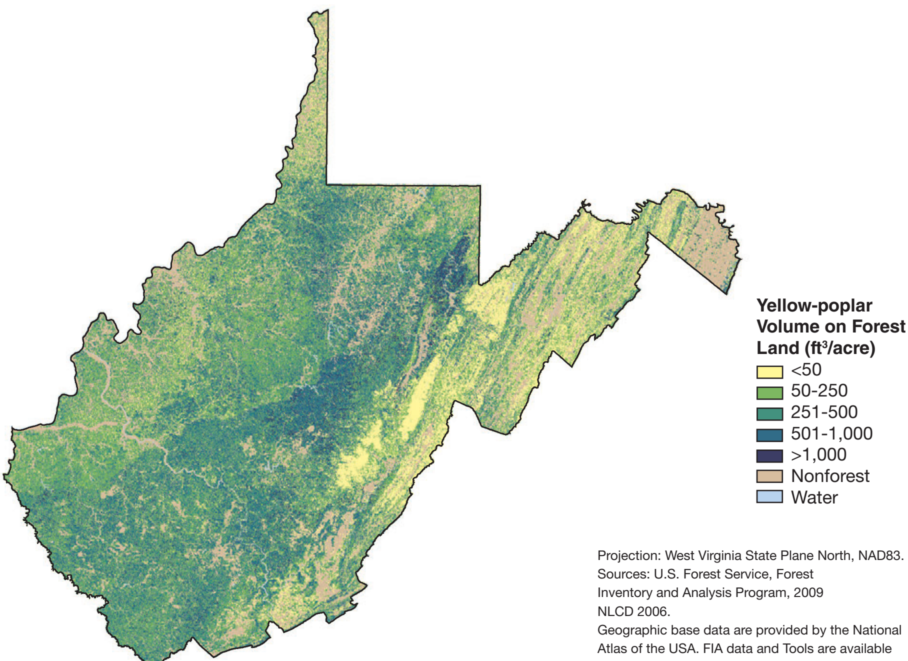


Figure 41.—Percentage change in growing-stock volume by diameter class on timberland, West Virginia.





Projection: West Virginia State Plane North, NAD83.
Sources: U.S. Forest Service, Forest
Inventory and Analysis Program, 2009
NLCD 2006.
Geographic base data are provided by the National
Atlas of the USA. FIA data and Tools are available
online at http://www.fia.fs.fed.us/tools-data/
Cartography: R.S. Morin. Mar. 2015

Figure 42.—Per-acre volume for select species on forest land (trees at least 5 inches d.b.h.), West Virginia, 2009. (Continued on next page)

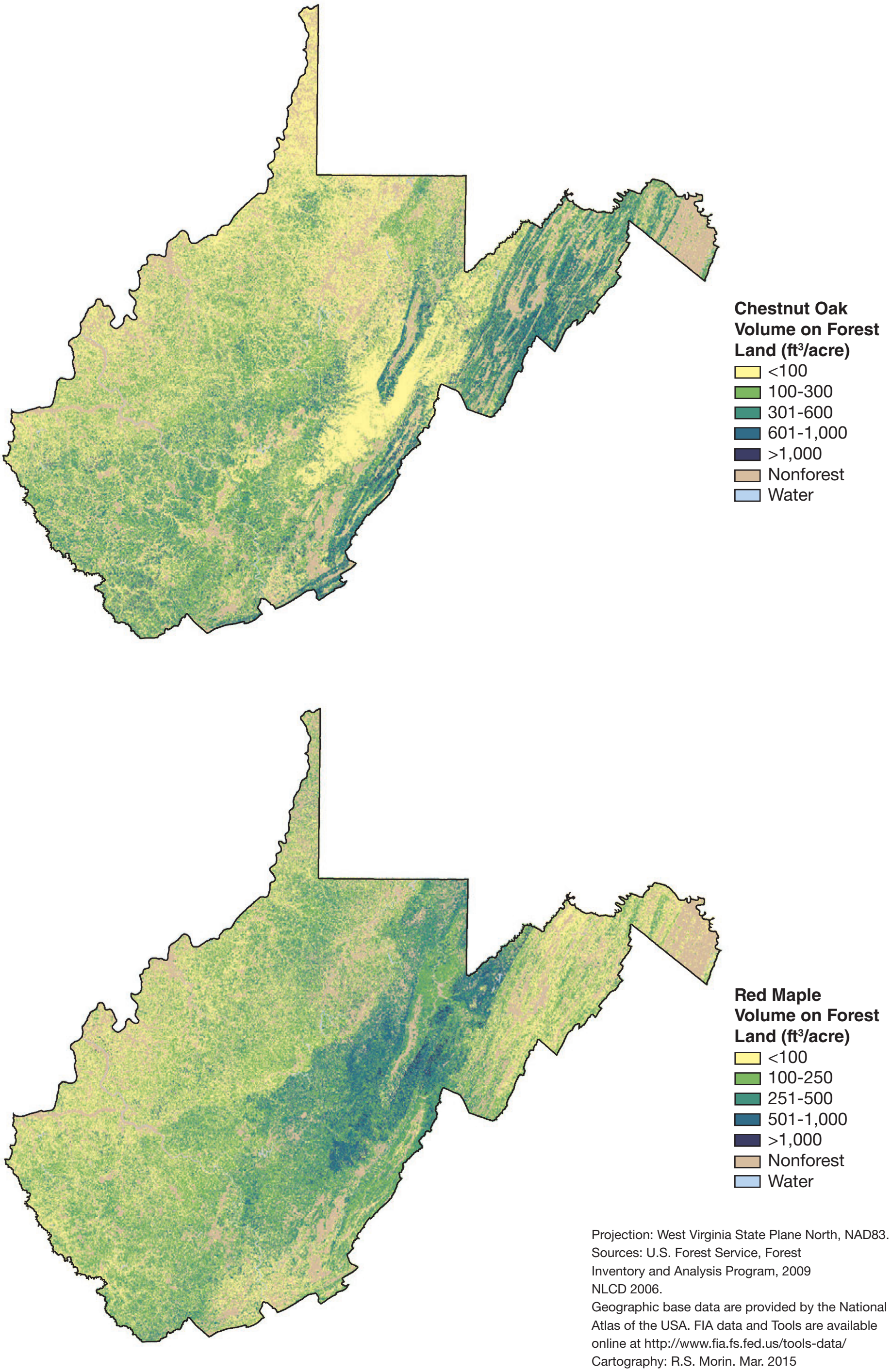
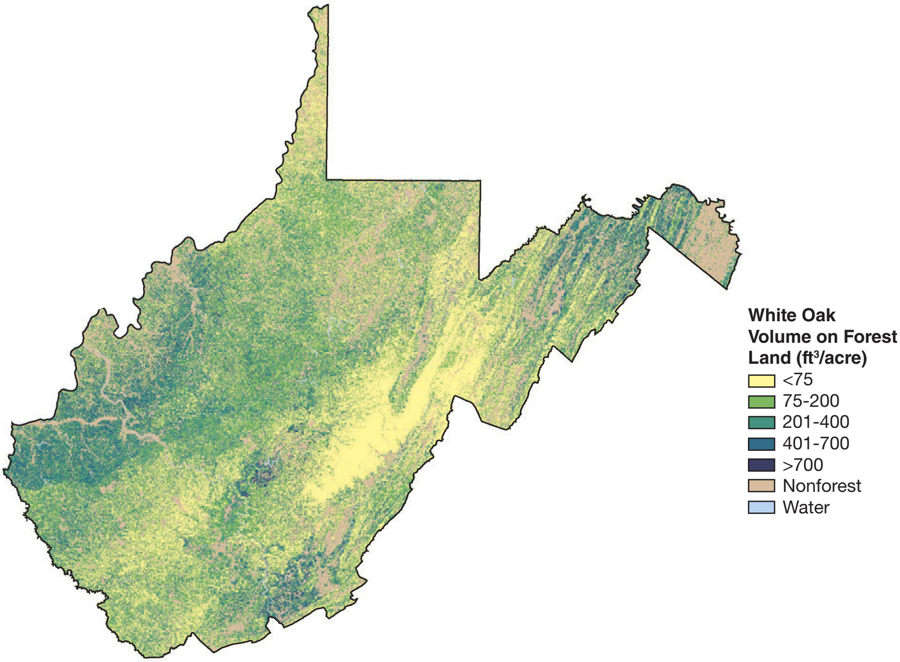
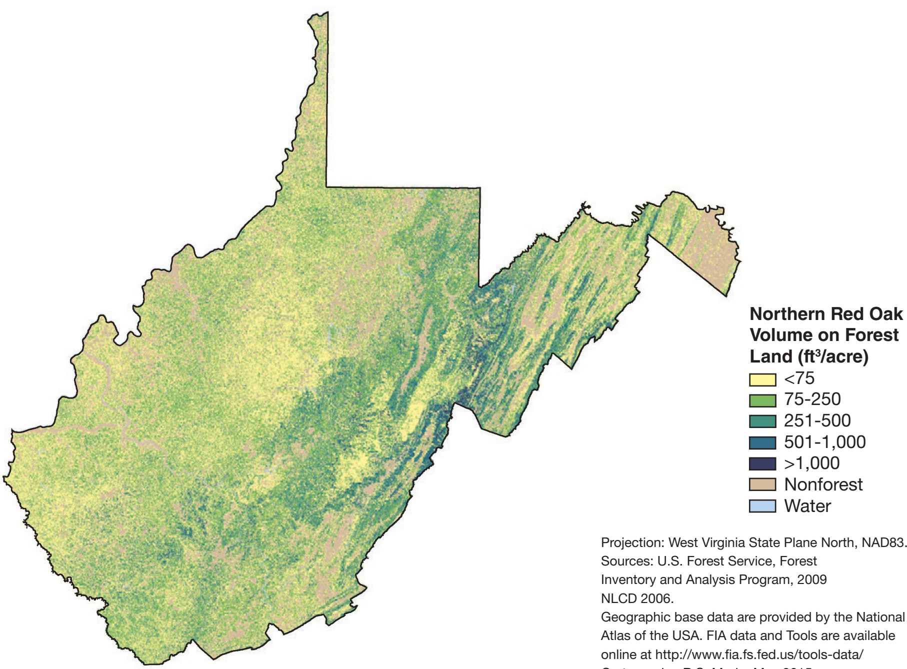


Figure 42. (Continued)—Per-acre volume for select species on forest land (trees at least 5 inches d.b.h.), West Virginia, 2009. (Continued on next page)





Projection: West Virginia State Plane North, NAD83.
Sources: U.S. Forest Service, Forest
Inventory and Analysis Program, 2009
NLCD 2006.
Geographic base data are provided by the National
Atlas of the USA. FIA data and Tools are available
online at http://www.fia.fs.fed.us/tools-data/
Cartography: R.S. Morin. Mar. 2015

Figure 42. (Continued)—Per-acre volume for select species on forest land (trees at least 5 inches d.b.h.), West Virginia, 2009. (Continued on next page)

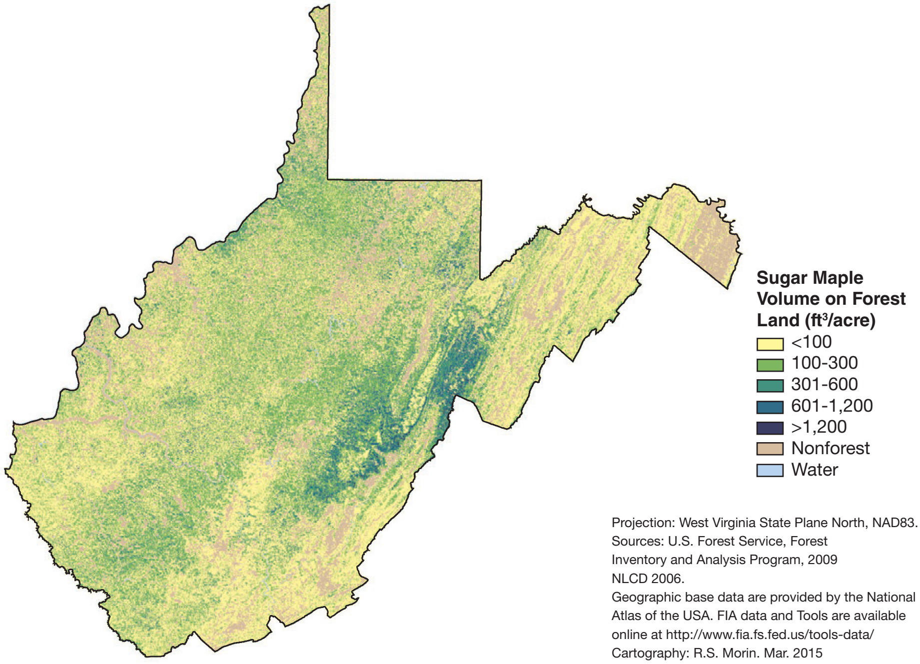


Figure 42. (Continued)—Per-acre volume for select species on forest land (trees at least 5 inches d.b.h.), West Virginia, 2009.

Yellow-poplar has 50 percent more growing-stock volume than the next most abundant species. The largest increases in growing-stock volume between 2008 and 2013 were from chestnut oak (8 percent), black cherry (8 percent), hickory (5 percent) and yellow-poplar (5 percent). Growing-stock volume decreased for American basswood (10 percent), black/scarlet oak (2 percent), and black birch (4 percent) (Fig. 43).

When volume is measured as board feet, the order of the five most voluminous species is different than for growing-stock volume measured by cubic feet. Yellow-poplar remains the leading species by a large margin, but northern red oak replaces chestnut oak as the second most voluminous and white oak replaces red maple in the third spot. Yellow-poplar makes up 18 percent of the total sawtimber volume in West Virginia (Fig. 44). American sycamore (31 percent) and chestnut oak (13 percent) had the largest gains in sawtimber volume between the 2008 and 2013 inventories. The species with largest decline in sawtimber volume was American basswood (10 percent). Total board-foot volume has increased by 6 percent since 2008.

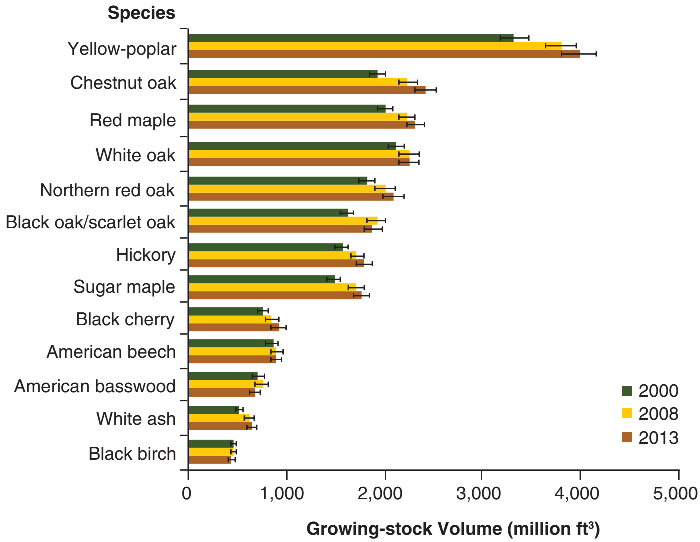


Figure 43.—Growing-stock volume on timberland by species and inventory year, West Virginia. Error bars represent 68 percent confidence intervals around the estimate.

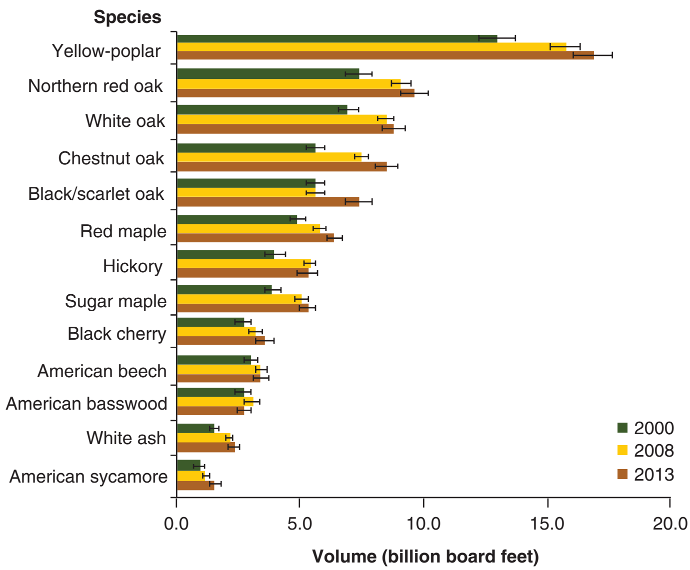


Figure 44.—Board-foot volume of growing-stock trees on timberland by species and inventory year, West Virginia. Error bars represent 68 percent confidence intervals around the estimate.

What this means

Due to the continuing increases in volume, West Virginia's timber resources are at record levels since FIA inventories began in 1949. Although growing-stock volumes continue to increase, the rate of increase has slowed and may decrease further as the forest ages. By contrast, significant increases are concentrated in sawtimber-size trees, illustrated by the significant increase in sawtimber volume. Even though the rate of increase is leveling off, the forests of West Virginia are adding value due to growth that is occurring on the higher valued trees. Landowners and the forest products industry can benefit from the increase in value, but care in management and harvesting practices will be important to ensure a steady supply of desirable species into the future as poletimber-size trees replace the sawtimber-size trees.

Sawtimber Quality

Background

Species, size, and quality of a tree determine its value in the forest products market. High quality timber is generally characterized by large diameter and the absence of defects such as knots, wounds, and poor form. This timber is used in the manufacture of cabinets, furniture, flooring, or other millwork is the most valuable. Lower quality trees are utilized as pallets, pulpwood, and fuelwood. The quality of an individual tree can be influenced by species as well as diameter, growth rate, and management practice. Hardwood trees must be at least 11 inches d.b.h. to qualify as sawtimber according to FIA standards. FIA assigns tree grades to sawtimber-size trees as a measure of quality. Tree grade is based on tree diameter and the presence or absence of defects. Tree grades are parallel to log grades used by sawmills, but they are not identical. The grades decrease in quality from grade 1 (high grade lumber) to grade 3. Grade 4 is assigned to tie/local use material.

What we found

The proportion of hardwood sawtimber volume in the highest quality categories (tree grades 1 and 2) increased by 5 percent between 2008 and 2013. There are currently 51 billion board feet in tree grades 1 and 2 in the State. The proportion of volume in tree grade 3 increased by 4 percent (Fig. 45).

Northern red oak is the only species with more than 70 percent of its sawtimber volume in tree grades 1 and 2. Yellow-poplar, chestnut oak, and white oak have at least 60 percent of their sawtimber volume in grades 1 and 2. By contrast, American beech has than less than 15 percent of its sawtimber volume in grades 1 and 2 (Fig. 46).

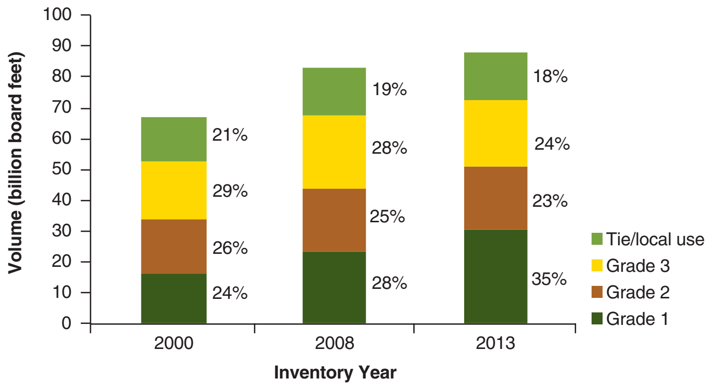


Figure 45. — Board-foot volume of hardwoods by tree grade and inventory year, West Virginia.

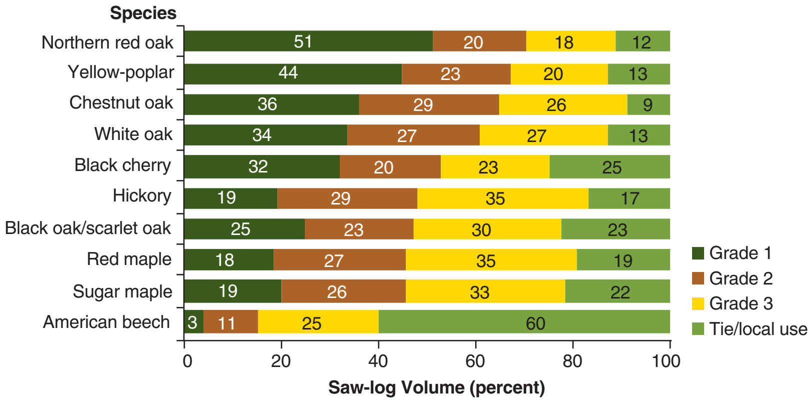


Figure 46.—Proportion of saw-log volume on timberland by species and tree grade, West Virginia, 2013.

What this means

The quality of saw logs in West Virginia has improved slightly since the last inventory, and the total value of sawtimber has increased substantially because of the overall increase in the board-foot volume of sawtimber material. Board-foot volume continues to increase in many species. Future changes in species composition may mean future reductions in overall tree quality. Many beech trees contain cankers and large amounts of rotten wood because of the impacts of beech bark disease. Red maple typically has more defects than other species. The species with a highest proportion of low-grade volume, American beech, also shows a large increase in saplings (Fig. 31). Red maple had the third highest proportion of low-grade volume and is also a relatively low value species commercially.

Average Annual Net Growth and Removals

Background

Well-managed forests supply a continuous flow of products and services without impairing long-term productivity. The rate of growth of a forest is an indicator of the overall condition, successional stage, and tree vigor. Average annual net growth (gross growth minus mortality) is calculated by measuring trees at two points in time and determining the average annual change over the time period. Net growth is negative when mortality exceeds gross growth. A useful measure to assess growth is the percentage of annual net growth to current inventory volume. Average annual net growth estimates are based on change in volume of growing stock on timberland between inventories. The terms average annual net growth and net growth are used interchangeably.

What we found

Between 1975 and 2013, average annual net growth increased in West Virginia (Fig. 47). Net growth averaged 519 million cubic feet annually between 2008 and 2013, which is about 2 percent of the growing-stock volume. The 2013 proportion of annual net growth to growing-stock volume decreased slightly from 2008 (Fig. 48). In 2013, about 96 percent of net annual growth was in hardwoods and 93 percent was on privately owned land.

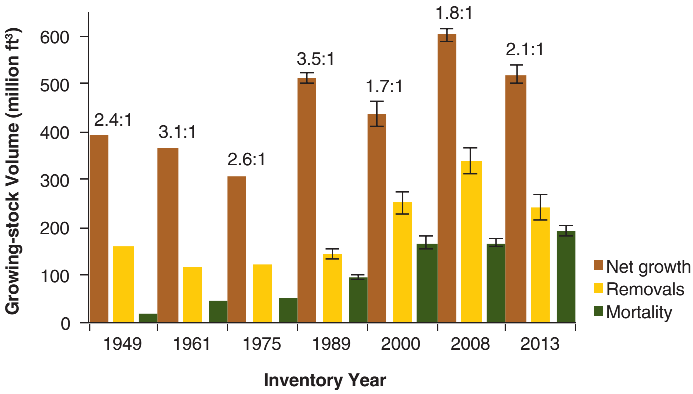


Figure 47.—Net growth, removals, mortality, and growth-to-removal ratio (above bar) of growing stock on timberland by inventory year, West Virginia. Where present, error bars represent 68 percent confidence intervals around the estimate.

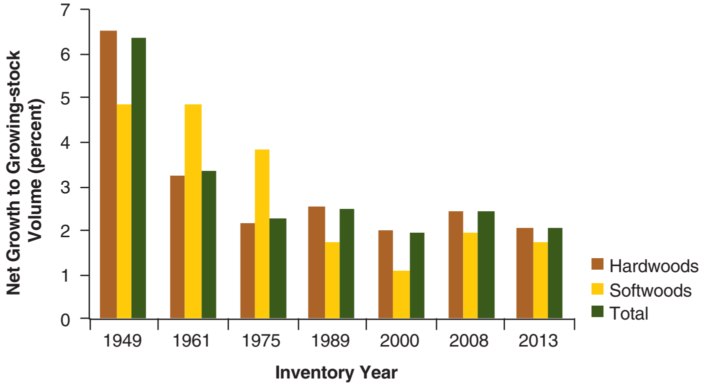


Figure 48.—Net growth of growing stock on timberland as a percent of growing-stock volume, by inventory year, West Virginia.

The top 10 species by growing-stock volume accounted for 80 percent of the average annual net growth of growing stock on timberland from 2008 to 2013. The ratio of growth-to-removals (G:R) averaged 2.1, which is an increase from what was reported for the period 2000 to 2008 (1.8) (Widmann et al. 2012). Variation between species was considerable. Net growth exceeded removals for most major species, but black/scarlet oak removals exceeded net growth. Red maple, chestnut oak, and hickory had the highest G:R ratios at 5.1, 3.7, and 3.5, respectively (Fig. 49). The largest positive changes in G:R ratio between 2008 and 2013 were in hickory (1.8 to 3.5) and chestnut oak (2.3 to 3.7). By contrast, sugar maple (3.9 to 1.9) and black/scarlet oak (1.5 to 0.8) had G:R ratios decrease.

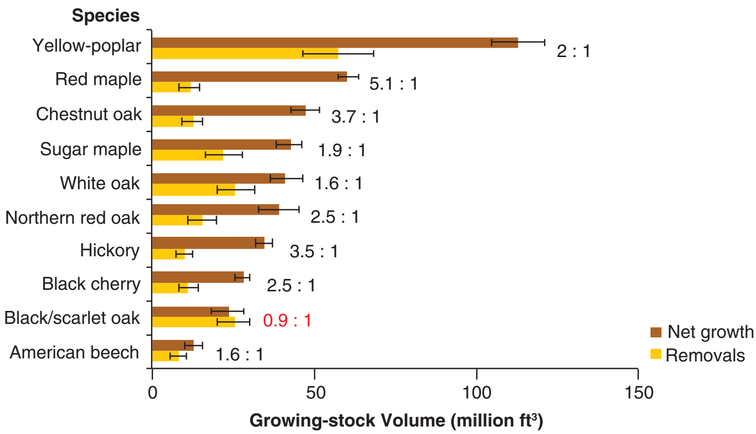


Figure 49.—Average annual net growth and removals of growing-stock trees for select species on timberland, West Virginia, 2013. 2013 growth-to-removals ratio listed at right of bar; 2013 average growth-to-removal ratio for all species is 2.1. Error bars represent 68 percent confidence intervals around the estimate.

What this means

The well-stocked stands in the current forests of West Virginia developed as a result of the G:R ratios being well above 1.0 for most of the second half of the 20th century. More recently, West Virginia's forests have matured and the rate of growth has slowed. At the current rates of growth, mortality, and removals, West Virginia's forests are increasing at a rate of roughly 2 percent of volume per year. This growth rate is higher on private land which is most likely due to larger proportion of public lands located on high elevation, low productivity sites. Fortunately, more than 80 percent of the volume of removals is due to harvesting and not land use change. Trees should regenerate as long as the land is not developed.

A comparison of the G:R ratios of individual species to the average G:R ratio for all species reflects sustainable harvesting. The low growth-to-removals ratio of black oak (e.g., 0.8) suggests that the species could be decreasing in abundance (Fig. 49) particularly, further supported by the dearth of oaks in the sapling size class (Fig. 31).

Average Annual Mortality

Background

Mortality is a natural part of stand development in healthy forest ecosystems. Many factors contribute to mortality: competition, succession, insects, disease, fire, human activity, drought, and others. Mortality is often initiated by one causal agent (inciting factor), and is then followed by contributing stress factors making the underlying cause difficult to identify. Although mortality is a natural event in a functional forest ecosystem, dramatic increases in mortality can be an indication of forest health problems. Average annual mortality estimates of growing-stock trees represent the average cubic-foot volume of sound wood that died each year between inventories. Biotic and abiotic disturbances can stress forests either as inciting factors or as contributors to mortality. The National Insect and Disease Forest Risk Assessment presents detailed maps of areas where elevated mortality is expected over the next 15 years (Krist et al. 2014).

What we found

The estimated average annual mortality rate for growing-stock trees in West Virginia is 191 million cubic feet, which is approximately 0.8 percent of growing-stock volume for 2013. This is a slight increase from the rate reported for 2008, but it is well within the range of mortality rates reported in the record of FIA inventories of West Virginia. Softwoods have a higher mortality rate than hardwoods during most inventory periods (Fig. 50). The mortality rate is similar to many other states in the region. For example, Pennsylvania's mortality rate is 0.8 percent, Maryland's is 0.8 percent, and Kentucky's is 0.9 percent. The highest mortality rates are generally found in the two smallest diameter classes (Fig. 51).

Mortality increased steadily between 2000 and 2013 for some species including yellow-poplar, black/scarlet oak, and white oak. Mortality of American beech decreased and most other species remain stable (Fig. 52). Most of the abundant species in West Virginia have relatively low mortality rates that are below the 0.8 percent annual average for all tree species combined. By contrast, black locust has a mortality rate that is nearly seven times the statewide average (Fig. 53).

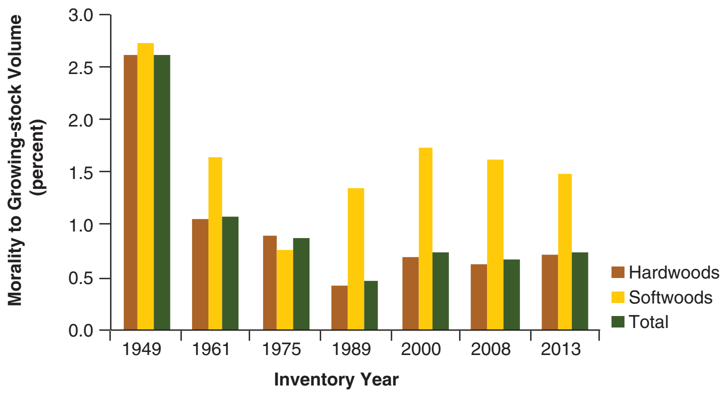


Figure 50.—Mortality of growing stock on timberland as a percentage of growing-stock volume, by inventory year, West Virginia.

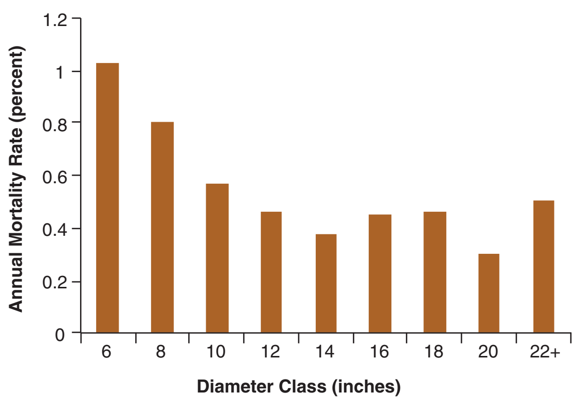


Figure 51.—Average annual mortality rate of growing-stock volume on timberland by diameter class, West Virginia, 2013.

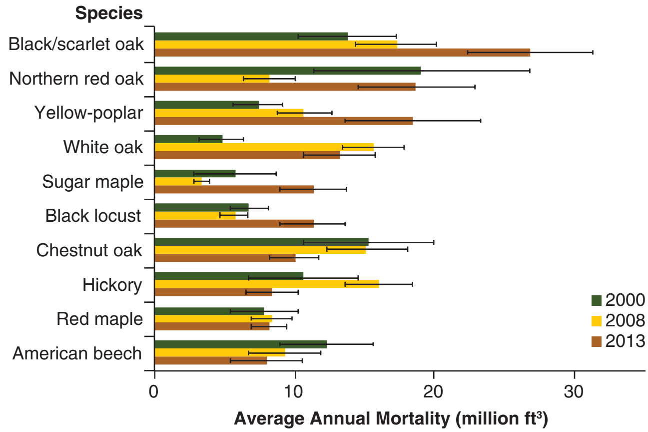


Figure 52.—Average annual mortality (expressed as volume) of growing stock on timberland for select species, by inventory year, West Virginia. Error bars represent 68 percent confidence intervals around the estimate.

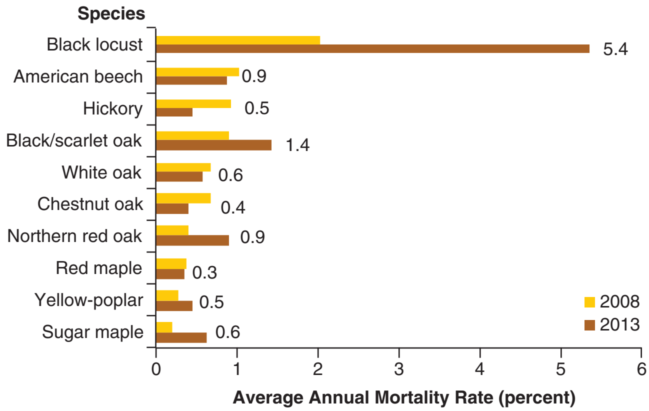


Figure 53.—Average annual mortality rate for select species, West Virginia, 2008 and 2013. 2013 mortality rate listed at right of bar; 2013 average mortality rate for all species = 0.8 percent.

What this means

Tree mortality rates in West Virginia are comparable to those in surrounding states. Some of the mortality can be explained by stand dynamics (e.g., competition and succession) and the impacts of insects and diseases that affect specific species. In the normal maturation process, some trees lose vigor and eventually die from being outcompeted or succumb to insect and disease during their weakened state; this is especially apparent in trees 8 inches and smaller d.b.h. (Fig. 51).

Most species in West Virginia have low mortality rates, but black locust has an elevated rate. The high mortality observed in black locust is likely due to a multitude of biotic and abiotic stressors including locust leafminer (*Odontota dorsalis*), locust twig borer (*Ecdytolopha insiticiana*), and frost damage.

Species Composition

Background

The species composition of a forest is the result of the long-term interaction of climate, soils, disturbance, competition among trees species, and other factors. Causes of forest disturbances in West Virginia include timber harvesting, insects and diseases, ice storms, droughts, wildfires, and land clearing followed by abandonment. White-tailed deer (*Odocoileus virginianus*) can also impact species composition by heavily browsing some species while avoiding others. As forests recover from disturbances and mature, changes in growing conditions favor the growth of shade-tolerant species over shade-intolerant species in the understory unless forest management practices intervene on behalf of shade intolerant species.

Forest attributes recorded by FIA that describe forest composition include forest type and numbers of trees by species and size. Forest types describe groups of species that frequently grow in association with one another and dominate the stand. Similar forest types are combined into forest-type groups. Changes in area by forest type are driven by changes in the species composition of the large diameter trees, and while these large trees represent today's forest, the composition of the smaller diameter classes represents the future forest. Comparisons of species composition by size can provide insights into future changes in overstory species.

What we found

The 2013 inventory identified 98 tree species (see appendix, page 128), 45 forest types, and 12 forest-type groups in West Virginia. The oak/hickory forest-type group covers 9.0 million acres, or 74 percent, of West Virginia's forests and the northern hardwood group covers another 2.2 million acres (18 percent) (Figs. 1, 3). By volume, the oak/hickory forest-type group is mainly composed of oak (42 percent) and yellow-poplar (18 percent) (Fig. 54A). Species other than oak and hickory represent 50 percent of the volume in this group. The maple/beech/birch forest-type group is mostly composed of sugar maple (23 percent), red maple (13 percent), black cherry (12 percent), and beech (8 percent) (Fig. 54B). Species other than maple, beech, and birch represent 60 percent of the volume in this group. These broad forest-type groups describe the current composition of overstory trees and have undergone little change in extent since 2008. Because of changes in data processing procedures, current area by forest-type groups is not comparable to the 2000 inventory.

The species composition of the understory in West Virginia differs from that of the overstory. The seedling- and sapling-size trees that form the understory represent the advanced regeneration which is available to grow into the overstory; understory trees also represent a potential shift in composition for future forests. In the seedling class (trees greater than 1 foot tall and less than 1 inch d.b.h.), American beech is the most numerous species followed by red maple, ash, black birch, and sugar maple (Fig. 55). The oaks occur at low densities in the seedling class and are outnumbered by many other species. Beech represents 11 percent of all seedlings, slightly more stems than the total of all oak species combined (10 percent). Since 2008, the number of seedlings on timberland decreased by nearly 11 percent and beech has replaced red maple as the most common seedling species.

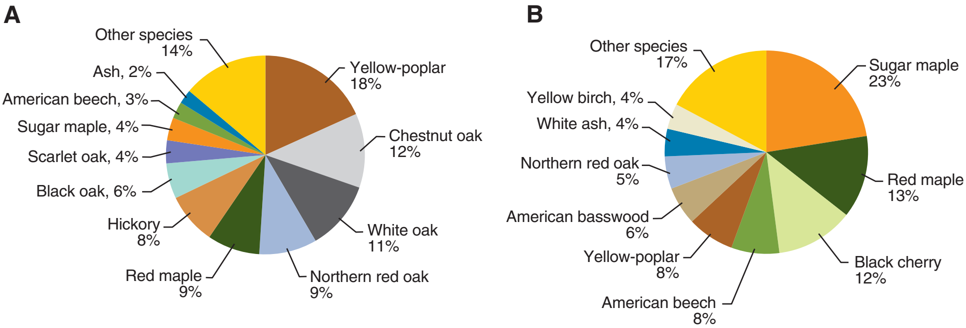


Figure 54.—Species composition within the oak/hickory forest-type group (A) and the maple/beech/birch forest-type group (B) on timberland, as a percent of total volume in the group, West Virginia, 2013. Error bars represent 68 percent confidence intervals around the estimate.

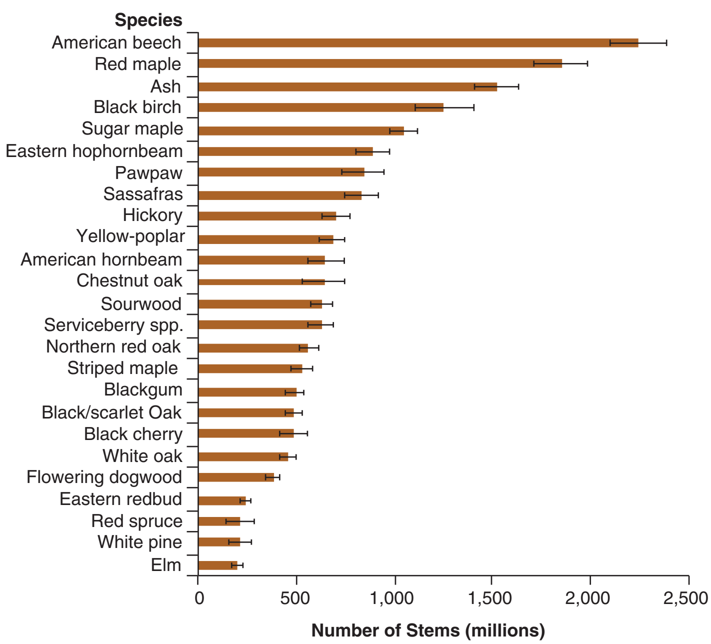


Figure 55.—Species ranking by number of seedlings (at least 1-foot tall and less than 1-inch d.b.h.), West Virginia, 2013. Error bars represent 68 percent confidence intervals around the estimate.

Saplings (trees with a d.b.h. of 1 to 4.9 inches.) have a different ranking than seedlings (Table 4). Red maple is the most numerous sapling followed by sugar maple, beech, and blackgum. As with the seedling class, oak species again rank poorly. By numbers of stems recorded in 2013, northern red oak, chestnut oak, and white oak saplings rank 21st, 23rd, and 27th, respectively. Compared to data from 2000, species with large increases in number of saplings include American beech (+33 percent), blackgum (+19 percent), sourwood (+34 percent), yellow-poplar (+12 percent),

Table 4.—Ranking of sapling numbers by species (trees at least 1 inch and less than 5 inches d.b.h.) 2013 and 2000; total number of stems 2013, and percentage change 2000 to 2013, on timberland, West Virginia

Rank 2013	Rank 2000	Species	Millions of stems 2013	Sampling error (percent)	Percent change since 2000
		Total all species	4,373	2.2	1.4
1	1	Red maple	661	5.2	-1.3
2	2	Sugar maple	510	5.0	-8.9
3	3	American beech	409	5.9	32.6
4	4	Blackgum	216	7.9	19.2
5	8	Sourwood	182	9.6	34.0
6	7	Yellow-poplar	169	9.5	12.0
7	15	Black birch	154	12.1	66.7
8	6	Hickory	144	7.5	-9.2
9	5	Flowering dogwood	109	9.8	-38.8
10	9	Sassafras	109	12.6	-9.0
11	16	American hornbeam, musclewood	96	13.3	13.5
12	17	Striped maple	95	14.0	18.2
13	13	Black locust	94	13.6	-2.3
14	11	Ash	92	9.2	-17.5
15	12	Eastern redbud	91	13.7	-9.7
16	10	Black cherry	90	13.8	-20.4
17	20	Eastern hophornbeam	85	10.7	19.8
18	19	Serviceberry spp.	78	13.1	0.7
19	18	Eastern hemlock	71	17.4	-8.5
20	25	Red spruce	66	22.6	13.4
21	24	Northern red oak	65	14.4	3.4
22	27	Pawpaw	63	15.5	24.8
23	22	Chestnut oak	61	16.0	-12.4
24	14	Elm	59	13.9	-38.4
25	21	Hawthorn spp.	55	26.3	-21.5
26	26	Eastern white pine	51	26.0	-9.5
27	28	White oak	50	13.9	-0.2
28	23	Black/scarlet oak	66	14.1	-1.4
29	30	Virginia/pitch pine	39	21.0	-14.6
29	31	Yellow buckeye	35	22.8	1.6

black birch (+67 percent), eastern hophornbeam (+20 percent), striped maple (+18 percent), and pawpaw (+25 percent). Species with large decreases in sapling numbers since 2000 are flowering dogwood (-39 percent), elm (-38 percent), hawthorn spp. (-21 percent), black cherry (-20 percent), ash (-17 percent), Virginia/pitch pine (-15 percent), chestnut oak (-12 percent), eastern white pine (-10 percent), hickory (-9 percent), sassafras (-9 percent), sugar maple (-9 percent), and eastern hemlock (-8 percent). These changes occurred as the total number of saplings of all species increased by 1.4 percent.

Among trees 5 inches d.b.h, and larger, red maple again is the most numerous followed by sugar maple, chestnut oak, and yellow-poplar (Fig. 56). In these size classes, red and sugar maple each increased by 12 percent since 2000. Of the major species, blackgum had the largest increase in numbers of trees 5 inches and larger, increasing by 24 percent. These increases contrast with the oaks of the same size class; white oak, northern red oak, and scarlet/black oak decreased by 12, 10, and 6 percent, respectively, during the same period.

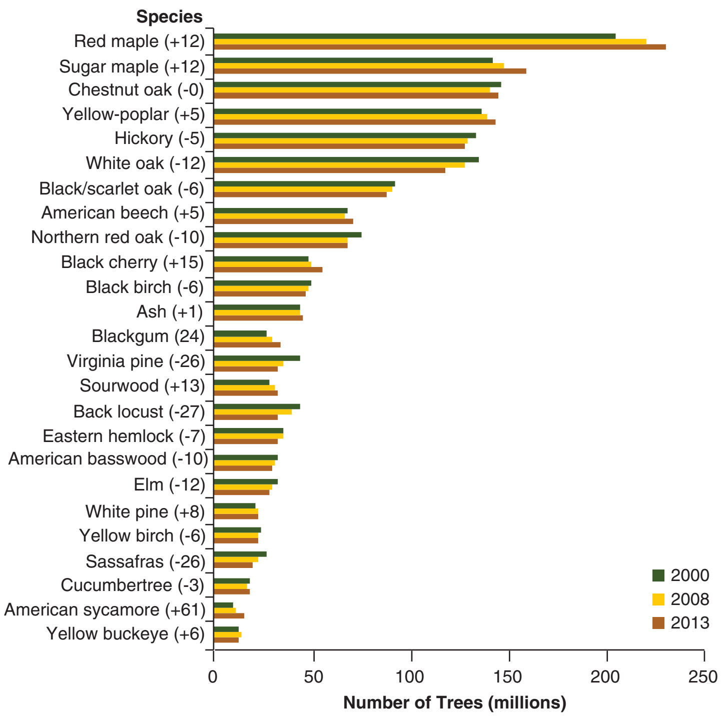


Figure 56.—Species ranking by the numbers of trees >5.0 inches d.b.h on timberland in 2013, with additional estimates for number of trees in the 2000 and 2008 West Virginia inventories. Percentage change from 2000 to 2013 shown in parentheses beside species name.

The oaks are better represented in large diameter classes (Figs. 57, 58). Oaks represent more than 46 percent of the trees 20 inches and larger d.b.h. in the current inventory, but only 6 percent of trees in the 2- and 4-inch diameter classes. Conversely, maple species have a disproportionate share (27 percent) of trees in the 2- and 4-inch diameter classes compared to their 5 percent proportion in the 20 inches d.b.h. and larger classes. Like the oaks, yellow-poplar also has a disproportionately large share (16 percent) of trees larger than 20 inches, but less than 4 percent of trees in the 2- and 4-inch diameter classes.

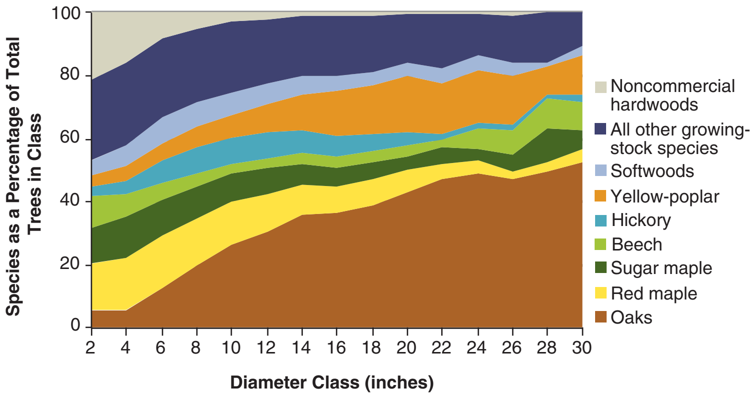


Figure 57.—Species composition as a percentage of all trees on timberland, by each diameter class, West Virginia, 2013.

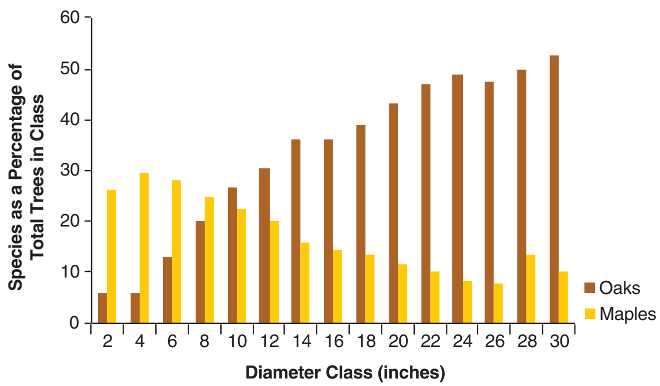


Figure 58.—Oaks and maples as a percentage trees in each diameter class on timberland, West Virginia, 2013.

Since 1961, oaks have decreased from 40 percent of the timber resource to 35 percent. Conversely, yellow-poplar and maple species have increased in the proportion of the resource they represent. The proportions represented by beech and hickory species remain relatively unchanged.

What this means

The stability of West Virginia's forest land area does not fully depict the underlying shifts in individual species. A lack of oaks in the small diameter classes means that as large oaks are harvested or die, they will likely be replaced by species that dominate the smaller diameter classes, such as red maple, sugar maple, blackgum, yellow-poplar, and black birch. Maples will play an increasingly important role in West Virginia's future forest. This will likely result in the area currently occupied by the oak/hickory forest-type group to undergo a long-term decline and be replaced by the maple/beech/birch group. American beech is prevalent in seedling and sapling size trees, and despite beech bark disease causing high mortality of large size beech trees, beech will likely remain a major component of many stands in the future because of large number of seedlings and saplings.

Decreases in the oak proportion of the resource have been attributed to inadequate oak regeneration, the subsequent lack of oaks growing into the larger diameter classes, and selective harvesting of oak over other species. Generally, current forest practices do not promote the regeneration of oaks, and silvicultural tools (fencing to exclude deer, controlled fires to inhibit oak competition, and use of oak seed trees) to promote oak regeneration are seldom used. Contributing factors to poor oak regeneration are lack of fire, understory growing conditions that favor more shade-tolerant hardwoods, white-tailed deer preferentially browsing oak seedlings, and the low intensity harvesting practices that leave only small gaps in the canopy.

Although much of the data for seedlings and saplings has high sampling errors, some general trends emerge from the sapling data:

- Species that are less preferred browse for white-tail deer are faring better than those species that are favored browse.
- Species that are shade tolerant are reproducing better than those that are shade intolerant.
- Species that can take advantage of small gaps in the canopy created by disturbance, such as harvesting, are increasing in number.

American beech, sourwood, striped maple, American hornbeam, eastern hophornbeam, and black birch are not preferred browse for white-tail deer, tolerant of shaded conditions, and can respond well to gaps created by partial harvests and other disturbances. These species have all increased in number in the understory. Some may also be filling niches vacated by flowering dogwoods that are dying from dogwood anthracnose, a fungal disease. Sourwood and striped maple often interfere with the establishment of more desirable species and can pose silvicultural problems to land managers (Gabriel and Walters 1990, Overton 1990).

However, projected changes in species composition related to climate change suggest that by 2060, growing conditions in the northeastern United Sates will become more suitable for oaks and less suitable for maples (Iverson and Prasad 1998, Rustad et. al. 2012, Vose et. al. 2012). Current trends in West Virginia do not reflect these projected changes; it is the current conditions that are driving changes in forest composition:browse by white-tailed deer, natural succession, cutting practices, fire suppression, and insects and diseases.

Long-term changes in forest composition can alter wildlife habitats and affect the value of the forest for timber products. The lack of recruitment of oaks into the larger diameter classes is changing the composition of the timber resource away from oaks toward more maples and other non-oak species. To remain sustainable, the composition of the timber harvest in the State will need to shift to reflect changes in the resource.

Ecosystem Indicators and Services

West Virginia's forests support a diverse forest products industry, which contributes millions annually to the State's economy. Photo by West Virginia Department of Commerce, used with permission.

Tree Crown Health and Damage

Background

The crown condition of trees is influenced by various biotic and abiotic stressors. Biotic stressors include native or introduced insects, diseases, invasive plant species, and animals. Abiotic stressors include drought, flooding, cold temperatures or freeze injury, nutrient deficiencies, the physical properties of soils that affect moisture and aeration, and toxic pollutants.

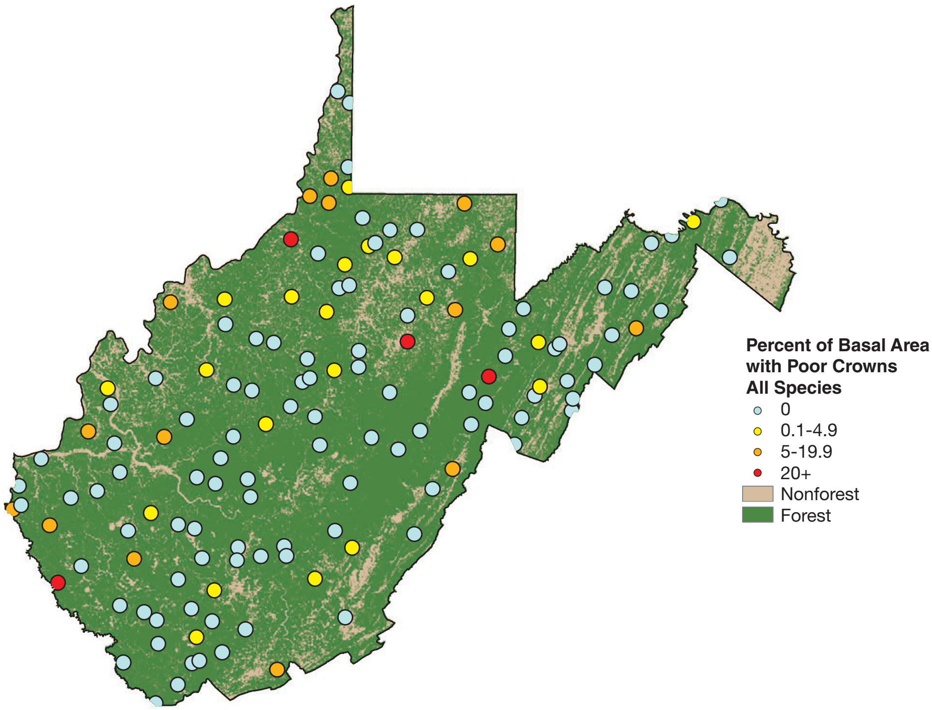
Invasions by exotic diseases and insects are one of the most important threats to the productivity and stability of forest ecosystems around the world (Liebhold et al. 1995, Pimentel et al. 2000, Vitousek et al. 1996). Over the last century, West Virginia's forests have suffered the effects of well-known exotic and invasive agents such as chestnut blight (*Cryphonectria parasitica*), European gypsy moth (*Lymantria dispar*), hemlock woolly adelgid (*Adelges tsugae*), and the beech bark disease complex. A more recent invader is emerald ash borer (*Agrilus planipennis*).

Tree-level crown dieback is collected on P2+ plots. Crown dieback is defined as recent mortality of branches with fine twigs and reflects the severity of recent stresses on a tree. A crown was labeled as "poor" if crown dieback was greater than 20 percent. This threshold is based on findings by Steinman (2000) that associated crown ratings with tree mortality. Additionally, crown dieback has been shown to be the best crown variable to use for predicting tree survival (Morin et al. 2015).

Tree damage is assessed for all trees with a d.b.h. of 5.0 inches or greater. Up to two of the following types of damage can be recorded: insect damage, cankers, decay, fire, animal damage, weather, and logging damage. If more than two types of damage are observed, the relative abundance of the damaging agents determine which two are recorded.

What we found

The incidence of poor crown condition is uncommon across West Virginia, but it is more prevalent in the northern part of the State (Fig. 59). The species with the highest proportion of live basal area containing poor crowns is white oak (8 percent). Conversely, all other species have a very low occurrence of poor crowns. Additionally, the proportion of basal area with poor crowns has dropped for most species since 2008, but this proportion increased nearly tenfold for American beech (Table 5).



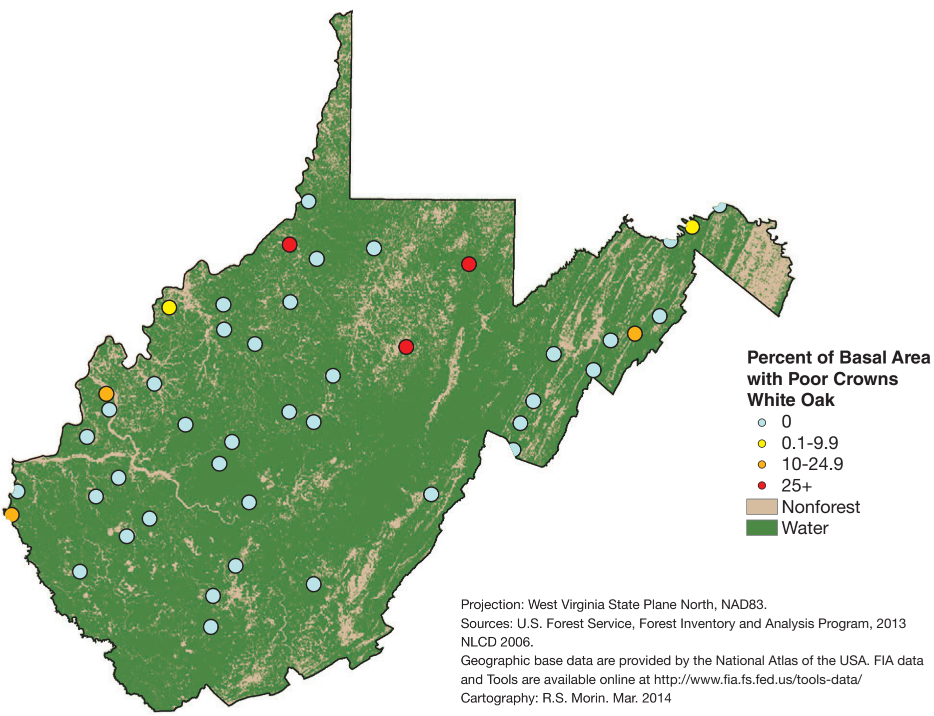


Figure 59.—Percent of live basal area with poor crowns, West Virginia, 2013. Plot locations are approximate.

Table 5.—Percentage of live basal area of tree species with poor crowns, West Virginia, 2008 and 2013

	Percent of Basal Area with Poor Crowns	
Species	2008	2013
White oak	2.0	7.7
American beech	0.4	3.9
Yellow-poplar	5.2	2.5
Red maple	6.3	1.9
Northern red oak	1.1	1.1
Sugar maple	5.6	1.0
Black cherry	5.1	0.8
Black/scarlet oak	7.2	0.2
Chestnut oak	0.3	0.0
Hickory	0.5	0.0

Average crown dieback ranges from 1 percent for hickory species to 4.7 percent for white oak (Table 6). Average crown dieback has not varied substantially over time for any species. An analysis of the trees from the 2008 inventory that were remeasured in the 2013 inventory reveals that the proportion of the trees that die increases with increasing crown dieback (Fig. 60). More than 68 percent of trees with crown dieback above 10 percent during the 2008 inventory were dead when visited again during the 2013 inventory.

Damage was recorded on approximately 25 percent of the trees in West Virginia, but there is considerable variation between species. The most frequent damage for all species is decay (20 percent of trees), but it ranges from 11 percent on white oak to 40 percent on American beech. Notably, cankers are present on 7 percent of American beech trees. The occurrence of all other injury types is very low (Fig. 61).

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

Species	Trees	Mean	SE	Minimum	Median	Maximum
	- number -	*percent*				
White oak	166	4.7	1.0	0	0	95
Black cherry	110	2.7	0.4	0	0	20
Black/scarlet oak	151	2.5	0.3	0	0	35
Northern red oak	98	2.4	0.7	0	0	65
American beech	116	2.2	0.8	0	0	80
Yellow-poplar	265	1.9	0.2	0	0	20
Red maple	408	1.8	0.2	0	0	60
Chestnut oak	207	1.5	0.2	0	0	15
Sugar maple	221	1.4	0.2	0	0	20
Hickory	240	0.9	0.1	0	0	10

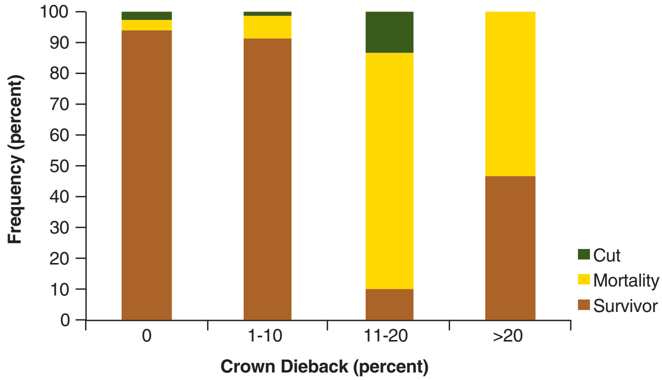


Figure 60.—Crown dieback distribution by tree survivorship for remeasured trees, West Virginia, 2008 to 2013.

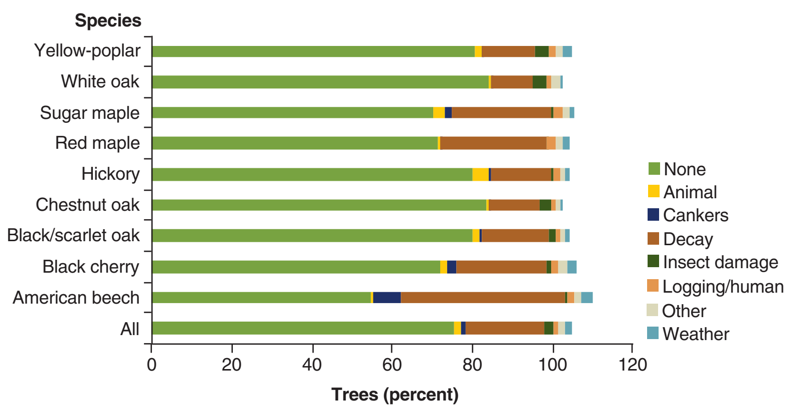


Figure 61.—Proportion of trees with types of damage, West Virginia, 2013. Note that columns don't sum to 100 because multiple damages can be recorded on trees.

What this means

The trees of the most important species in the forests of West Virginia are generally in good health. As in most eastern forests, decay is the most commonly observed damage in West Virginia's forests. This is not unusual given that most West Virginia's forests are large diameter stands composed of mature trees. The high occurrence of cankers and decay in American beech is likely due to trees suffering from the impacts of beech bark disease (see Beech Bark Disease section). The health of tree crowns of American beech, eastern hemlock, and ash species should be monitored closely due to likely future impacts of beech bark disease, hemlock woolly adelgid, and emerald ash borer, respectively.

Down Woody Materials

Background

Down woody materials, in the various forms of fallen trees and shed branches, fulfill a critical ecological niche in forests of West Virginia. Down woody materials provide valuable wildlife habitat, stand structural diversity, a store of carbon/biomass, and contribute to forest fire hazards via surface woody fuels.

What we found

The total carbon stored in down woody materials (fine and coarse woody debris and residue piles) on West Virginia's forest land exceeds 39 million tons. Downed woody debris carbon is normally distributed by stand-age class with moderately aged stands having the highest total carbon (~14 million tons) (Fig. 62). The downed dead wood biomass in West Virginia's forests is dominated by coarse woody debris (Fig. 63) at approximately 50 million tons; fine woody debris accounts for more than a third of statewide total of stored carbon in down woody materials.

The volume of coarse woody debris is highest in the private ownership category at approximately 4.8 billion cubic feet in West Virginia's forests (Fig. 64). National Forests within the State have the second largest, albeit substantially lower totals of coarse woody debris volume (478 million cubic feet) compared to private ownerships. Privately owned forest lands have the highest volumes of dead wood in piles at over 195 million cubic feet.

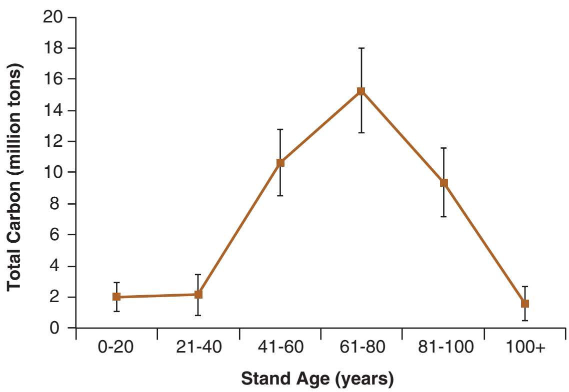


Figure 62.—Carbon stocks (short tons) in down woody materials by stand-age class on forest land, West Virginia, 2010. Error bars represent 68 percent confidence intervals around the estimate.

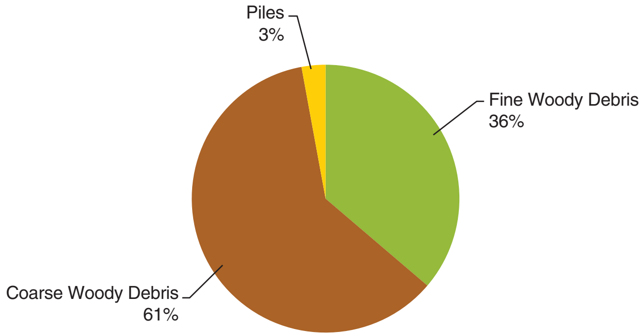


Figure 63.—Proportion of down woody material biomass by component on forest land, West Virginia, 2010.

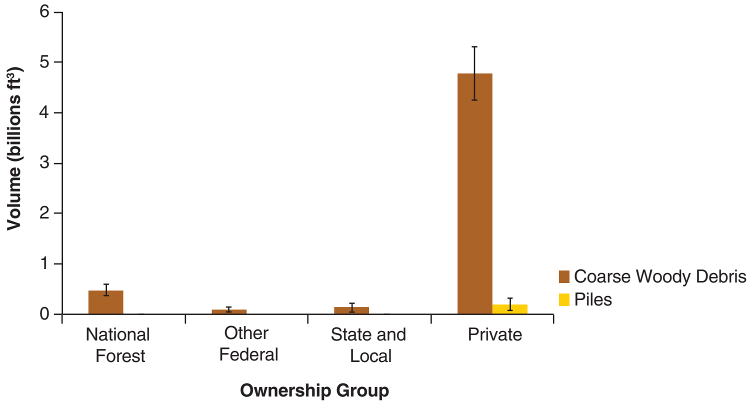


Figure 64.—Volume of coarse woody debris and deadwood piles on forest land by ownership group, West Virginia, 2010. Error bars represent 68 percent confidence intervals around the estimate.

What this means

Given the relatively moist temperate forests across the West Virginia, only in times of drought would the biomass of down woody materials be considered a fire hazard. Although the carbon stocks of down woody materials are relatively small compared to those of soils and standing live biomass across West Virginia, it is still a critical component of the carbon cycle as a transitory stage between live biomass and other detrital pools such as the litter. Beyond the transition of dead wood carbon to other pools, if future temperature and precipitation patterns change there is a potential for a reduction in these stocks due to increased rates of decay (Russell et al. 2014 a, b). The loss of dead wood carbon stocks could indicate the reduction of other pools in the future. Compared to southeastern states where there is more pervasive industrial management of forests (Woodall et al. 2013), there were relatively few residue piles sampled in this first down woody materials inventory of West Virginia's forests. Given that most coarse woody debris volume was estimated to be in private ownership, it is the management of West Virginia's private forests that may affect the future of down woody material contributions to statewide forest carbon stocks and wildlife habitat (i.e., stand structure). Because fuel loadings are estimated to be low across West Virginia, down woody materials as a potential fire danger will likely be outweighed by the numerous ecosystem services provided by down woody materials.

Regeneration Status

Background

Forest systems of West Virginia face numerous regeneration stressors such as invasive plants, insects, diseases, herbivory, and climate change. As forest stands mature and undergo stand replacement disturbances, it is imperative to know the condition of the regeneration component before the disturbance occurs. Forest regeneration was listed as one of the top issues to be addressed in a comprehensive analysis of West Virginia's forest resources (West Virginia Division of Forestry 2010).

West Virginia is dominated by forest systems that regenerate naturally but planting and seeding are options to enhance natural regeneration in some stands. In most situations, establishing desirable reproduction is the key to replacing stands with desired high-canopy species. The composition and abundance of tree seedlings drive the character of forest ecosystems in the early years of stand development and set the stage for future sustainability of timber and ecosystem services (Johnson et al. 2009, Smith et al. 1997).

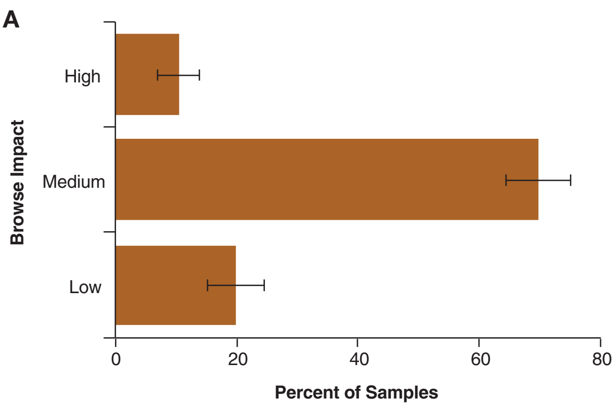
The quality and health of West Virginia's young forest depends directly on the condition of the regeneration component. Early successional forest, or young forest habitat, provides unique flora and fauna and is vital for landscape heterogeneity and biodiversity (Greenberg et al. 2011). Some prime examples of wildlife that depend on young forest include golden-winged warbler (*Vermivora chrysoptera*), American woodcock (*Scolopax minor*), and cottontail rabbit (*Sylvilagus floridanus*) (Gilbart 2012).

FIA added protocols on a subset of plots to collect detailed information on regeneration; this is known as the regenerational indicator sample (McWilliams et al. 2015). In West Virginia 84 sample plots measured in 2012 and 2013. Field crews measured the height of all established tree seedlings less than 1 inch d.b.h. and assessed browse impact for the area surrounding the sample location. The inclusion of "small" seedlings supplements FIA's traditional seedling estimates that are limited to stems at least 1 foot tall. This regeneration indicator data improves FIA's ability to evaluate this important aspect of forest health and sustainability.

What we found

Young forest remains a minor component of the overall ecosystem as older, more mature stands continue to increase in extent. Since 1989, the area of young forest (0 to 20 years old) increased from 1 percent of the total forest area to 5 percent. The statewide trend is driven by oak/hickory and maple/beech/birch forest-type groups that make up 74 and 18 percent of West Virginia's overall forest acreage, respectively. Although the percentage of young forest increased from 1 percent to 5 percent for both these groups, young forest habitat is rare in the State.

Seventy percent of the plots have medium levels of browse of understory plants (Fig. 65A). Examination of browse impact across the State reveals that 10 percent of the plots have high levels of browse impact with most of these plots located in the Allegheny Plateau region that is characterized by relatively smaller forest patch sizes (habitat fragmentation) than the less populated areas to the south and east (Fig. 65B) (Widmann et. al. 2012).



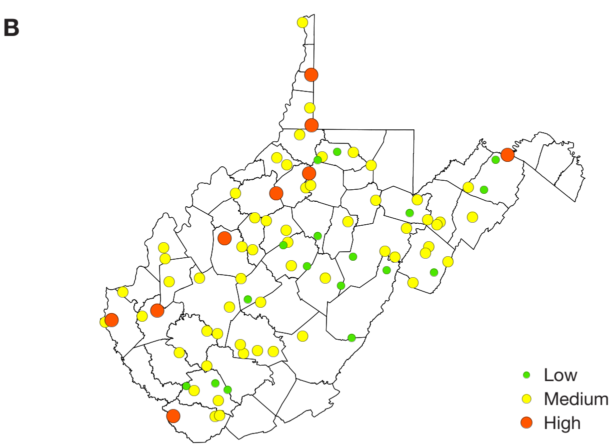


Figure 65.—Browse impact level (A) and approximate locations (B) of forested sample plots from which regeneration data was collected, West Virginia, 2012-2013. Error bars represent 68 percent confidence intervals around the estimate.

The number of seedlings is estimated at 107.8 billion, or an average of 8,400 seedlings per acre. About 80 percent of the seedlings are less than 1 foot tall, 17 percent are 1.0 to 4.9 feet, and 3 percent are 5.0 feet and taller (Fig. 66). Overall seedling abundance exhibits no apparent pattern across West Virginia (Fig. 67).

Fifty-six species or species groups are represented in the regeneration indicator samples. Maple is the most abundant genera, with 38 percent of seedlings (Fig. 68). Ash is the second most common genera at 16 percent, followed by oak (12 percent) and hickory/black walnut (3 percent). Red maple is the most prominent species, with 34 percent of all seedlings. Many of the taxa with at least 1 percent of the seedling pool are species that typically develop as understory or mid-story components, such as serviceberry spp., striped maple, and sassafras.

Comparing species abundance relative to the number of trees, by height and diameter class, highlights potential pathways for future canopy dominants. Figure 69 depicts results for select species or species groups based on the percentage each contribute to the total for each size class. Prospective "gainers" are those tree species with relatively high percentages of stems in the regeneration pool of seedlings and saplings compared to larger trees. Maple, ash, birch, and the "other species" group are the most apparent gainers. Expectations for ash should be tempered with information on the prospective demise of ash due to emerald ash borer. Prospective "losers" in the process of developing future canopy dominants are species with lower percentages in the regeneration pool than the adult pool. Potential losers are yellow-poplar, red and white oak, hickory, black cherry, eastern white pine, and Virginia pine. Some of the more uncommon oak species, namely southern red and shingle oak, have high sampling errors due to a small number of samples; these species appear to be losing ground and should be monitored closely.

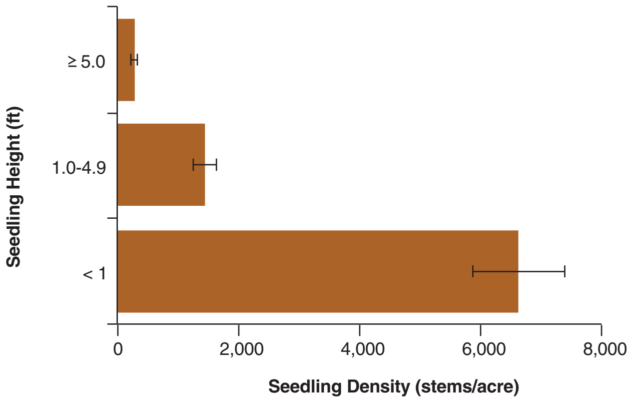
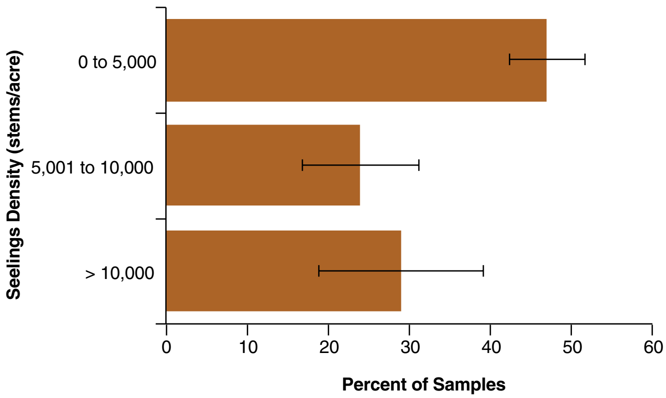


Figure 66.—Seedling density on forest land by height class, West Virginia, 2012-2013. Error bars represent 68 percent confidence intervals around the estimate.

A



B

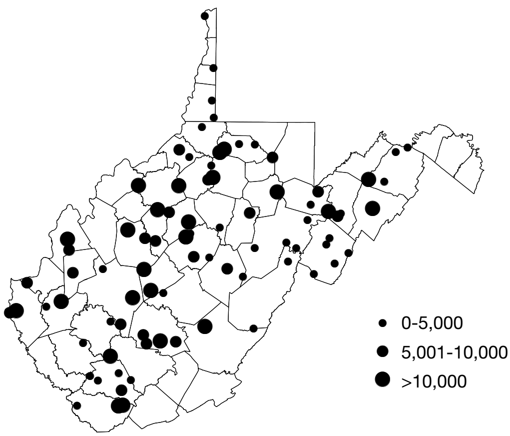


Figure 67.—Distribution (A) and approximate locations of P2+ samples (B) on forest land by number of seedlings density class, West Virginia, 2012-2013.

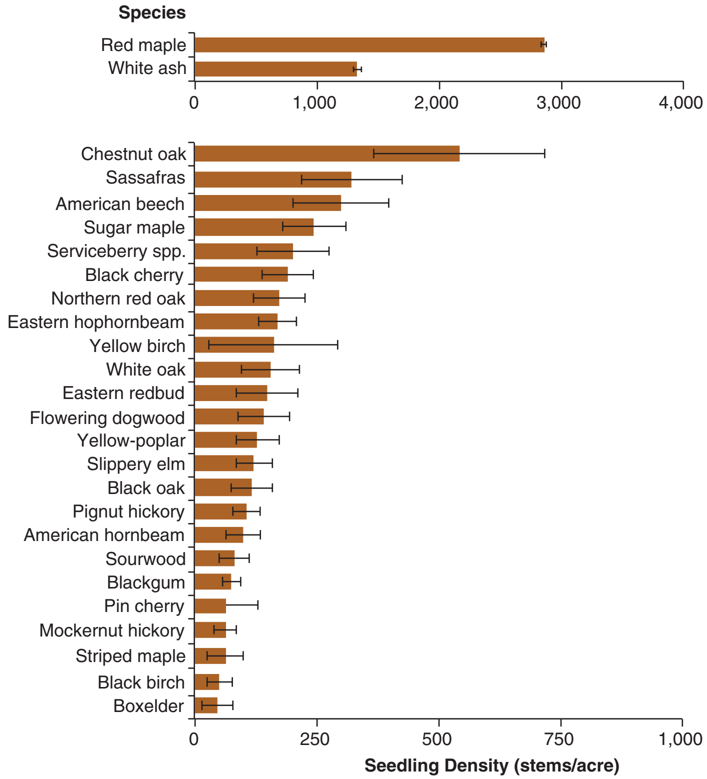


Figure 68.—Average seedling density on forest land by species, West Virginia, 2012-2013. Error bars represent 68 percent confidence intervals around the estimate.

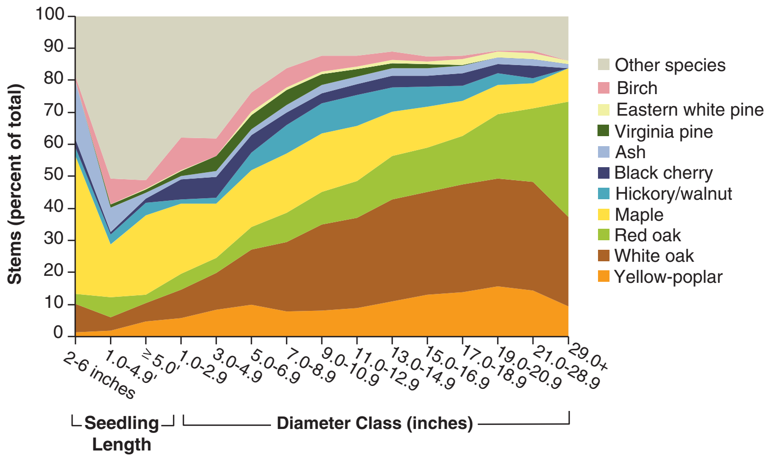


Figure 69.—Percent of total number of seedlings, live saplings, and dominant/co-dominant growing-stock trees on forest land for select species by species group and size, West Virginia. Seedling estimates are for 2012-2013. Sapling and tree estimates are for 2009-2013. Black walnut is included with hickory spp.

What this means

West Virginia forests face a variety of forest health risks and forest reproduction is an integral factor in maintaining a preferred species composition into the future. Oak/hickory is by far the most important forest-type group driving forest values in West Virginia and has been described as playing a keystone role in forest ecosystems processes (Fralish 2004). Oak regeneration difficulties are a well-known issue in the eastern United States (Holt and Fischer 1979). Existing management guides for oak provide the basis for mitigating regeneration shortages (Brose et al. 2008).

Nearly all oak regeneration in West Virginia is a result of natural advance regeneration. Xerophytic oaks depend on drought tolerance and the ability to resprout to compete and require stand replacement disturbances, i.e., disturbance and fire, to reduce competing vegetation and provide adequate light for seedling development (Brose et al. 2008, Larsen and Johnson 1998). A lack of fire and disturbance causes replacement of oaks by more mesophytic and shade tolerant species, a process described as "mesophycation" (Abrams 1992). Loss of oak/hickory forest affects not just wildlife that depend on oaks for food and cover, but a herbaceous community supporting unique flora and fauna that contributes immensely to the State's biodiversity (Fralish 2004). Although oak/hickory forests decreased by only 3 percent since 1989, maple/beech/birch forests increased by 26 percent indicating that the mesophycation process is well underway in West Virginia. The observation that maples, particularly red maple, are poised to expand in the future as stands undergo stand replacement disturbance suggest this trend will continue without intervention.

Deer browse is a serious stress factor affecting regeneration in the eastern United States (Russell et al. 2001). Eventually, most forest stands will experience either anthropogenic or natural stand replacement events (mortality or harvest) and require regeneration to establish new young forest. Management options for establishing regeneration of palatable species, such as oaks and hickories, will be driven by the level of browse pressure present.

Most of the significant species found in oak/hickory forests are under-represented in the seedling and sapling component; this has important implications for forest management and policy. Yellow-poplar, red oak, white oak, and hickory will continue to lose importance in the absence of efforts and policies directed to towards regenerating these species following stand replacement events. Sound management practices that consider existing advance regeneration, competing vegetation, available light, and the need to control deer browsing have the potential to reverse this trend (Jackson and Finley 2011), but often require significant investment.

Private forest landowners are the foundation of most benefits derived from West Virginia's forest because they control nine out of every 10 acres of forest land and timberland in the State. The relatively small forest tract size of these ownerships complicates forest policy aimed at regenerating the State's forests. About half of the family forests are in tracts less than 100 acres. The interactions of factors make it more difficult to regenerate forests but does not preclude regeneration of oak/hickory because management techniques to develop young oak/hickory forests have proven successful.

The results presented here reflect only about one-quarter of the measurements that will eventually comprise the first dataset for the regeneration indicator. The next West Virginia forest inventory will complete the dataset and will facilitate more detailed analyses and understanding of future trends in composition, structure, and health of West Virginia's forests.

Forest Habitats

Forests, woodlands and savannas provide habitats for 142 species of West Virginia birds, 58 species of mammals, and 55 species of amphibians and reptiles (NatureServe 2009). Like all states, West Virginia has developed a comprehensive wildlife conservation strategy, also known as a state wildlife action plan (West Virginia Division of Natural Resources 2005). The 2005 plan is currently in revision. Species and habitats in greatest need of conservation (SGNC) are listed in the plan. The following habitats and affected species are listed as high or very high conservation priorities in the plan:

- Red spruce forests (20 species; high conservation priority)
- Hemlock forests (19 species; very high conservation priority)
- Calcareous forests and woodlands (21 species; very high conservation priority)
- Floodplain forests and swamps (18 species; very high conservation priority)

For example, red spruce is identified as a high conservation priority due to threats from development, forest fragmentation, degradation, and the resulting impacts of habitat loss on dependent wildlife species such as northern flying squirrel (*Glaucomys sabrinus*) and Cheat Mountain salamander (*Plethodon nettingi*).

Different forest types at different structural stages (represented by tree age and diameter classes) provide natural communities (habitats) at a "coarse filter" scale of conservation. However, this coarse filter approach may be inadequate to evaluate optimal habitat for rare, imperiled, or wide-ranging wildlife species, so a "fine filter" approach is used to identify species-specific conservation needs. Representing an intermediate or "mesofilter" scale of habitat evaluation are specific features (e.g., snags, riparian forest strips), which may serve particular habitat requirements for multiple species. For example, late successional forest habitat is important for cerulean warbler (*Setophaga cerulea*), but golden-winged warbler (*Vermivora chrysoptera*) requires early successional forest habitat. We report on conditions and trends in forest attributes of forest age and stand size. One of the fine scale conservation features associated with forest habitats is the presence and abundance of snags and nest cavities. We report on the quantity and distribution of standing dead trees.

Forest Age and Stand Size

Background

Some species of wildlife depend upon early successional forests made up of smaller, younger trees, while others require older, interior forests containing large trees with complex canopy structure. Yet other species inhabit the ecotone (edge) between different forest stages and many require multiple structural stages of forests to meet different phases of their life history needs. Abundance and trends in structural and successional stages serve as indicators of carrying capacity for wildlife species (Hunter et al. 2001). Historical trends in West Virginia's forest habitats are reported for timberland, which comprises nearly 97 percent of all forest land in the State. For current habitat conditions, estimates are reported for all forest land.

What we found

The small diameter stand-size class (sizes are defined on page 35 in the Stand Size and Structure section) comprises less than 7 percent of West Virginia timberland and it decreased by 400,000 acres, or one-third, between 1989 and 2013, with most of that decrease occurring between 1989 and 2000. Similarly, the medium diameter stand-size class decreased by 1.4 million acres, a 43 percent decrease, between 1989 and 2013. In contrast, large diameter stand-size class increased by nearly 1.6 million acres, a 22 percent increase, over the same period, with less change occurring during the past 5 years (Fig. 70). Abundance of timberland in the two older age classes (81 to 100 years old and older than 100 years) has fluctuated since 1989; timberland area has increased for these older age classes during the past decade (Fig. 71). In West Virginia, all three stand-size classes contain forests from at least four age classes. Medium stand-size class is predominated by forests of 41 to 60 years of age, with lower abundance of both younger and older forest. Large stand-size class has a similar age distribution, but skewed slightly to the right, predominated by 61- to 80-year age class. Young forest (0 to 20 years) comprises the greatest area in small diameter stand-size class, with very little small diameter forest older than 20 years (Fig. 72).

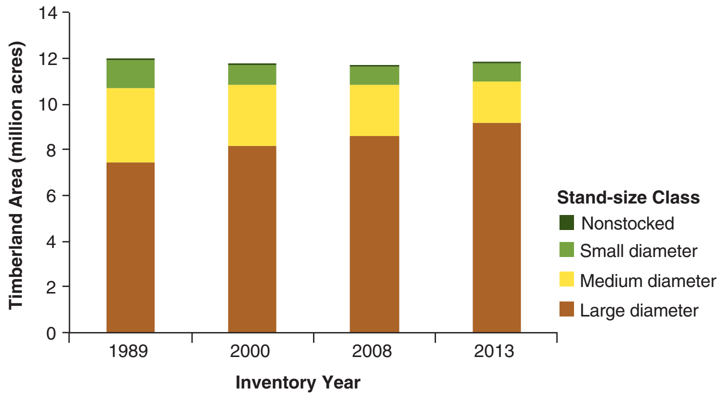


Figure 70.—Area of timberland by stand-size class and inventory year, West Virginia.

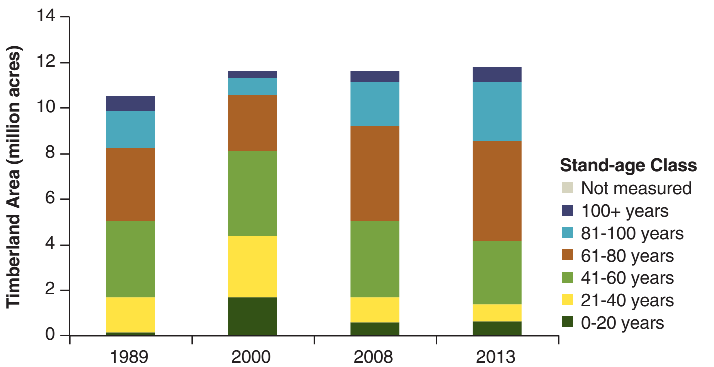


Figure 71.—Area of timberland by stand-age class and inventory year, West Virginia.

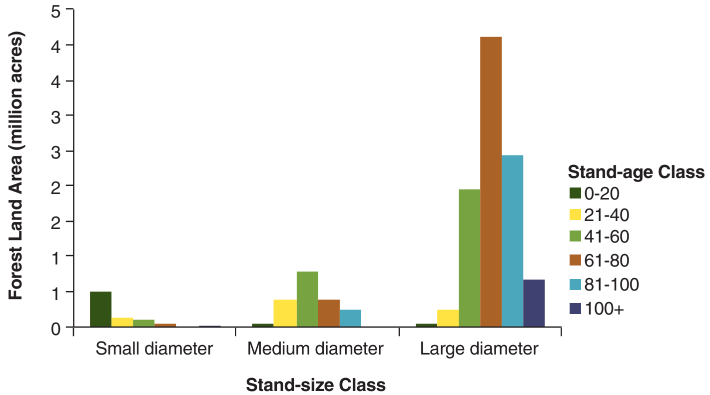


Figure 72.—Area of forest land by age class and stand-size class, West Virginia, 2013.

What this means

Increasing area in timberland of large diameter stand-size class and older age class comes at the expense of small diameter stand-size class and younger age class. Both stand-size class and stand-age class are indicators of forest structural/successional stage. More than 82 percent of 0- to 20-year-old forest is in small diameter size class, and more than 63 percent of small diameter forest is 0 to 20 years of age. Almost none of 0- to 20-year-old forest occurs in medium or large diameter stand-size class, as expected, but this characteristic is not typical of other states. There is no small-diameter forest in stand ages over 80 years, and very little in forest older than 60 years. The large diameter stand-size class includes the most age heterogeneity, including timberland in all age classes. Such mixtures of different aged or sized trees provide a vertical diversity of vegetation structure that can enhance habitat conditions for some species. Managing forest conditions in both younger and older age classes (and smaller and larger structural stages) to maintain both early and late successional habitats for a diversity of forest-associated species may conserve habitat and viable populations of many forest-associated wildlife species.

Standing Dead Trees

Background

Specific habitat features like nesting cavities and standing dead trees provide critical habitat components for many forest-associated wildlife species. FIA collects data on standing dead trees (at least 5-inch d.b.h.) of numerous species and sizes in varying stages of decay. Standing dead trees that are large enough to meet habitat requirements for wildlife are referred to as 'snags'. According to the Dictionary of Forestry, snags are defined as "…for wildlife habitat purposes, a snag is sometimes regarded as being at least 10 inches (25.4 cm) in diameter at breast height and at least 6 feet (1.8 m) tall" (Society of American Foresters 1998). Standing dead trees serve as important indicators not only for wildlife habitat, but also for past mortality events and carbon storage. And they serve as sources of down woody material (discussed elsewhere in this report), which also provides habitat features for wildlife. The number and density of standing dead trees, together with decay classes, species, and sizes, define an important wildlife habitat feature across West Virginia's forests.

What we found

More than 149 million standing dead trees are present on West Virginia forest land. This equates to a statewide density of 12.3 standing dead trees per acre of forest land, with higher densities on public (19.6) than on private (11.1) ownership classes.

Three species groups contribute more than 10 million standing dead trees (Fig. 73). The "other eastern hard hardwoods" group leads in contributions with more than 32 million, most of which are black locust (28.7 million). Nine species groups exceed 10 standing dead trees per 100 live trees (of at least 5 inches d.b.h.) of the same species group, with other eastern hard hardwoods species group again topping the list with 39 standing dead trees per 100 live trees (of at least 5 inches d.b.h.) (Fig. 74). More than 78 percent of standing dead trees are smaller than 11 inches d.b.h., with 40 percent between 5 and 6.9 inches d.b.h.; less than 5 percent are over 17 inches d.b.h. (Fig. 75), which is slightly lower than the 8 percent of live trees (of at least 5 inch d.b.h.) that are over 17 inches.

Standing dead trees are assigned to one of five decay classes. The class comprising the largest percentage of standing dead trees is the middle class (only limb stubs present; 41 percent); the class of most decay (no evidence of branches remain) comprises the smallest percentage (5 percent). The remaining three decay classes are more similar in abundance, ranging from 13 to 22 percent of standing dead trees. Distribution of decay classes are similar across diameter classes (Fig. 75).

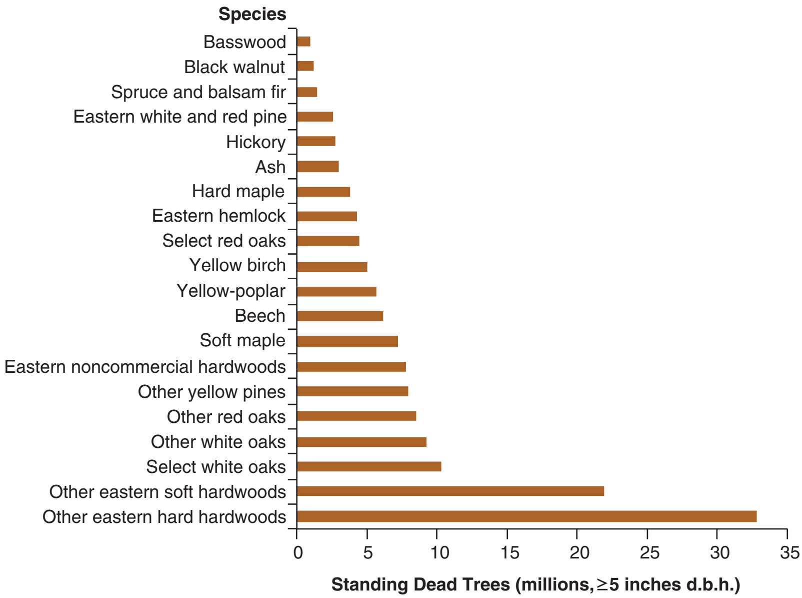


Figure 73.—Number of standing dead trees by species group, West Virginia, 2013.

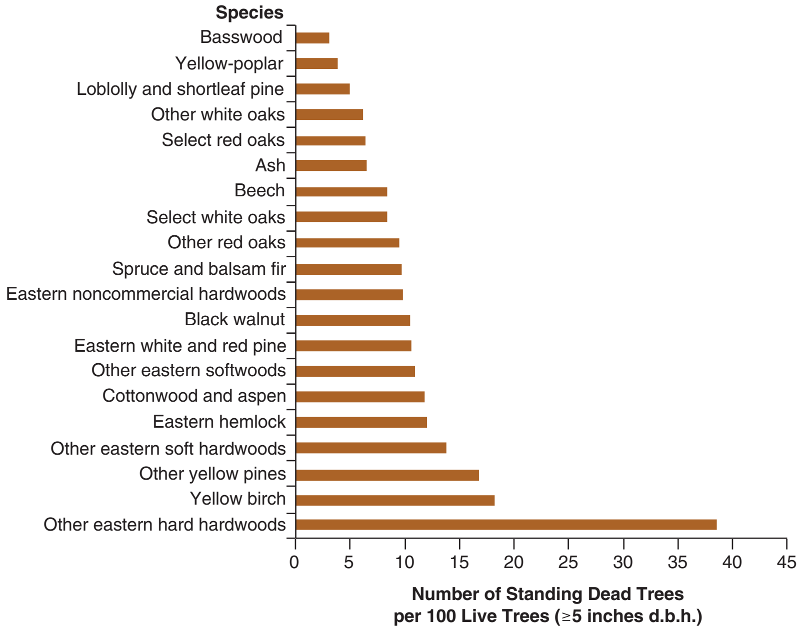


Figure 74.—Number of standing dead trees per 100 live trees by species group, West Virginia, 2013.

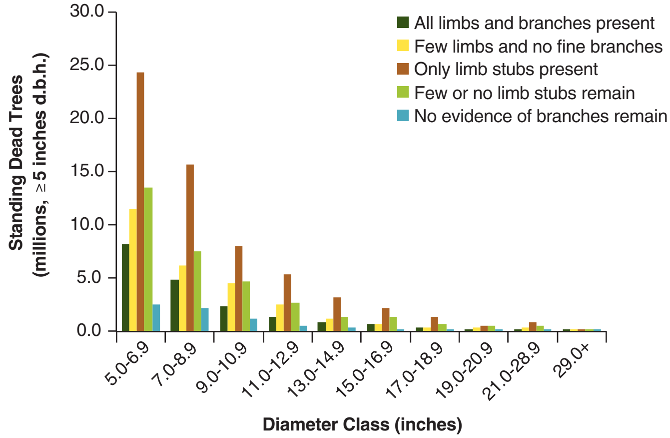


Figure 75.—Distribution of standing dead trees by decay class and diameter class for all standing dead trees, West Virginia, 2013.

What this means

Providing a variety of forest structural stages and retaining specific features such as snags allow forest managers to maintain the abundance and quality of habitat for forest-associated wildlife species in West Virginia.

There is an average 12.3 standing dead trees per acre of West Virginia forest land and 2.4 standing dead trees are present for every 100 live trees (at least 5 inches d.b.h.). Dead trees may contain significantly more cavities per tree than occur in live trees (Fan et al. 2003), thereby providing habitat features for foraging, nesting, roosting, hunting perches, and cavity excavation for wildlife, from primary colonizers such as insects, bacteria, and fungi to birds, mammals, and reptiles. Most cavity nesting birds are insectivores which help to control insect populations.

Watershed Protection

Background

West Virginia is characterized by a moist-temperate climate and a rugged well-drained landscape with an average elevation of more than 1,500 feet. The relief difference between the highest and lowest points of the state is 4,613 feet. The highest point is at Spruce Knob on the eastern continental divide in Pendleton County (4,860 feet) and the lowest point is at Harpers Ferry on the Potomac River (247 feet). The lowest point in the western part of the State is Huntington, on the Ohio River, at 564 feet in elevation. Rainfall in the State averages 44 inches per year, although at higher elevations on the west side of the Allegheny Mountains, rainfall of 60 inches or more per year is common, while on the east side of the Allegheny Mountains rainfall is about half as much because of the rain shadow effect of the mountains.

During the early 20th century, unregulated logging, overgrazing, and wildfires resulted in damaged landscapes throughout West Virginia. The deforested landscapes were susceptible to rapid runoff of storm water and soil erosion that intensified flash flooding. Pittsburgh and other places along the Monongahela River suffered from periodic flooding, including major floods in 1888 and 1907. In 1911, public pressure for the Federal Government to buy degraded lands in the eastern portion of the Nation resulted in passage of the Weeks Act by the U.S. Congress (Forest History Society 2013). One of the principle objectives of the bill was for the Federal Government to purchase lands within the watersheds of navigable streams to regulate flow. The act allowed for the U.S. Forest Service to manage the purchased lands and resulted in the 1920 establishment of the Monongahela National Forest.

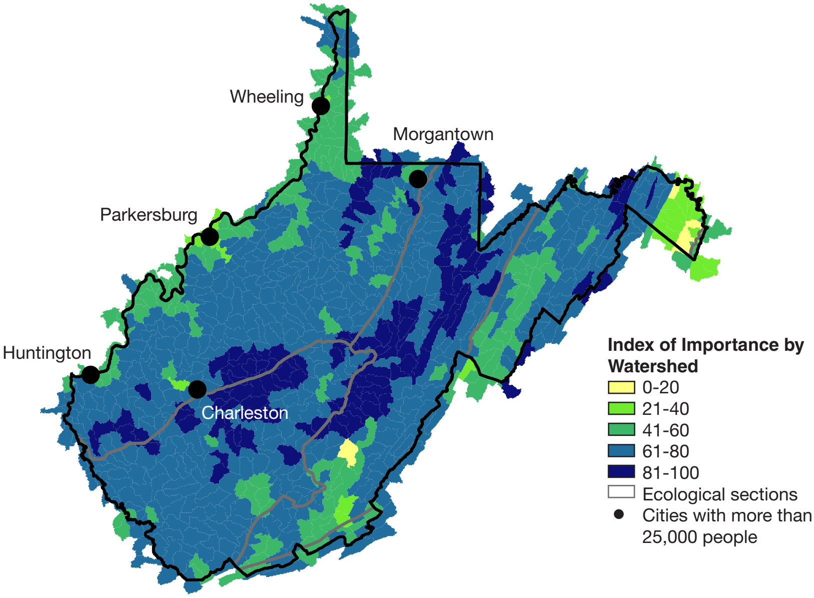
Watersheds in West Virginia drain to the east through Maryland and Virginia by way of the Potomac and James Rivers to Chesapeake Bay and in the west, to the Ohio River mostly by way of the Monongahela, Kanawha, and others rivers that feed directly into the Ohio River.

What we found

Data from the Forest Service's Forests to Faucets project (U.S. Forest Service n.d.) was used to evaluate the importance of West Virginia's forests for contributions to water quality. Importance values are reported in a nationwide relative index ranging from 0 (no importance) to 100 (most important) (Fig. 76). Much of the State is covered in forests that are important for surface drinking water. The Allegheny Mountains ecoregion has the largest area of watersheds in the highest category of importance for surface drinking water (Fig. 76a), but the ecoregion that has the largest area of private forest importance is the Northern Cumberland Mountains (Fig. 76b). Very little of West Virginia's forests that are important for surface drinking water are threatened by development (Fig. 76d) or wildland fire (Fig. 76e).

The Ohio River watershed encompasses 85 percent of West Virginia land area and is 80 percent forested. Watersheds that drain east to the Chesapeake Bay account for 15 percent of the State land area and are 72 percent forested.

A) Forest importance to surface drinking water.



B) Private forest importance to surface drinking water.

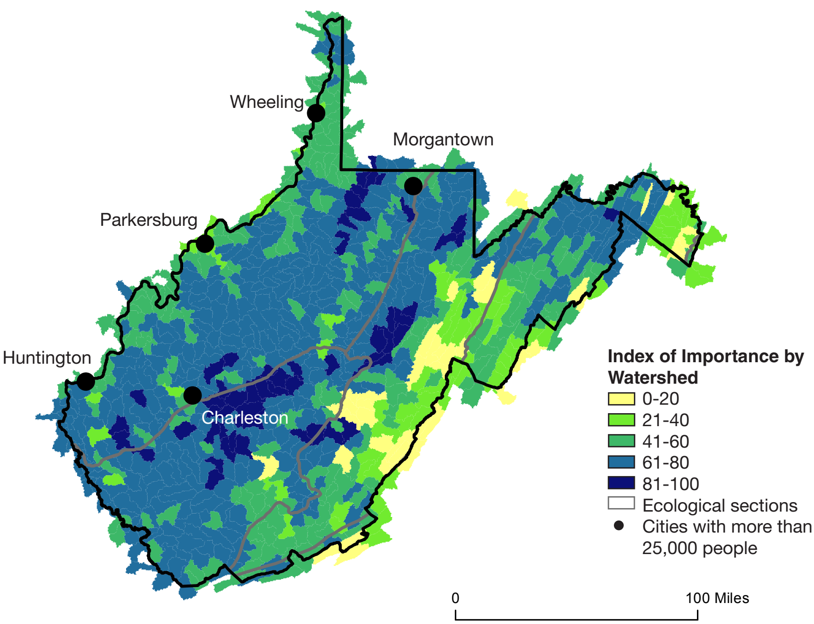
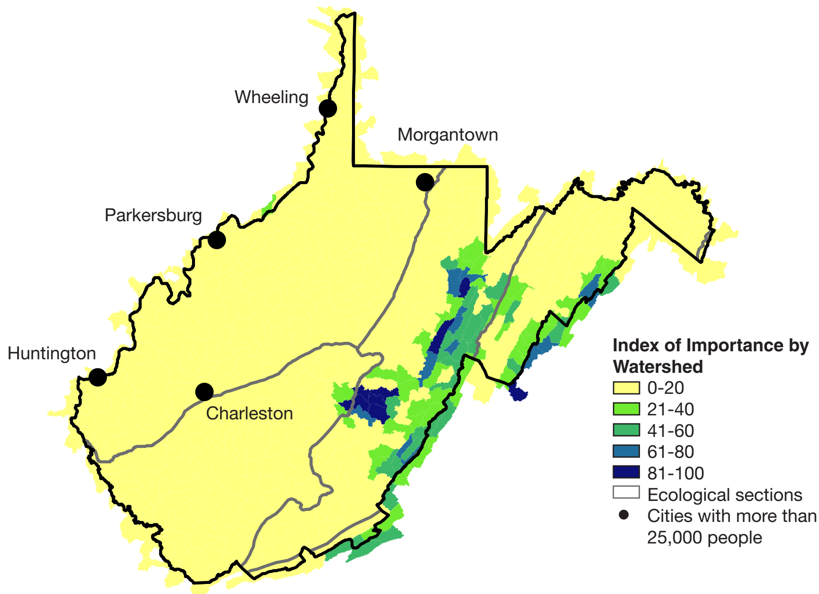


Figure 76.—Importance values to surface drinking water, West Virginia. (Continued on next page)

C) NFS forest importance to surface drinking water.



D) Development threat to forests important to surface drinking water.

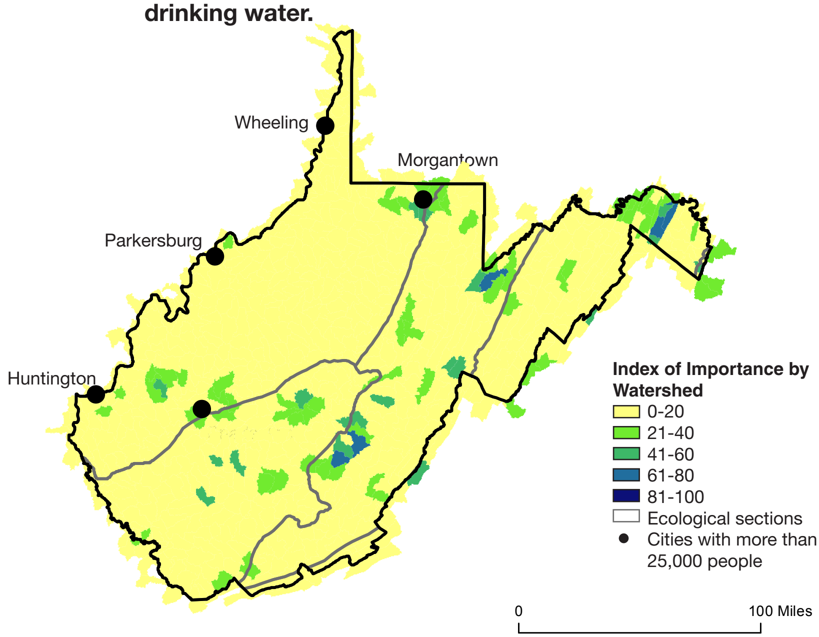


Figure 76. (Continued)—Importance values to surface drinking water, West Virginia. (Continued on next page)

E) Wildland fire threat to forests important to surface drinking water.

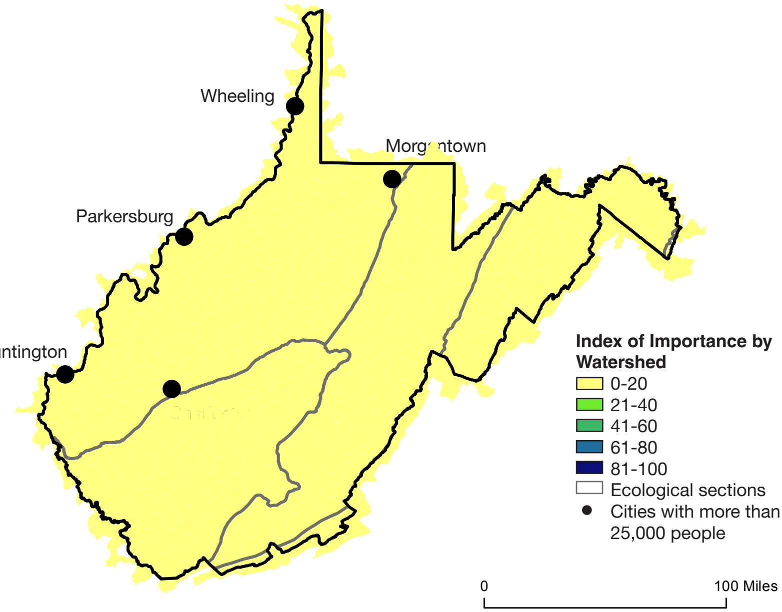


Figure 76. (Continued)—Importance values to surface drinking water, West Virginia.

Forests in West Virginia are particularly important for surface drinking water in three ecological sections: Allegheny Mountains, Northern Cumberland Mountains, and the Southern Unglaciated Allegheny Plateau ecoregion are slightly less important to surface drinking water than the forests of the Northern Ridge and Valley. The forests held and managed by private land owners are much more important to surface drinking water than public forest lands (Fig. 77).

Another important link between forests and clean water occurs in riparian zones—those areas of land bordering streams, rivers, and lakes. These riparian forests serve to protect water quality by reducing surface runoff to streams, limiting sediment and nutrient runoff to surface waters. We used the National Land Cover Dataset (2011) (Homer et al. 2015) to evaluate the land use within the riparian zone—200 feet of perennial streams and 100 feet of intermittent streams—and to determine the proportion of the riparian zone that is developed versus forested. West Virginia has very well-forested riparian zones, which benefits the water quality in the State (Fig. 78).

Generally, as the elevation of a site increases, it is more likely to be publicly owned. Only 5 percent of the forest land that is less than 2,000 feet in elevation is in public ownership, whereas 46 percent of forest land in the 3,000 to 4,000 foot elevation

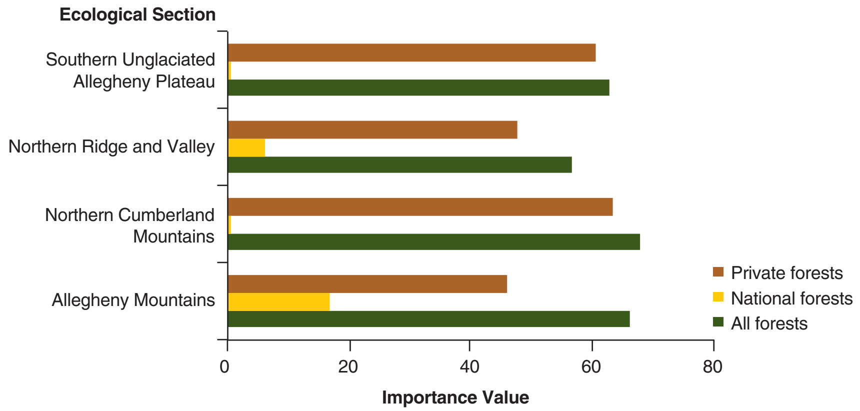


Figure 77.—Average importance of surface drinking water by ecoregion and ownership, West Virginia.

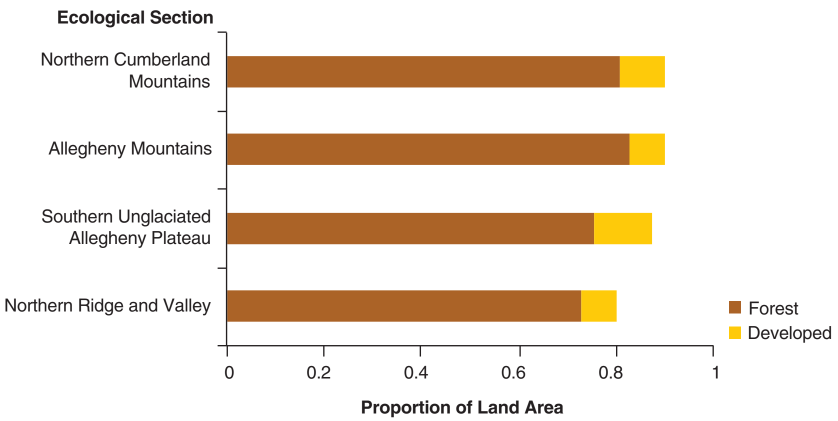


Figure 78.—Proportion of forest and developed land in riparian zones by ecoregion, West Virginia, 2011.

class is publicly owned and 87 percent of forest land over 4,000 feet in elevation are in public ownerships (Fig. 79). Of the 1.6 million acres in public ownership in West Virginia, 66 percent is managed by national forests in the State. Ninety-five percent of the national forest land is above 2,000 feet in elevation.

Many forests in West Virginia grow on steep slopes which causes its forests to be particularly vulnerable to soil erosion caused by land disturbance (Fig. 80). Thirty-eight percent (4.6 million acres) of forest land in the State is on land with a slope of 40 percent or greater and only 23 percent (2.8 million acres) of the forest land has a slope of 20 percent or less. There is little difference in the ownership category of forest land by slope.

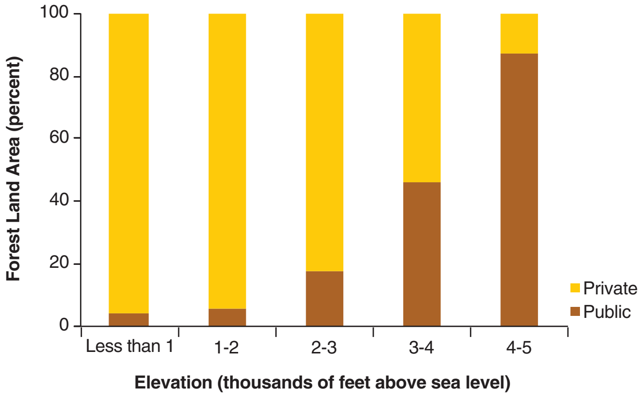


Figure 79.—Proportion of forest land by elevation and major ownership group, West Virginia, 2013.

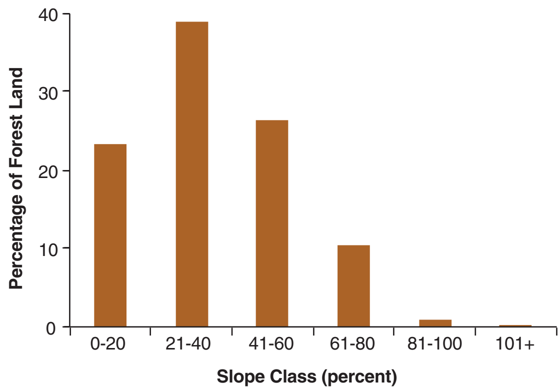


Figure 80.—Proportion of forest land by slope class, West Virginia, 2013. Percent slope is the rise in land divided by the horizontal distance.

What this means

The moist-temperate climate of West Virginia contributes not only to the high production of quality hardwood, but also produces abundant volumes of fresh water. Forests in the State include the headwaters of several important rivers with many downstream communities dependent on water flowing out of the State. The larger percentage of publicly owned high-elevation forests means that the headwaters of many watersheds are on public land. This reflects the objectives of the Weeks Act that guided purchases of National Forest land in the State. Because management of publicly owned forests is typically restricted by more rules and regulations than privately owned forest, public ownership brings a higher level of protection for these unique and often more vulnerable forests. Forested watersheds provide water purification, mitigation of floods and droughts, improve low-water navigation, retention of soil, maintain wildlife habitats, and produce timber products. Maintaining low-water navigation on the Monongahela, Kanawha, and Ohio Rivers are of particular importance because of the commercial transportation of goods. The U.S. Army Corps of Engineers has constructed several large dams and reservoirs in West Virginia to regulate river flows. Though the original intent of much of the land purchased for national forests was primarily for watershed protection, these lands today provide many additional ecological services plus opportunities for recreation.

Surface runoff is rare in forest environments as most rainfall moves to streams by subsurface flow pathways where nutrient uptake, cycling, and contaminant absorption processes are rapid (Neary et al. 2009). Because of the dominance of subsurface flow processes in forests, peak flows are moderated and base flows are prolonged. The abundance of steep slopes in West Virginia causes its forests to be particularly vulnerable to soil erosion caused by land disturbance. Because surface runoff and soil erosion is minimal from forested landscapes, keeping land in forest is important to maintaining high quality water in West Virginia. To insure soil erosion is kept to a minimum during forest management operations, the State has mandated a set of best management practices be followed when timber is harvested (West Virginia Division of Forestry 2005).

Invasive Plant Species

Background

Invasive plant species (IPS) are both native and nonnative species that can cause detrimental ecological effects. These species can quickly invade forests and change light, nutrient, and water availability. IPS can form dense monocultures which not only reduce tree regeneration but also impact wildlife habitat by altering forest structure and forage availability. Aside from the effects invasive species cause in forested environments, they can also impact agricultural systems. An example is common barberry (scientific names of IPS are found in Table 7), an alternate host for wheat stem rust, which can cause the complete loss of grain fields. Common buckthorn is another troublesome IPS as it is an alternate host for the soybean aphid (*Aphis glycines*). While there are some beneficial uses for these invaders (e.g., culinary, medicinal, and soil contaminant extraction [reed canarygrass]) (Kurtz 2013), the detrimental effects can be significant. Each year the inspection, management, and mitigation of IPS costs billions of dollars.

Table 7.—The list of 39 invasive plant species and 1 undifferentiated genera monitored by the Northern Research Station on FIA P2 invasive plots, 2007 to present

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

What we found

During the 2013 inventory, a subset of 324 P2 plots were monitored for the presence of 40 IPS (39 species and 1 undifferentiated genus) (Table 7) in West Virginia. Field crews observed 21 of the 40 IPS monitored species (Table 8). Multiflora rose is the most commonly observed IPS (60 percent of P2 invasive plots) and is found throughout the State (Fig. 81). This aggressive shrub produces an abundance of seeds, survives in harsh environments, and has been promoted by various organizations for erosion control as well as wildlife and food cover. These characteristics have made multiflora rose a very successful invader and it is the most common IPS of the 40 monitored by the Northern Research Station FIA (Kurtz and Hansen 2013). Black locust (38 percent) and Nepalese browntop (36 percent) are the next most commonly observed IPS and both occur on more than one-third of the plots.

Table 8.—Invasive plant species observed P2 invasive plots, West Virginia, 2013

Name	Observances	Percentage of plots
Multiflora rose	193	59.6
Black locust	122	37.7
Nepalese browntop	118	36.4
Autumn olive	75	23.1
Tree of heaven	54	16.7
Nonnative bush honeysuckles	53	16.4
Japanese honeysuckle	53	16.4
Japanese barberry	39	12
Garlic mustard	29	9
Oriental bittersweet	21	6.5
European privet	10	3.1
Princesstree	8	2.5
Creeping jenny	7	2.2
Japanese meadowsweet	5	1.5
Common barberry	4	1.2
Japanese knotweed	3	0.9
Bull thistle	2	0.6
Canada thistle	1	0.3
Dames rocket	1	0.3
Giant knotweed	1	0.3
European cranberrybush	1	0.3

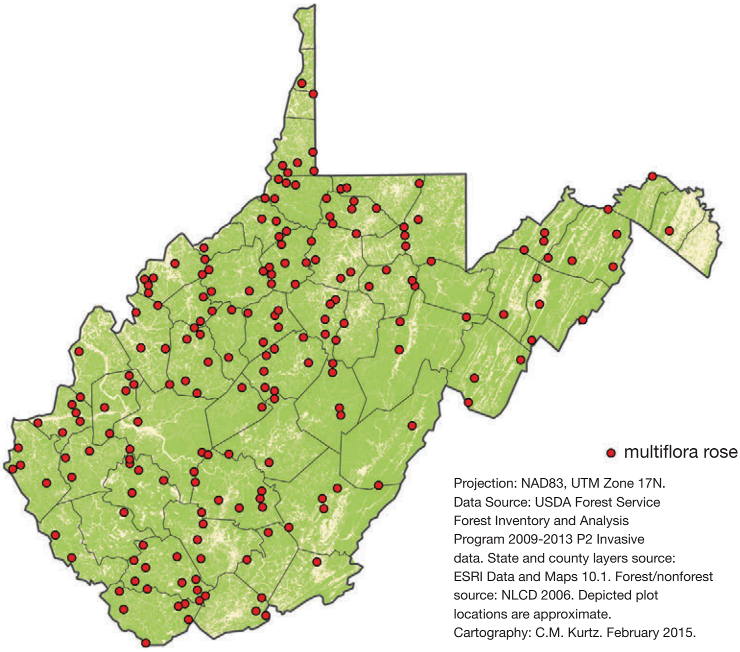


Figure 81.—Distribution of multiflora rose on P2 invasive plots, West Virginia, 2013. Plot locations are approximate.

Over 79 percent of the plots have one or more of the monitored IPS. The number of IPS per plot range from 0 to 9 (Fig. 82). Figure 83 shows the distribution of plots where IPS were found. IPS are fairly homogeneous throughout the State with the highest number in the western, northern, and northwestern parts. Note that not all populations are documented as the IPS inventory is a survey of forested land, so areas with less forest have fewer plots.

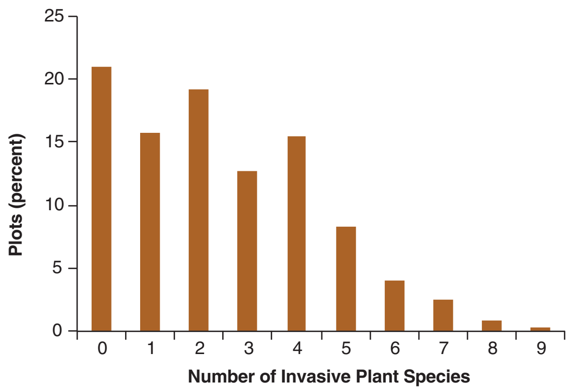


Figure 82.—Proportion of P2 invasive plots by number of invasive plant species observed, West Virginia, 2013.

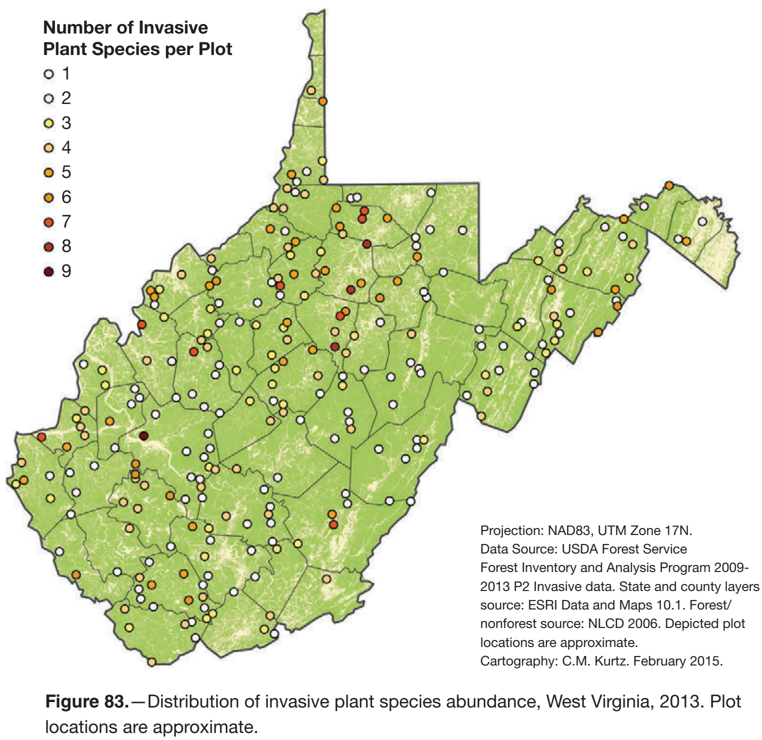


Figure 83.—Distribution of invasive plant species abundance, West Virginia, 2013. Plot locations are approximate.

Multiflora rose is the most commonly observed IPS throughout the period between 2008 and 2013. However, IPS are observed on a higher portion of plots in 2013 compared to the previous inventory (60 percent of plots versus 48 percent of plots in 2008) (Widmann et al. 2012). In both survey periods, 21 of the 40 IPS were recorded. However there were slight differences in the less common IPS; reed canarygrass, common buckthorn, and leafy spurge were observed only in 2008 and dames rocket, giant knotweed, and European cranberrybush were observed only in 2013.

What this means

West Virginia's forests have fewer plots invaded (79 percent) than neighboring Ohio where 93 percent of plots have one or more of the monitored IPS. Ohio also has a greater number of the monitored IPS (28 species) (Widmann et al. 2014) than West Virginia (21). The presence of IPS within West Virginia's forests is of concern, and it is important that these species are monitored over time to ensure that managers and the general public are aware of their occurrence and spread.

IPS are good competitors and can alter forested ecosystems by displacing native species and impacting the fauna that depend upon the native species. Several factors contribute to IPS success including prolific seed production, rapid growth rate, vegetative propagation, and hardiness in harsh conditions. Invasion by IPS can be exacerbated by many factors such as ungulates, development, forest fragmentation, and timber harvesting. When forests are invaded, IPS have the potential to negatively impact the carbon budget by reducing future tree cover. Furthermore, IPS can cause negative economic implications by reducing timber yield and aesthetics. Further investigation of the inventory data may help to reveal influential site characteristics and regional trends.

Forest Pests

Beech Bark Disease

Background

American beech is a major component of the maple/beech/birch forest-type group, which comprises 18 percent of the forest resource (by area) in West Virginia (Figs. 1, 3). American beech is an important pulpwood and firewood species and is also important for wildlife due to the hard mast that it produces. Beech bark disease (BBD) is an insect-fungus complex involving the beech scale insect (*Cryptococcus fagisuga* Lind.) and the exotic canker fungus *Neonectria coccinea* (Pers.:Fr.) var. *faginata* Lohm. or the native

Neonectria galligena Bres. that kills or injures American beech. Three phases of BBD are generally recognized: 1) the advancing front, which corresponds to areas recently invaded by scale populations; 2) the killing front, which represents areas where fungal invasion has occurred (typically 3 to 5 years after the scale insects appear, but sometimes as long as 20 years) and tree mortality begins; 3) the aftermath forest, which are areas where the disease is endemic (Houston 1994, Shigo 1972). BBD was inadvertently introduced via ornamental beech trees at Halifax, Nova Scotia, in 1890 and then began spreading to the south and west. By 1999 beech bark disease had been discovered in several counties in West Virginia and currently 12 counties have known infestations, including the portion of the State where beech densities are highest (Fig. 84).

What we found

The annual mortality rate for American beech by live volume is more than twice as high in the infested counties compared to counties where infestation has not been reported (2.2 percent versus 1 percent outside). The impacts of BBD mortality have resulted in reductions of large diameter beech along with corresponding increases in small diameter beech since 1989 (Fig. 85). The number of beech seedlings also increased slightly between 2008 and 2013.

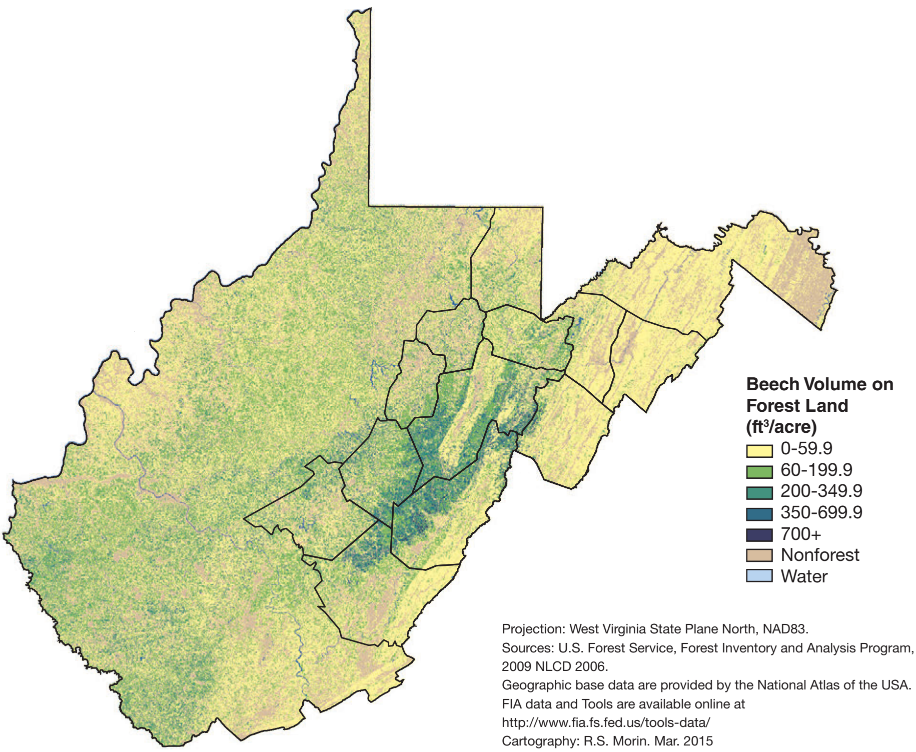


Figure 84.—American beech volume per acre (trees at least 5 inches d.b.h.) on forest land, West Virginia, 2009. Counties where beech bark disease has been detected are outlined on the map.

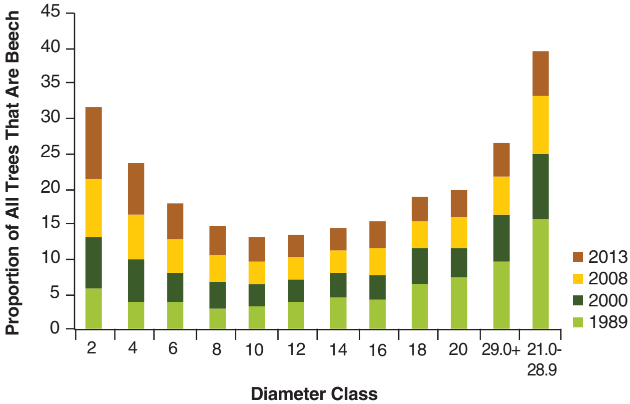


Figure 85.—Proportion of all trees on timberland that are American beech by diameter class and inventory year, West Virginia.

What this means

Most of the forest area that is infested by BBD is in the killing front phase. Killing front forests are often characterized by mortality of large beech trees along with increasing amounts of beech seedlings and saplings. This condition, often referred to as "beech brush," can interfere with regeneration of other hardwood species such as sugar maple (Hane 2003) and is characterized by trees with low vigor and slow growth that often succumb to the disease before growing into the overstory. These trees are also unlikely to reach sawtimber size or produce mast that is important for wildlife.

Hemlock Woolly Adelgid

Background

Eastern hemlock is a minor component of the forest resources in West Virginia. However, due to its high value as a timber species, the wildlife habitat it provides, and the unique niche it fills in riparian areas, it is an ecologically important species. Forests with the highest proportion of hemlock volume are located in Northern Cumberland Mountain and Allegheny Mountain ecoregions (Fig. 86; see also Fig. 1). Hemlock woolly adelgid (HWA; *Adelges tsugae*) is native to East Asia and was first noticed in the eastern United States in the 1950s (Ward et al. 2004). Since then, it has slowly expanded its range; in areas where populations are established, they often reach high densities, causing widespread defoliation and sometimes mortality of hosts. (McClure et al. 2001, Orwig et al. 2002). Mortality generally begins to increase dramatically after about 15 years of infestation (Morin and Liebhold 2015).

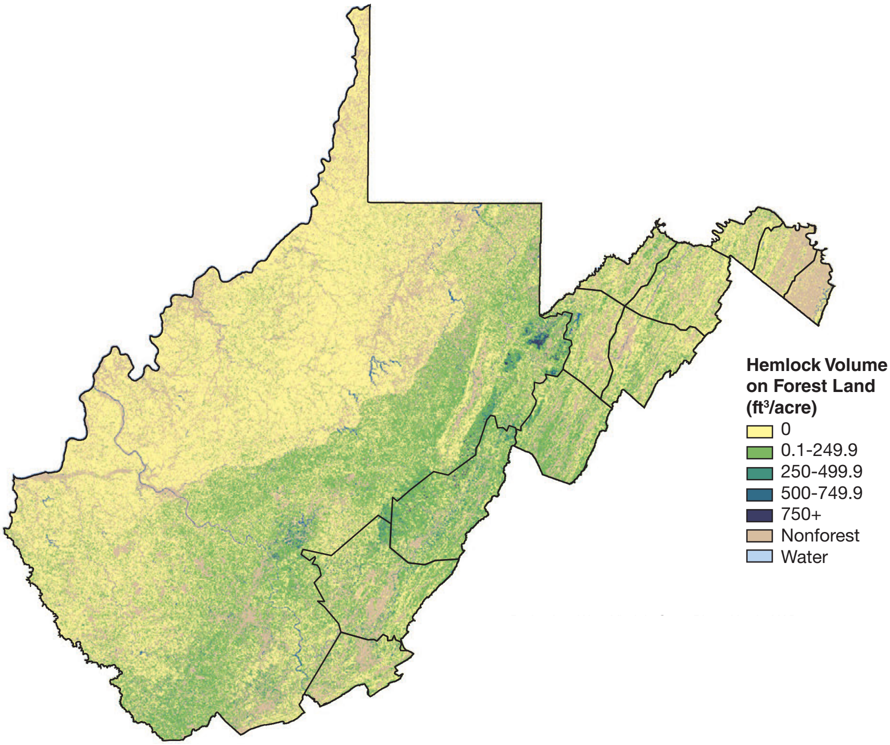


Figure 86.—Eastern hemlock volume per acre (trees at least 5 inches d.b.h.) on forest land, West Virginia, 2009. Counties where hemlock woolly adelgid was detected at least 15 years ago are outlined on the map.

What we found

HWA was first discovered in the eastern panhandle in the early 1990s and it has since spread across most of the State. The ratio of standing dead to live hemlock trees has increased substantially since 2000 in counties infested by HWA for 15 years or more (Fig. 87). Although hemlock volume continues to increase in those areas that are uninfested or where HWA has been present for less than 15 years, hemlock volume has begun to decrease where HWA has been present for 15 or more years (Fig. 88).

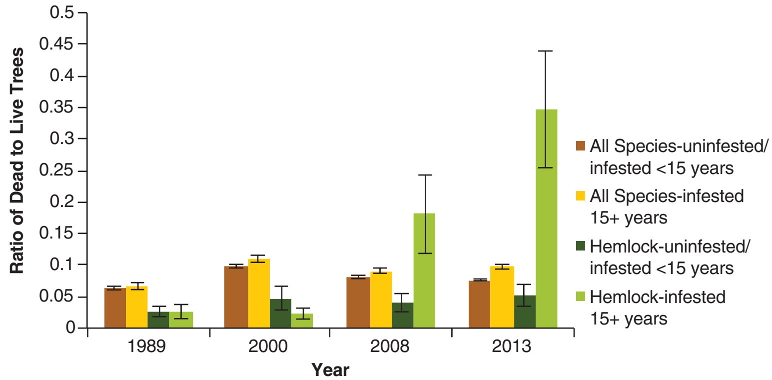


Figure 87.—Ratio of dead to live trees, all species and hemlock, on timberland by hemlock woolly adelgid infestation status and inventory year, West Virginia. Error bars represent 68 percent confidence intervals around the estimate.

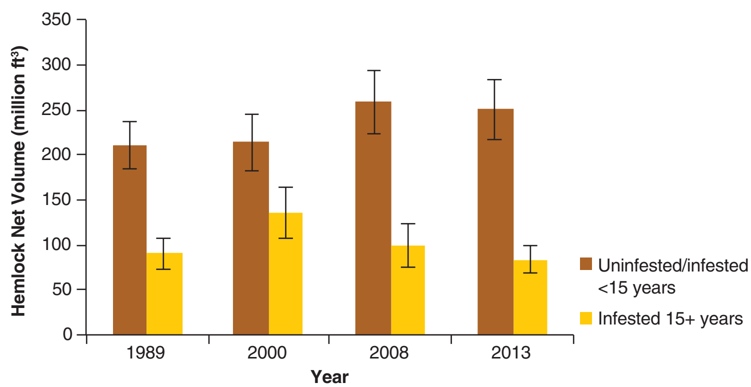


Figure 88.—Net volume of eastern hemlock on timberland by hemlock woolly adelgid infestation status and inventory year, West Virginia. Error bars represent 68 percent confidence intervals around the estimate.

What this means

HWA has already spread across most of West Virginia. Mortality of hemlock and proportion of standing dead trees has increased substantially in areas where HWA has been present for 15 years more. Some of the areas of the State with the highest densities of hemlock have not been infested long enough to have suffered major impacts yet, but hemlock mortality is likely to increase substantially in the near future. The loss of hemlock as a result of HWA invasion has been shown to have impacts on ecosystem properties such as stream temperatures and soil chemistry (Orwig et al. 2008, Stadler et al. 2005) so the status of this important species needs continued monitoring.

Emerald Ash Borer

Background

Emerald ash borer (*Agrilus planipennis;* EAB) is a wood-boring beetle native to Asia that is a pest of all North American ash. While there is some insect preference for stressed trees, trees greater than 1 inch in diameter are susceptible regardless of vigor. Since its 2002 discovery in southeastern Michigan, EAB has spread across the eastern half of the United States and has been identified in 25 states by early 2015. EAB was detected in West Virginia in 2007.

What we found

West Virginia is home to an estimated 138.5 million ash trees (≥1 inch d.b.h.) that account for 764.6 million ft^3 of live tree volume on forest land. White ash is the most common species, making up 97 percent of total ash abundance. Ash is widely distributed across the State, though it is rarely the most abundant species in a stand (Fig. 89). Since 2000, the rate of ash mortality has doubled, reaching 0.68 percent in 2013 (Fig. 90).

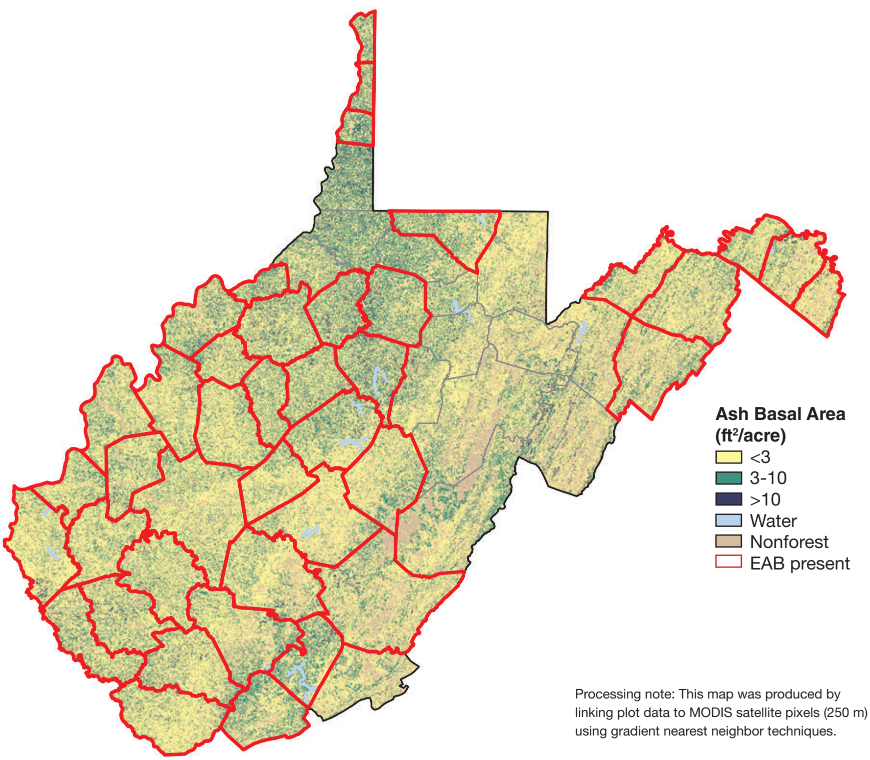


Figure 89.—Distribution of ash on forest land, West Virginia, 2009. Counties where emerald ash borer is present as of April 28, 2015, are outlined on the map.

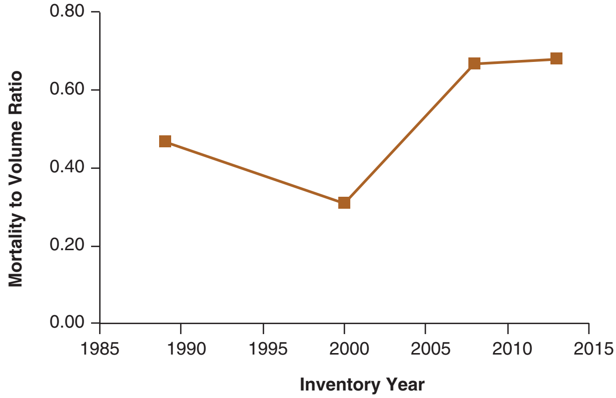


Figure 90.—Ratio of average annual mortality of ash growing-stock volume to live ash growing-stock volume on timberland by inventory year, West Virginia.

What this means

EAB has caused extensive ash mortality throughout the eastern United States and represents a significant threat to the ash resource in West Virginia. While naturally aging forests are one of the underlying causes of increased mortality, there has been a dramatic rise in ash mortality since the 2000 inventory. As EAB continues to spread, the loss of ash in forested ecosystems will affect species composition and alter community dynamics. Continued monitoring of ash resources will help to identify the long-term impacts of EAB in the State.

Gypsy Moth

Background

The European gypsy moth (*Lymantria dispar*) was first introduced into West Virginia in the mid 1980s. Since then, periodic outbreaks have occurred and large areas of forest were defoliated by this invasive insect, making it the most destructive forest pest in the State. The largest outbreaks occurred in the early 2000s when nearly 1 million acres were defoliated over a 2-year period. Aerial surveys in 2005 to 2007 determined that gypsy moth populations were once again on the rise and were the likely cause of defolition on nearly 500,000 acres in the State (U.S. Forest Service n.d.).

What we found

About 38 percent of the live tree volume in West Virginia's forests is preferred by gypsy moth. The most abundant preferred species in West Virginia are the oaks. The density of preferred gypsy moth host species is highest in the eastern panhandle of West Virginia (Fig. 91), and gypsy moth defoliation events have occurred most often in that same area (Fig. 92). Between 2000 and 2002 more than 1 million acres were defoliated (Fig. 93). Most of the defoliated area occurred in the oak/hickory forest-type group.

What this means

Gypsy moth has been impacting the forests of West Virginia for 40 years. During that time defoliation has been cyclical with peaks every 5 to 10 years (Fig. 93). Defoliation has an impact on the health and survival of host tree species (Morin and Liebhold 2016). The West Virginia Department of Agriculture has a comprehensive suppression program to reduce the impacts of gypsy moth which includes aerial spray when gypsy moth population cycles peak.

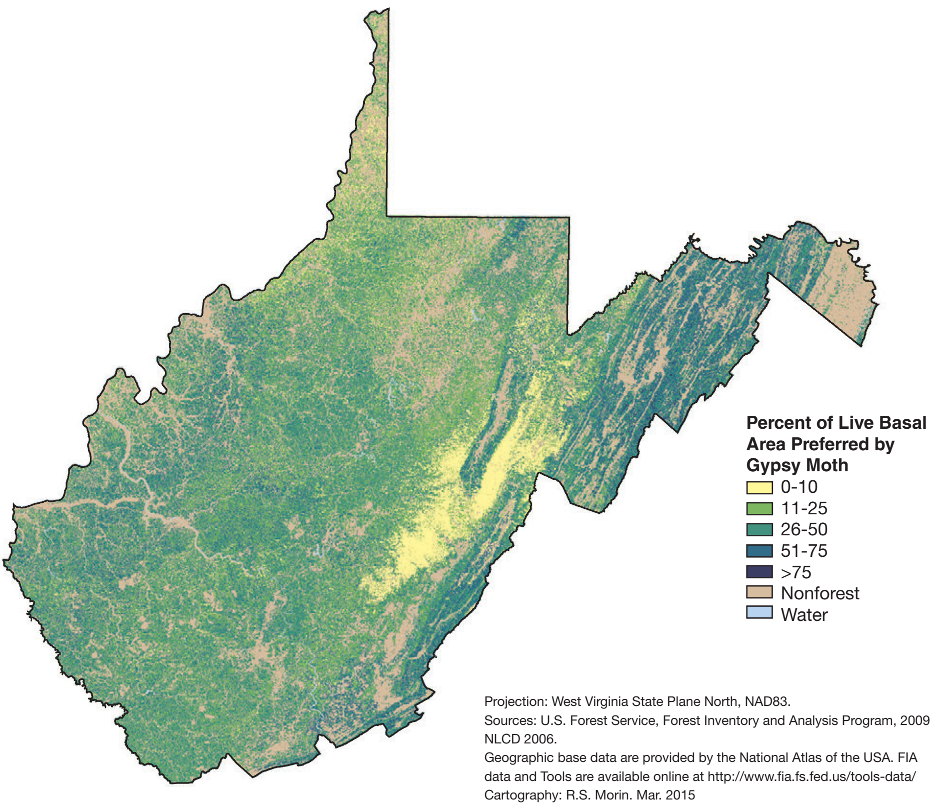


Figure 91.—Percentage of live basal area of trees preferred by gypsy moth, West Virginia, 2009.

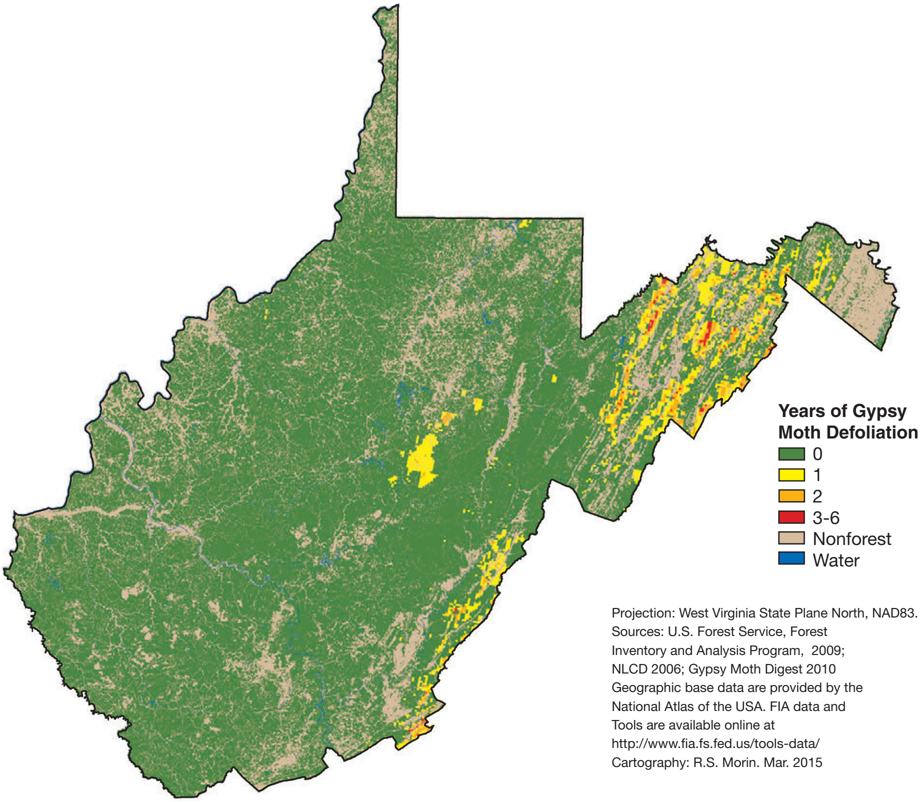


Figure 92.—Years of gypsy moth defoliations, 1997 to 2010.

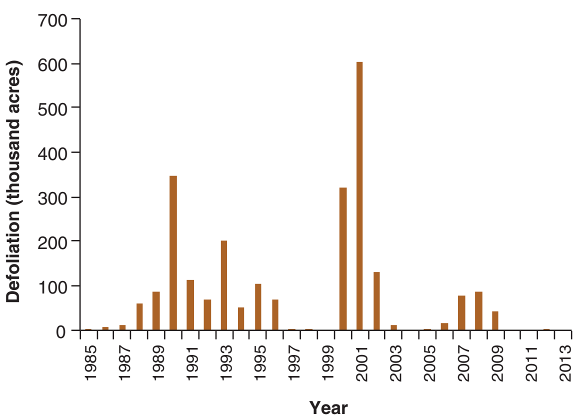


Figure 93.—Acres of gypsy moth defoliation by year, West Virginia, 1985 to 2013. (U.S. Forest Service, n.d.).

Forest Products

Background

The harvesting and processing of timber products produces a stream of income shared by timber owner, managers, marketers, loggers, truckers, and processors. The wood products and paper manufacturing industries in West Virginia employed 5,600 people in 2012, with an average annual payroll of $211 million (U.S. Census Bureau 2015). To better manage the State's forests, it is important to know the species, amounts, and locations of timber being harvested.

A canvass of West Virginia's wood-processing mills is conducted periodically to estimate the amount of wood that is harvested and processed into products. The last survey was conducted in 2007. For this report, the 2007 survey results, minus any known mills that have closed since the 2007 mill survey, is supplemented by the most recent surveys conducted in surrounding states that processed wood harvested from West Virginia.

What we found

There are 95 active primary wood processing mills that processed 143.2 million cubic feet of industrial roundwood, a decrease of 11 percent from 2007 (Piva and Cook 2010). Eighty-two percent of the industrial roundwood processed by West Virginia mills comes from the forest land of West Virginia.

A total of 155.1 million cubic feet of industrial roundwood was harvested from West Virginia's forest land, a decrease of 18 percent from 2007 (Fig. 94). Saw logs account for half of the total industrial roundwood harvested; pulp and composite

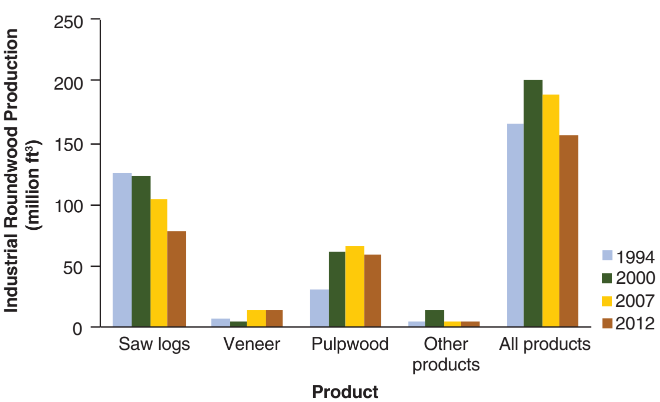


Figure 94.—Industrial roundwood production by product and year, West Virginia.

panel products make up another 38 percent. Other products harvested are veneer logs, cooperage, posts, mine timbers, and other miscellaneous products. Yellow-poplar accounts for a quarter of the total industrial roundwood harvest (Fig. 95). Other important species groups harvested are the red oaks, white oaks, white pine, and other pines. In the process of harvesting industrial roundwood, 80.8 million cubic feet of harvest residues were left on the ground, of which nearly one-third was merchantable material. The processing of industrial roundwood generates 1.8 million green tons of wood and bark residues. More than half of the mill residues generated are used for fiber products at pulp and composite panel mills. Other major uses of the mill residues are industrial fuelwood (19 percent) and mulch (14 percent). Only 1 percent of the mill residues are not used for other products (Fig. 96).

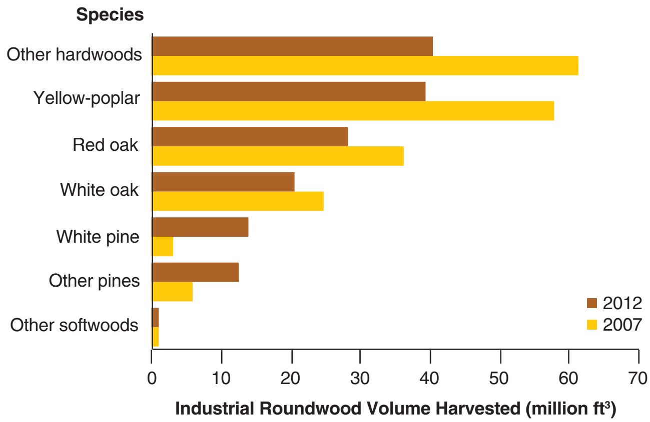


Figure 95.—Industrial roundwood volume harvested by species group, West Virginia, 2007 and 2012.

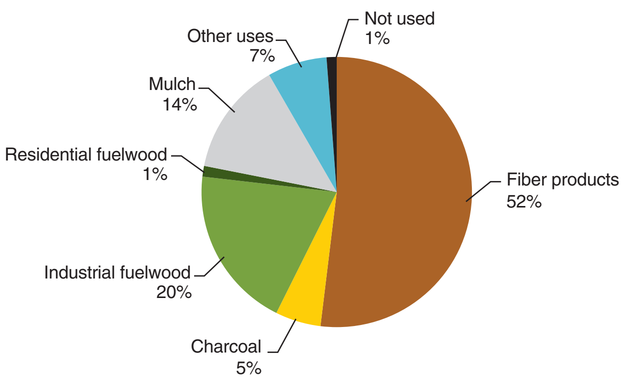


Figure 96.—Uses of mill residues generated by primary wood-using mills, West Virginia, 2012.

The number of employees working in the forest products industry decreased nearly 38 percent since 2007 (Fig. 97) (U.S. Census Bureau 2015), but annual payroll decreased by only 26 percent during that same period. Total value of shipments decreased by 43 percent between 2007 and 2009, then rebounded by 34 percent between 2009 and 2012 for an overall decrease of 23 percent between 2007 and 2012.

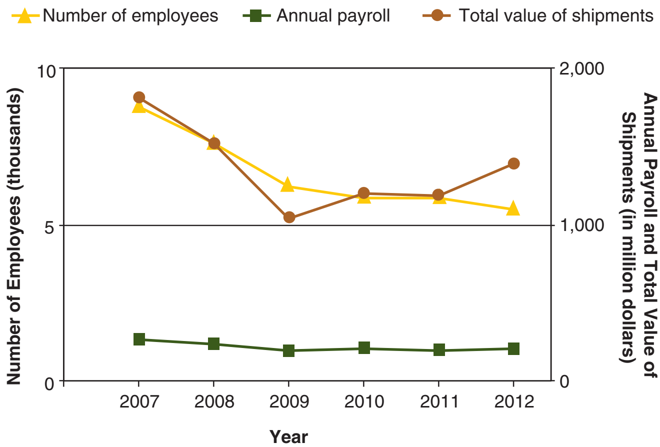


Figure 97.—Number of employees, annual payroll, and total value of shipments for the forest products industry in West Virginia, 2007 to 2012 (U.S. Census Bureau 2015).

What this means

The demand for higher value forest products, such as white oak cooperage and black walnut veneer, much of which is being exported from the United States, kept the overall annual payroll and total value of shipments from decreasing as much as the number of employees between 2007 and 2012. As the economy improves and the demand for wood products increases, the forest product mills that were able to survive through the recession are increasing their production, resulting in an increase in the number of employees in the forest products industry.

Much of the harvest residue generated in the State goes unused. More than 30 percent of the harvest residue is from growing-stock sources (wood material that could be used to produce products). Since half of the industrial roundwood harvested is for saw logs, a large volume of usable, small dimension wood material above the saw log top is left as residues. Small, localized, industrial fuelwood or wood pellet manufactures could lead to better utilization of this resource.

Economics

Background

Forest management activities support local economies by providing jobs in every West Virginia county while protecting natural resources. In addition to the 5,600 people employed in wood products and paper manufacturing, the forest industry as a whole in West Virginia employs over 30,000 people, and pays $3.2 million annually in severance taxes (U.S. Census Bureau 2015). The forest industry also enhances tourism by assuring the diversity, strength, and beauty of forests and wildlife.

What we found

West Virginia has had one of the largest declines in the country in employment in the primary wood products industry since 2007 (Figs. 97, 98). Furthermore, throughout all eastern hardwood states, West Virginia and Pennsylvania had the largest declines in primary wood products employment since 2001. These two states seem to have been most affected by the decline in the furniture industry. Although many mills have closed, there are still many in operation (see Forest Products section), including mills producing plywood, flooring, fuel pellets, oriented strand board, laminated veneer lumber, and log home materials.

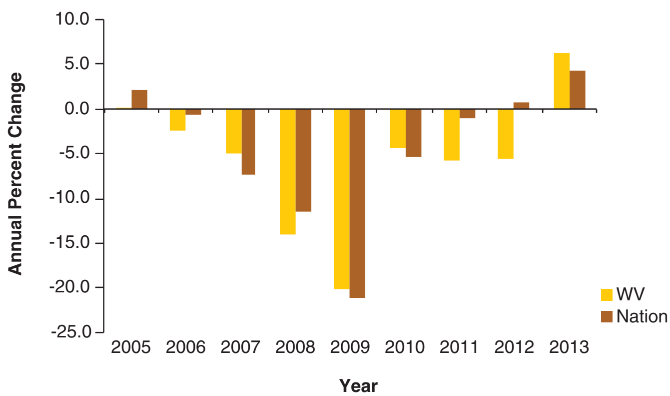


Figure 98.—Annual fluctuation in employment in primary wood products industry, West Virginia and United States, 2005 to 2013 (U.S. Census Bureau 2015).

A decline in hardwood exports (roundwood) also occurred between 2006 and 2009 in the United States, but there was a sharp increase after 2009 including a record high in exports in 2014. Exports increased 13 percent from 2013 to 2014 and nearly 50 percent of that increase was from red oak and yellow-poplar groups, species that are abundant in West Virginia (Fig. 99).

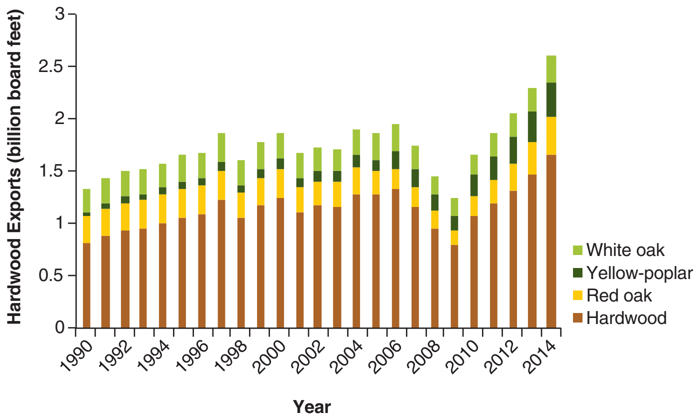


Figure 99.—Volume of hardwood exports (billion board feet), by species, United States, 1990 to 2014.

What this means

Forest management contributes greatly to the economy of West Virginia. However, the economic downturn that began in 2007 had negative consequences for forestry-related employment and production, including exports. Fortunately, hardwood exports and the jobs market are on the upswing in 2013 (Figs. 98, 99).

West Virginia's Future Forests

Background

What will West Virginia's forests look like in 2060? The Northern Forest Futures study examined several alternative future scenarios that cover a range of different assumptions about the economy, population, climate, and other driving forces that will affect the future conditions of forests (Shifley and Moser 2016).

This section of the report focuses on projected changes to the forests of West Virginia between 2010 and 2060. A large component of future forest change will be the result of normal forest growth, aging, natural regeneration, and species succession. However, those trends will be affected by other external forces:

- Population increases will cause roughly 0.5 million acres of forest land to be converted to urban land (Nowak and Walton 2005).
- Economic conditions will affect forest products consumption, production, and harvest rates.

- The spread of invasive species will affect forest change.
- Changes in population, the economy, energy consumption, and energy production. will affect future climate change.
- Climate change will affect patterns of forest growth and species succession.

The Northern Forest Futures study utilized several alternative scenarios that cover a range of different assumptions about the economy, population, climate and other driving forces. The assumptions were incorporated into analytical models that estimated how northern forests are likely to change under each alternative scenario. The seven scenarios (A1B-C, A1B-BIO, A2-C, A2-BIO, A2-EAB, B2-C, and B2-BIO) are based on a storyline and storyline variation. They are identified by their storyline identifier (A1B, A2, or B2) followed by a hyphen and then their storyline variation (C, BIO, or EAB).

The three storylines use the following scenarios:

1) A1B—Rapid economic globalization. International mobility of people, ideas, and technology. Strong commitment to market-based solutions. Strong commitment to education. High rates of investment and innovation in education, technology, and institutions at the national and international levels. A balanced energy portfolio including fossil intensive and renewable energy sources. Uses the CGCM3.1 climate model (Canadian Centre for Climate Modelling and Analysis, n.d.b).

2) A2—Consolidation into economic regions. Self-reliance in terms of resources and less emphasis on economic, social, and cultural interactions between regions. Technology diffuses more slowly than in the other scenarios. International disparities in productivity, and hence income per capita, are largely maintained or increased in absolute terms. Utilizes the CGCM3.1 climate model.

3) B2—A trend toward local self-reliance and stronger communities. Community-based solutions to social problems. Energy systems differ from region to region, depending on the availability of natural resources. The need to use energy and other resources more efficiently spurs the development of less carbon-intensive technology in some regions. Uses the CGCM2 Coupled Global Climate Model (Canadian Centre for Climate Modelling and Analysis, n.d.a).

The three storylines use the following scenarios:

1) C—Standard scenario—available for all three storylines (A1B, A2, and B2).

2) BIO—Increased harvest and utilization of woody biomass for energy scenario—available for all three storylines (A1B, A2, and B2).

3) EAB—Potential impact of continued spread of the emerald ash borer (EAB) with associated mortality of all ash trees in the affected areas—available for only scenario A2.

What we found

Forest land will decrease hundreds of thousands of acres under all storylines. This will reverse the long-term trend of increasing forest area in West Virginia (Fig. 100). The amount of forest land loss projected depends on the storyline. Under storyline A1B-C, forest land area is projected to decline by 8 percent over the next 50 years; by 5 percent under storyline A2-C; and by 4 percent under storyline B2-C. Storylines with greater increases in population and economic activity project less forest land. Only three scenarios are represented in Figure 100 because the projected area of forest land is assumed to be unaffected by alternative climate change assumptions. The projected losses of forest land from 2010 to 2060 are relatively small compared to the cumulative increase in forest area since the start of the 20th century. Projections indicate that by 2060, forest is expected to decline from 78 percent to between 71 to 75 percent of West Virginia's land area.

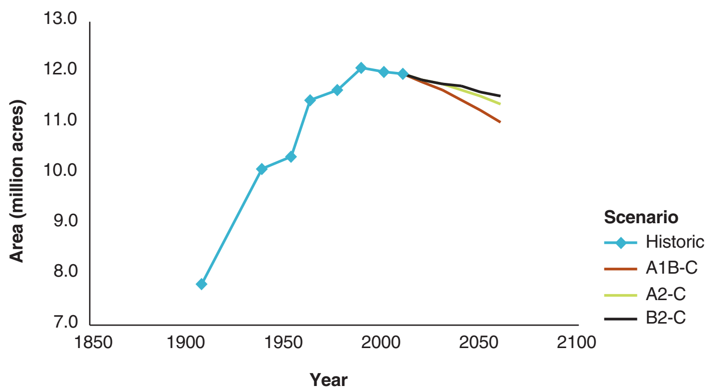


Figure 100.—Projected forest land area for West Virginia by scenario, 2010-2060.

The area in the oak/hickory forest-type group is expected to decrease under all storylines and scenarios from 2010 to 2060 while the area in the maple/beech/birch forest-type group is expected to increase (Fig. 101). The disturbance patterns that initiated many of the oak/hickory forests, such as land clearing (and subsequent reforestation), large fires, and even-age forest management, are declining in extent and intensity. Furthermore, oak/hickory forests are more likely to be adjacent to major metropolitan areas and thus are more likely to lose forest land to other uses because of urban and suburban encroachment. The maple/beech/birch forest type-group is composed primarily of shade-tolerant species and regenerates largely by gap-phase processes.

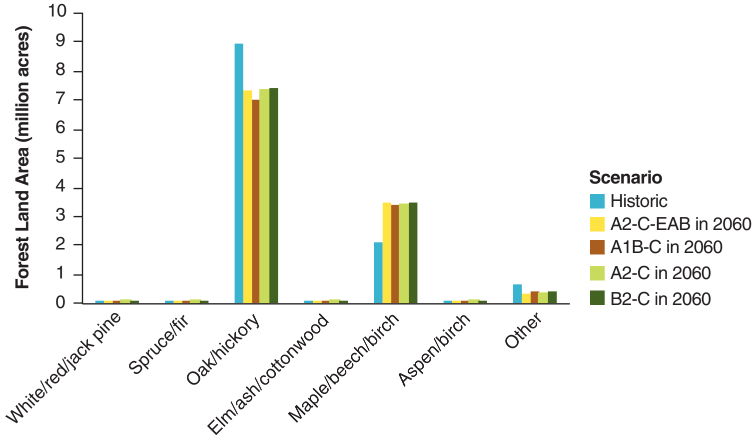


Figure 101.—Projected forest land area by forest-type group and scenario in 2010 to 2060.

Only 1 percent of West Virginia's forest land was in the elm/ash/cottonwood forest-type group in 2010 and even less is projected to be in the elm/ash/cottonwood forest-type group under all seven variations in 2060 (Fig. 101). Emerald ash borer (EAB) was discovered in Fayette County, West Virginia, in October 2007. Ordinarily one would expect the impacts of EAB mortality to impact the elm/ash/cottonwood forest-type group more than the other groups. This is not the case in West Virginia because ash species comprise 2.6 percent of the total live tree volume on forest land in West Virginia but only 2.2 percent of the volume in the elm/ash/cottonwood forest.

All three high biomass utilization scenarios (A1B-C-BIO, B2-C-BIO and A2-C-BIO) result in lower levels of live tree volume in 2060 than do their corresponding normal biomass utilization scenarios (A1B-C, B2-C, and A2-C) (Fig. 102). The live tree volume on forest land in 2060 is projected to be less than the 2010 volume under all seven scenarios—primarily due to the projected loss of forest land. The area of forest land is expected to decrease but the volume per acre (2,263 cubic feet per acre in 2010) is expected to increase for the normal biomass scenarios (A1B-C [3 percent], B2-C [1 percent], and A2-C [3 percent]), but decrease for the high biomass scenarios (A1B-C-BIO [-19%], B2-C-BIO [-5%], and A2-C-BIO [-10%]) (data not shown). Average annual removals of growing stock on timberland, for each of the seven scenarios, are depicted in Figure 103. Removals rates may not be sustainable for the high biomass utilization scenarios.

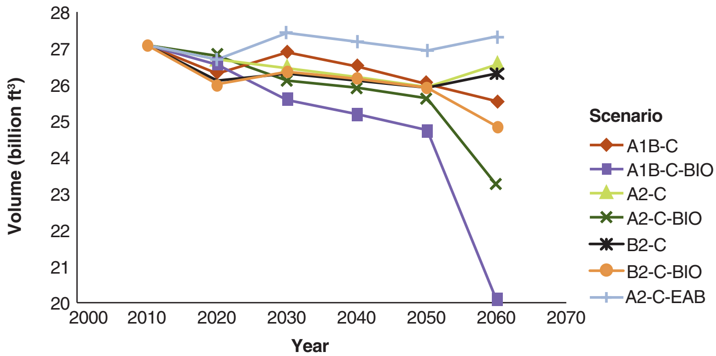


Figure 102.—Projected tree volume on forest land in West Virginia by scenario, 2010 to 2060.

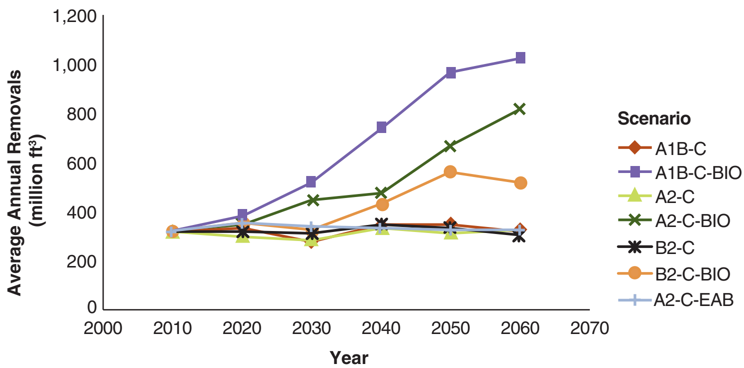


Figure 103.—Projected average annual growing-stock removals on timberland in West Virginia by scenario, 2010 to 2060.

What this means

The area of forest land is expected to decrease, but the volume per acre is expected to increase as forests continue to mature. Nevertheless, the rate of volume increase is expected to be significantly slower than in the past. Over the past 50 years, forest managers have had the luxury of rapidly increasing forest volume with growth greatly exceeding removals. If these projections hold true, that will not be the case for future generations of forest managers and wood-using industries. Changing trends result from the combined effects of gradually decreasing forest area and an aging forest resource with high volume but low net growth per acre. These projections should be considered as possible trends that will be influenced by actual future climate conditions, demographic changes, and economic policies relative to the assumptions.

Literature Cited

Abrams, M.D. 1992. **Fire and the development of oak forests.** BioScience. 42(5): 346-353.

Bechtold, W.A.; Patterson, P.L., eds. 2005. **Forest Inventory and Analysis national sample design and estimation procedures.** Gen. Tech. Rep. SRS-GTR-80. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 85 p.

Bones, J.T. 1978. **The forest resources of West Virginia.** Resour. Bull. NE-56. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 105 p.

Breiman, L. 2001. **Random forests**. Machine Learning. 45: 15-32. http://dx.doi.org/10.1023/A:1010933404324.

Butler, B.J. 2008. **Family forest owners of the United States, 2006.** Gen. Tech. Rep. NRS-27. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 72 p. http://dx.doi.org/10.2737/NRS-GTR-27.

Butler, B.J.; Dickinson, B.J.; Hewes, J.H.; Butler, S.M.; Andrejczyk, K.; Markowski-Lindsay, M. 2016a. **USDA Forest Service National Woodland owner survey, 2011-2013: design, implementation, and estimation methods.** Gen. Tech. Rep. NRS-157. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 55 p. http://dx.doi.org/10.2737/NRS-GTR-157.

Butler, B.J.; Hewes, J.H.; Dickinson, B.J.; Andrejczyk, K.; Butler, S.M.; Markowski-Lindsay, M. 2016b. **USDA Forest Service National Woodland Owner Survey: national, regional, and state statistics for family forest and woodland ownerships with 10+ acres, 2011-2013.** Resour. Bull. NRS-99. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 39 p. http://dx.doi.org/10.2737/NRS-RB-99.

Brose, P.H.; Gottschalk, K.W.; Horsley, S.P.; Knopp, P.D.; Kochenderfer, J.N.; McGuiness, B.J.; Miller, G.W.; Ristau, T.E.; Stoleson, S.H.; Stout, S.L. 2008. **Prescribing regeneration treatments for mixed-oak forests of the mid-Atlantic region.** Gen. Tech. Rep. NRS-33. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 100 p. http://dx.doi.org/10.2737/NRS-GTR-33.

Canadian Centre for Climate Modelling and Analysis. N.d.a. **CGCM2-coupled global climate model, medium resolution (T47).** Ottawa, ON, Canada: Environment Canada. www.cccma.ec.gc.ca/models/cgcm2.shtml (accessed July 27, 2012).

Canadian Centre for Climate Modelling and Analysis. N.d.b. **CGCM3.1-coupled global climate model (CGCM3), medium resolution (T47)**. Ottawa, ON, Canada: Environment Canada. www.cccma.ec.gc.ca/models/cgcm3.shtml (accessed July 27, 2012).

Cleland, D.T.; Freeouf, J.A.; Keys, J.E., Jr.; Nowacki, G.J.; Carpenter, C.; McNab, W.H. 2007. **Ecological subregions: sections and subsections of the conterminous United States [1:3,500,000]**. Gen. Tech. Rep. WO-76D. Washington, DC: U.S. Department of Agriculture, Forest Service. [map on CD-ROM].

Charry, B.; McCollough, M. 2007. **Conserving wildlife on and around Maine's roads.** Falmouth, ME: Maine Audubon. 8 p.

Conservation Biology Institute. 2010. **Protected areas database of the United States.** PAD-US (CBI edition). Available at http://protectedareas.databasin.org (accessed January, 2014).

Coulston, J.W.; Moisen, G.G.; Wilson, B.T.; Finco, M.V.; Cohen, W.B.; Brewer, C.K. 2012. **Modeling percent tree canopy cover: a pilot study.** Photogrammetric Engineering & Remote Sensing. 78 (7): 715-727. http://dx.doi.org/10.14358/PERS.78.7.715.

DiGiovanni, D.M. 1990. **Forest statistics for West Virginia—1975 and 1989.** Resour. Bull. NE-114. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station. 172 p.

Donovan, T.M.; Lamberson, R.H. 2001. **Area-sensitive distributions counteract negative effects of habitat fragmentation on breeding birds.** Ecology. 82: 1170-1179. http://dx.doi.org/10.1890/0012-9658(2001)082[1170:ASDCNE]2.0.CO;2.

Eyre, F.H., ed. 1980. **Forest cover types of the United States and Canada.** Bethesda, MD: Society of American Foresters. 148 p.

Fan, Z.; Shifley, S.R.; Spetich, M.A.; Thompson, F.R., III; Larsen, D.R. 2003. **Distribution of cavity trees in midwestern old-growth and second-growth forests.** Canadian Journal of Forest Research. 33:1481-1494. http://dx.doi.org/10.1139/x03-068.

Ferguson, R.H. 1964. **The timber resources of West Virginia.** Resour. Bull. NE-2. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 123 p.

Forest History Society. 2013. **The Weeks Act.** Durham, NC: Forest History Society. http://www.foresthistory.org/ASPNET/Policy/WeeksAct/index.aspx (accessed March 31, 2016).

Forman, R.T.T.; Godron, M. 1986. **Landscape ecology.** New York, NY: J. Wiley & Sons. 619 p. ISBN: 978-0471870371.

Forman, R.T.T.; Sperling, D.; Bissonette, J.A.; Clevenger, A.P.; Cutshall, C.D. [et al.]. 2003. **Road ecology: science and solutions.** Washington, DC: Island Press. 504 p. ISBN: 978-1559639330.

Fralish, J.S. 2004. **The keystone role of oak and hickory in the central hardwoods forest.** In: Spetich, M.A., ed. Upland oak ecology symposium. Gen. Tech. Rep. SRS-73. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 78-87.

Fry, J.; Xian, G.; Jin, S.; Dewitz, J.; Homer, C. [et al.]. 2011. **Completion of the 2006 National Land Cover Database for the conterminous United States.** Photogrammetric Engineering and Remote Sensing. 77:858-864.

Gabriel, W.J.; Walters, R.S. 1990. ***Acer pensylvanicum.*** **Striped maple.** In: Burns, R.M.; Honkala, B.M., tech. cords. Silvics of North American, volume 2, hardwoods. Agric. Hndbk. 654. Washington, DC: U.S. Department of Agriculture, Forest Service: 53-59.

Gilbart, M. 2012. **Under cover: wildlife of shrublands and young forest.** Cabot VT: Wildlife Management Institute. 87 p.

Greenberg, C.H.; Collins, B.S.; Thompson, F.R., III. 2011. **Sustaining young forest communities, ecology and management of early successional habitat in the central hardwood region, USA.** In: Managing Forest Ecosystems, volume 21. New York, NY: Springer. 310 p. http://dx.doi.org/10.1007/978-94-007-1620-9.

Griffith, D.M.; Widmann, R.H. 2003. **Forest statistics for West Virginia: 1989 and 2000.** Resour. Bull. NE-157. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station. 119 p.

Hammer, R.B.; Stewart, S.I.; Winkler, R.L.; Radeloff, V.C.; Voss, P.R. 2004. **Characterizing dynamic spatial and temporal residential density patterns from 1940-1990 across the north central United States.** Landscape and Urban Planning. 69: 183-199. http://dx.doi.org/10.1016/j.landurbplan.2003.08.011.

Hane, E.N. 2003. **Indirect effects of beech bark disease on sugar maple seedling survival.** Canadian Journal of Forest Research. 33: 807-813. http://dx.doi.org/10.1139/x03-008.

Hawbaker, T.J.; Radeloff, V.C. 2004. **Roads and landscape pattern in northern Wisconsin based on a comparison of four road data sources.** Conservation Biology. 18: 1233-1244. http://dx.doi.org/10.1111/j.1523-1739.2004.00231.x.

Heath, L.S.; Hansen, M.; Smith, J.E.; Miles, P.D.; Smith, B.W. 2009. **Investigation into calculating tree biomass and carbon in the FIADB using a biomass expansion factor approach.** In: McWilliams, W.; Moisen, G.; Czaplewski, R., comps. Forest Inventory and Analysis (FIA) symposium 2008 proceedings; 2008 October 21-23; Park City, UT. RMRS-P-56CD. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Holt, H.A.; Fischer, B.C. 1979. **An overview of oak regeneration problems.** In: Holt, H.A.; Fischer, B.C., eds. Proceedings of regenerating oaks in upland hardwood forests; 1979 February 22-23; West Lafayette, IN. West Lafayette, IN: Indiana Cooperative Extension Service, Purdue University. 132 p.

Homer, C.G.; Dewitz, J.A.; Yang, L.; Jin, S.; Danielson, P.; Xian, G.; Coulston, J.; Herold, N.D.; Wickham, J.D.; Megown, K. 2015. **Completion of the 2011 National Land Cover Database for the conterminous United States-representing a decade of land cover change information.** Photogrammetric Engineering and Remote Sensing. 81: 345-354.

Honnay, O.; Jacquemyn, H.; Bossuyt, B.; Hermy, M. 2005. **Forest fragmentation effects on patch occupancy and population viability of herbaceous plant species.** New Phytologist. 166: 732-736. http://dx.doi.org/10.1111/j.1469-8137.2005.01352.x.

Houston, D.R. 1994. **Major new tree disease epidemics: beech bark disease.** Annual Review of Phytopathology. 32:75-87. http://dx.doi.org/10.1146/annurev.py.32.090194.000451.

Hunter, W.C.; Buehler, D.A.; Canterbury, R.A.; Confer, J.L.; Hamel, P.B. 2001. **Conservation of disturbance-dependent birds in eastern North America.** Wildlife Society Bulletin. 29(2): 440-455.

Iverson, L.R; Prasad, A.M. 1998. **Predicting abundance of 80 tree species following climate change in the eastern United States.** Ecological Monographs. 68(4): 465-485. http://dx.doi.org/10.2307/2657150.

Jackson, D.R.; Finley, J.C. 2011. **Herbicides and forest management, controlling unwanted trees, brush, and other competing vegetation.** University Park, PA: Pennsylvania State University. 20 p. http://pubs.cas.psu.edu/freepubs/pdfs/UH174.pdf (accessed May, 2015).

Jin, S.; Yang, L.; Danielson, P.; Homer, C.; Fry, J.; Xian, G. 2013. **A comprehensive change detection method for updating the National Land Cover Database to circa 2011.** Remote Sensing of Environment. 132:159–175. http://dx.doi.org/10.1016/j.rse.2013.01.012.

Johnson, P.S.; Shifley, S.R.; Rogers, R. 2009. **The ecology and silviculture of oaks, 2nd edition.** Wallingford, Oxon, UK: CABI Publishing. 580 p. ISBN: 978-1845934743.

Kapos, V.; Lysenko, I.; Lesslie, R. 2002. **Assessing forest integrity and naturalness in relation to biodiversity.** Working Paper 54. Rome: Food and Agriculture Organization of the United Nations, Forest Resources Assessment Programme. 65 p. ftp://ftp.fao.org/docrep/fao/006/ad654e/ad654e00.pdf (accessed February 24, 2016).

Kline, J.D.; Azuma, D.L.; Alig, R.J. 2004. **Population growth, urban expansion, and private forestry in western Oregon.** Forest Science. 50: 33-43.

Krist, F.J., Jr.; Ellenwood, J.R.; Woods, M.E.; McMahan, A.J.; Cowardin, J.P.; Ryerson, D.E.; Sapio, F.J.; Zweifler, M.O.; Romero, S.A. 2014. **2013-2017 National insect and disease forest risk assessment.** FHTET-14-01. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Forest Health Technology Enterprise Team. 199 p.

Kurtz, C.M. 2013. **An assessment of invasive plant species monitored by the Northern Research Station Forest Inventory and Analysis Program, 2005 through 2010.** Gen. Tech. Rep. NRS-109. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 70 p. http://dx.doi.org/10.2737/NRS-GTR-109.

Kurtz, C.M.; Hansen M.H. 2013. **An assessment of multiflora rose in northern U.S. forests.** Res. Note NRS-182. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 5 p. http://dx.doi.org/10.2737/NRS-RN-182.

Langford, W.T.; Gergel, S.E.; Dietterich, T.G.; Cohen, W. 2006. **Map misclassification can cause large errors in landscape pattern indices: examples from habitat fragmentation.** Ecosystems. 9: 474-488. http://dx.doi.org/10.1007i-10021-005-0119-1.

Larsen, D.R.; Johnson, P.S. 1998. **Linking the ecology of natural oak regeneration to silviculture.** Forest Ecology and Management. 106: 1-7.

Lepczyk, C.A.; Hammer, R.B.; Stewart, S.I.; Radeloff, V.C. 2007. **Spatiotemporal dynamics of housing growth hotspots in the North Central U.S. from 1940 to 2000.** Landscape Ecology. 22: 939-952. http://dx.doi.org/10.1007/s10980-006-9066-2.

Liebhold, A.M.; MacDonald, W.L.; Bergdahl, D.; Mastro, V.C. 1995. **Invasion by exotic forest pests: a threat to forest ecosystems.** Forest Science Monograph. 30: 1-49.

McClure, M.S.; Salom, S.M.; Shields, K.S. 2001. **Hemlock wooly adelgid.** FHTET-2001-03. Morgantown, WV: U.S. Department of Agriculture, Forest Service, Forest Health Technology Enterprise Team. 14 p.

McMahon, G.; Cuffney, T.F. 2000. **Quantifying urban intensity in drainage basins for assessing stream ecological conditions.** Journal of the American Water Resources Association. 36: 1247-1261.

McRoberts, R.E. 1999. **Joint annual forest inventory and monitoring system: the North Central perspective.** Journal of Forestry. 97: 21-26.

McRoberts, R.E. 2005. **The enhanced Forest Inventory and Analysis program.** In: Bechtold, W.A.; Patterson, P.L., eds. The enhanced Forest Inventory and Analysis program—national sampling design and estimation procedures. Gen. Tech. Rep. SRS-80. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 11-20.

McWilliams, W.H.; Westfall, J.A.; Brose, P.H.; Dey, D.C.; Hatfield, M. [et al.]. 2015. **A regeneration indicator for Forest Inventory and Analysis: history, sampling, estimation, analytics, and potential use in the midwest and northeast USA.** Gen. Tech. Rep. NRS-148. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 74 p. http://dx.doi.org/10.2737/NRS-GTR-148.

Miles, P.D.; Smith, W.B. 2009. **Specific gravity and other properties of wood and bark for 156 tree species found in North America.** Res. Note NRS-38. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 35 p. http://dx.doi.org/10.2737/NRS-RN-38.

Moody, A.; Woodcock, C.E. 1995. **The influence of scale and the spatial characteristics of landscapes on land-cover mapping using remote sensing.** Landscape Ecology. 10: 363-379. http://dx.doi.org/10.1007/bf00130213.

Morin, R.S.; Liebhold, A.M. 2015. **Invasions by two non-native insects alter regional forest species composition and successional trajectories.** Forest Ecology and Management. 341: 67-74. http://dx.doi.org/10.1016/j.foreco.2014.12.018.

Morin, R.S.; Liebhold, A.M. 2016. **Invasive forest defoliator contributes to the impending downward regional trend of oak dominance in eastern North America.** Forestry: An International Journal of Forest Research. http://dx.doi.org/10.1093/forestry/cpv053.

Morin, R.S.; Randolph, K.C.; Steinman, J. 2015. **Mortality rates associated with crown health for eastern forest tree species.** Environmental Monitoring and Assessment. 187: 87. http://dx.doi.org/10.1007/s10661-015-4332-x.

NatureServe Explorer. 2009. **List of vertebrate species in the contiguous U.S. [database], ver. 7.1.** Arlington, VA: NatureServe. http://explorer.natureserve.org/servlet/NatureServe (accessed February 17, 2011).

Neary, D.G.; Ice, G.G.; Jackson, R.C. 2009. **Linkages between forest soils and water quality and quantity.** Forest Ecology and Management. 258: 2269-2281. http://dx.doi.org/doi:10.1016/j.foreco.2009.05.027.

Nowak, D.J.; Walton, J.T. 2005. **Projected urban growth and its estimated impact on the US. Forest resource (2000-2050).** Journal of Forestry. 103(8): 383-389.

O'Connell, B.M.; LaPoint, E.B.; Turner, J.A.; Ridley, T.; Pugh, S.A. [et al.]. 2014. **The Forest Inventory and Analysis database: database description and user guide ver. 6.0.1 for P2**. Washington, DC: U.S. Department of Agriculture, Forest Service. 748 p. http://www.fia.fs.fed.us/library/database-documentation/ (accessed April, 2015).

Orwig D.A.; Foster, D.R.; Mausel, D.L. 2002. **Landscape patterns of hemlock decline in New England due to the introduced hemlock woolly adelgid.** Journal of Biogeography. 29: 1475-1487. http://dx.doi.org/10.1046/j.1365-2699.2002.00765.x.

Orwig, D.A.; Cobb, R.C.; D'Amato, A.W.; Kizlinski, M.L.; Foster, D.R. 2008. **Multi-year ecosystem response to hemlock woolly adelgid infestation in southern New England forests.** Canadian Journal of Forest Research. 38: 834–843. http://dx.doi.org/10.1139/X07-196.

Overton, R.P. 1990. ***Oxydendrum arboreum* (L.) DC. Sourwood.** In: Burns, R.M.; Honkala, B.M., tech. cords. Silvics of North America, volume 2, hardwoods. Agric. Hndbk. 654. Washington, DC: U.S. Department of Agriculture, Forest Service: 877.

Pimentel, D.; Lach, L.; Zuniga, R.; Morrison, D. 2000. **Environmental and economic costs of nonindigenous species in the United States.** BioScience. 50(1): 53-65. http://dx.doi.org/10.1641/0006-3568(2000)050[0053:eaecon]2.3.co;2.

Piva, Ronald J.; Cook, Gregory W. 2011. **West Virginia timber industry—an assessment of timber product output and use, 2007**. Resour. Bull. NRS-46. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 58 p. http://dx.doi.org/10.2737/NRS-RB-46.

Powell, D.S. 1985. **Forest composition of Maine: an analysis using number of trees.** Resour. Bull. NE-85. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 40 p.

Radeloff, V.C.; Hammer, R.B.; Stewart, S.I.; Fried, J.S.; Holcomb, S.S.; McKeefry, J.F. 2005. **The wildland urban interface in the United States.** Ecological Applications. 15: 799-805. http://dx.doi.org/10.1890/04-1413.

Riitters, K.H.; Wickham, J.D. 2003. **How far to the nearest road?** Frontiers in Ecology and the Environment. 1: 125-129. http://dx.doi.org/10.1890/1540-9295(2003)001[0125:HFTTNR]2.0.CO;2.

Riva-Murray, K.; Riemann, R.; Murdoch, P.; Fischer, J.M.; Brightbill, R.A. 2010. **Landscape characteristics affecting streams in urbanizing regions of the Delaware River Basin (New Jersey, New York, and Pennsylvania, U.S.)**. Landscape Ecology. 25: 1489-1503. http://dx.doi.org/10.1007/s10980-010-9513-y.

Rosenberg, K.V.; Rohrbaugh, R.W., Jr.; Barker, S.E.; Lowe, J.D.; Hames, R.S.; Dhondt, A.A. 1999. **A land manager's guide to improving habitat for scarlet tanagers and other forest-interior birds.** Ithaca, NY: The Cornell Lab of Ornithology. 23 p.

Russell, F.L.; Zippin, D.B.; Fowler, N.L. 2001. **Effects of white-tailed deer *(Odocoileus virginianus)* on plants, plants populations and communities: a review.** The American Midland Naturalist. 146(1): 1-26. http://dx.doi.org/10.1674/0003-0031(2001)146[0001:eowtdo]2.0.co;2.

Russell, M.B., Woodall, C.W., D'Amato, A.W., Fraver, S., Bradford, J.B. 2014a. **Linking climate change and downed woody debris decomposition across forests of the eastern United States.** Biogeosciences. 11: 6417-6425. http://dx.doi.org/10.5194/bg-11-6417-2014.

Russell, M.B.; Woodall, C.W.; Fraver, S.; D'Amato, A.W.; Domke, G.M.; Skog, K.E. 2014b. **Residence time and rate of decay for downed woody debris biomass/carbon in eastern US forests.** Ecosystems. 17: 765-777. http://dx.doi.org/10.1007/s10021-014-9757-5.

Rustad, L.; Campbell, J.; Dukes J.S.; Huntington, T.; Lambert K.F.; Mohan, J.; Rodenhouse, N. 2012. **Changing climate, changing forest: The impacts of climate change on forests of the northeastern United States and eastern Canada.** Gen. Tech. Rep. NRS-99. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 48 p. http://dx.doi.org/10.2737/NRS-GTR-99.

Shao, G.; Wu, J. 2008. **On the accuracy of landscape pattern analysis using remote sensing data.** Landscape Ecology. 23: 505-511. http://dx.doi.org/10.1007/s10980-008-9215-x.

Shifley, S.R.; Moser, W.K., eds. 2016. **Future forests of the northern United States.** Gen. Tech. Rep. NRS-151. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 388 p.

Shigo, A.L. 1972. **The beech bark disease today in the northeastern U.S.** Journal of Forestry. 54: 286-289.

Smith, D.M.; Larson, B.C.; Kelty, M.J.; Ashton, P.M.S. 1997. **The practice of silviculture: applied forest ecology, 9th edition.** New York, NY: John Wiley and Sons, Inc. 537 p.

Society of American Foresters. 1998. **The dictionary of forestry.** Bethesda, MD: Society of American Foresters. 210 p.

Stadler, B.; Muller, T.; Orwig, D.; Cobb, R. 2005. **Hemlock woolly adelgid in New England forests: canopy impacts transforming ecosystem processes and landscapes.** Ecosystems. 8: 233–247. http://dx.doi.org/10.1007/s10021-003-0092-5.

Steinman, J. 2000. **Tracking the health of trees over time on forest health monitoring plots.** In: Hansen, M.; Burk, T., eds. Integrated tools for natural resources inventories in the 21st century; 1998 August 16-20; Boise, ID. Gen. Tech. Rep. NC-212. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station: 334-339.

Tavernia, B.G.; Nelson, M.D.; Riemann, R.; Dickinson, B.; Moser, W.K.; Wilson, B.T.; Garner, J.D. 2016. **Conservation of biological diversity**. In: Shifley, Stephen R.; Moser, W. Keith, eds. Future forests of the northern United States. Gen. Tech. Rep. NRS-151. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station: 43-76. Chapter 3.

Theobald, D.M. 2005. **Landscape patterns of exurban growth in the USA from 1980 to 2020.** Ecology and Society. 10(1): 32.

U.S. Census Bureau. 2000. **United States Census 2000.** Washington, DC: U.S. Department of Commerce, Census Bureau. http://www.census.gov/2010census/ (accessed January, 2015).

U.S. Census Bureau. 2010. **United States Census 2010.** Washington, DC: U.S. Department of Commerce, Census Bureau. http://www.census.gov/2010census/ (accessed January, 2015).

U.S. Census Bureau. 2015. **Annual survey of manufacturers.** Washington, DC: U.S. Department of Commerce, Census Bureau. http://www.census.gov/manufacturing/asm/index.html (accessed February 25, 2015).

U.S. Environmental Protection Agency [US EPA]. 2015. **Inventory of U.S. greenhouse gas emissions and sinks: 1990–2013.** EPA 430-R-15-004. Washington, DC: U.S. Environmental Protection Agency, Office of Atmospheric Programs. http://www.epa.gov/climatechange/ghgemissions/usinventoryreport.html (accessed May, 2015).

U.S. Forest Service. 2010. **Forest inventory and analysis national core field guide: field data collection procedures for P2 plots, ver. 5.0.** Washington, DC: U.S. Department of Agriculture, Forest Service. Available at: http://www.fia.fs.fed.us/library/field-guides-methods-proc/ (accessed March 3, 2016).

U.S. Forest Service. 2014. **The Forest Inventory and Analysis Database: Database description and user guide ver. 6.0.1 for P3.** Washington, DC: U.S. Department of Agriculture, Forest Service. 182 p. Available at: http://www.fia.fs.fed.us/library/database-documentation/ (accessed April 2015).

U.S. Forest Service. N.d.a. **Forests to faucets.** Washington, DC: U.S. Department of Agriculture, Forest Service. http://www.fs.fed.us/ecosystemservices/FS_Efforts/forests2faucets.shtml (accessed Feb. 12, 2016).

U.S. Forest Service. N.d. **Gypsy moth digest—defoliation.** Newtown Square, PA: U.S. Department of Agriculture, Forest Service. http://www.na.fs.fed.us/fhp/gm/defoliation/index.shtml (accessed April 2015).

Vitousek, P.M.; D'Antonio, C.M.; Loope, L.L.; Westbrooks, R. 1996. **Biological invasions as global environmental change.** American Scientist. 84: 468-478.

Vose, J.M.; Peterson, D.L.; Patel-Weynand, T., eds. 2012. **Effects of climatic variability and change on forest ecosystems: acomprehensive science synthesis for the U.S. forest sector.** Gen. Tech. Rep. PNW-GTR-870. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 265 p.

Walters, B.F.; Settle, J.; Piva, R.J. 2012. **Indiana timber industry: an assessment of timber product output and use, 2008.** Resour. Bull. NRS-63. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 72 p. http://dx.doi.org/10.2737/NRS-RB-63.

Ward, J.S.; Montgomery, M.E.; Cheah, C.A.S.-J.; Onken, B.P.; Cowles, R.S. 2004. **Eastern hemlock forests: guidelines to minimize the impacts of hemlock woolly adelgid.** NA-TP-03-04. Morgantown, WV: U.S. Department of Agriculture, Forest Service, Northeastern Area State and Private Forestry. 28 p.

Wear, D.N.; Liu, R.; Foreman, M.J.; Sheffield, R.M. 1999. **The effects of population growth on timber management and inventories in Virginia.** Forest Ecology and Management. 118: 107-115. http://dx.doi.org/10.1016/S0378-1127(98)00491-5.

West Virginia Division of Natural Resources. 2005. **It's about habitat… West Virginia wildlife conservation action plan.** Charleston, WV: West Virginia, Division of Natural Resources, Wildlife Resources Section. 1057 p. http://www.wvdnr.gov/Wildlife/PDFFiles/wvwcap.pdf (accessed February 11, 2016).

West Virginia Division of Forestry. 2005. **West Virginia silvicultural best management practices for controlling soil erosion and sedimentation from logging operations**. Charleston, WV: West Virginia Division of Forestry. 31 p.

West Virginia Division of Forestry. 2010. **West Virginia statewide forest resource assessment, a comprehensive analysis of the state's forests and related natural resources.** Charleston, WV: West Virginia Division of Forestry. 498 p.

Westfall, J.A.; Frieswyk, T.; Griffith, D. 2009. **Implementing the measurement interval midpoint method for change estimation.** In: McRoberts, R.E.; Reams, G.A.; Van Deusen, P.C.; McWilliams, W.H., eds. Proceedings of the eighth annual forest inventory and analysis symposium; 2006 October 16-19; Monterey, CA. Gen. Tech. Rep. WO-79. Washington, DC: U.S. Department of Agriculture, Forest Service: 231-236.

Widmann, R.H.; Cook, G.W.; Barnett, C.J.; Butler, B.J.; Griffith, D.M. [et al.]. 2012. **West Virginia's Forests 2008.** Resour. Bull. NRS-61. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 64 p. [DVD included]. http://dx.doi.org/10.2737/NRS-RB-61.

Widmann, R.H; Randall, C.K.; Butler, B.J.; Domke, G.M.; Griffith, D.M. [et al.]. 2014. **Ohio's forests 2011.** Resour. Bull. NRS-90. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 68 p. http://dx.doi.org/10.2737/NRS-RB-90.

Wilcox, B.A.; Murphy, D.D. 1985. **Conservation strategy: the effects of fragmentation on extinction.** American Naturalist. 125: 879-887. http://www.jstor.org/stable/2461453.

Wilson, B.T.; Lister, A.J.; Riemann, R.I. 2012. **A nearest-neighbor imputation approach to mapping tree species over large areas using forest inventory plots and moderate resolution raster data.** Forest Ecology and Management. 271:182-198. http://dx.doi.org/10.1016/j.foreco.2012.02.002.

Woodall, C.W.; Heath, L.S.; Domke, G.M.; Nichols M. 2011. **Methods and equations for estimating aboveground volume, biomass, and carbon for forest trees in the U.S.'s national inventory, 2010.** Gen. Tech. Rep. NRS-88. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 30 p. http://dx.doi.org/10.2737/NRS-GTR-88.

Woodall, C.W.; Walters, B.F.; Oswalt, S.N.; Domke, G.M.; Toney, C.; Gray, A.N. 2013. **Biomass and carbon attributes of downed woody materials in forests of the United States.** Forest Ecology and Management. 305: 48-59. http://dx.doi.org/10.1016/j.foreco.2013.05.030.

Wray, R.D. 1952. **Forest statistics for West Virginia.** Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 48 p.

Appendix—Scientific and common names for tree species observed in FIA plots in West Virginia.

Common name	Scientific Name
American beech	*Fagus americana*
Black cherry	*Prunus serontina*
Black locust	*Robinia pseudoacacia*
Black oak	*Quercus velutina*
Blackgum	*Nyssa sylvatica*
Chestnut oak	*Quercus prinus*
Eastern hemlock	*Tsuga canadensis*
Eastern hophornbeam	*Ostrya virginiana*
Eastern white pine	*Pinus strobus*
Hickory spp.	*Carya* spp.
Northern red oak	*Quercus rubra*
Paper birch	*Betula papyfirous*
Pin cherry	*Prunus pensylvanica*
Quaking aspen	*Populus tremuloides*
Red maple	*Acer rubrum*
Red spruce	*Picea rubens*
Sassafras	*Sassafras albidum*
Scarlet oak	*Quercus coccinea*
Striped maple	*Acer pensylvanicum*
Sugar maple	*Acer saccharum*
Black birch	*Betula lenta*
White ash	*Fraxinus americana*
White oak	*Quercus alba*
Yellow birch	*Betula allegheniensis*
Yellow-poplar	*Liriodendron tulipifera*
Virginia pine	*Pinus virginiana*
American basswood	*Tilia americana*
American sycamore	*Platanus occidentalis*
Sourwood	*Oxydendrum arboreum*
Pawpaw	*Asimina triloba*
Flowering dogwood	*Cornus florida*
Elm spp.	*Ulmus* spp.
Ash spp.	*Fraxinus* spp.
Pitch pine	*Pinus rigida*
American hornbeam	*Carpinus caroliniana*
Southern red oak	*Quercus falcata* var. *falcata*
Shingle oak	*Quercus ibricaria*

Morin, Randall S.; Cook, Gregory W.; Barnett, Charles J.; Butler, Brett J.; Crocker, Susan J.; Hatfield, Mark A.; Kurtz, Cassandra M.; Lister, Tonya W.; Luppold, William G.; McWilliams, William H.; Miles, Patrick D.; Nelson, Mark D.; Perry, Charles H.; Piva, Ronald J.; Smith, James E.; Westfall, James A.; Widmann, Richard H.; Woodall, Christopher W. 2016. **West Virginia Forests 2013.** Resour. Bull. NRS-105. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 128 p.

The annual inventory of West Virginia's forests, completed in 2013, covers nearly 12.2 million acres of forest land with an average volume of more than 2,300 cubic feet per acre. This report is based data collected from 2,808 plots located across the State. Forest land is dominated by the oak/hickory forest-type group, which occupies 74 percent of total forest land area. Seventy-eight percent of forest land area consists of a plurality of large diameter trees, 15 percent contains medium diameter trees, and 7 percent contains small diameter trees. The volume of growing stock on timberland has been rising since the 1950s and currently totals over 25 billion cubic feet. The average annual net growth of growing-stock trees on timberland from 2008 to 2013 is approximately 519 million cubic feet per year. Important species compositional changes include increases in sapling numbers of yellow-poplar, American beech, and noncommercial species, which coincide with decreases in numbers of trees and saplings of oak species. Additional information is presented on forest attributes, land use change, carbon, timber products, species composition, regeneration, and forest health. Detailed information on forest inventory methods, data quality estimates, and summary tables of population estimates, are available at http://dx.doi.org/10.2737/NRS-RB-105.

KEY WORDS: forest resources, forest health, forest products, volume, biomass, carbon, habitat

Northern Research Station

www.nrs.fs.fed.us